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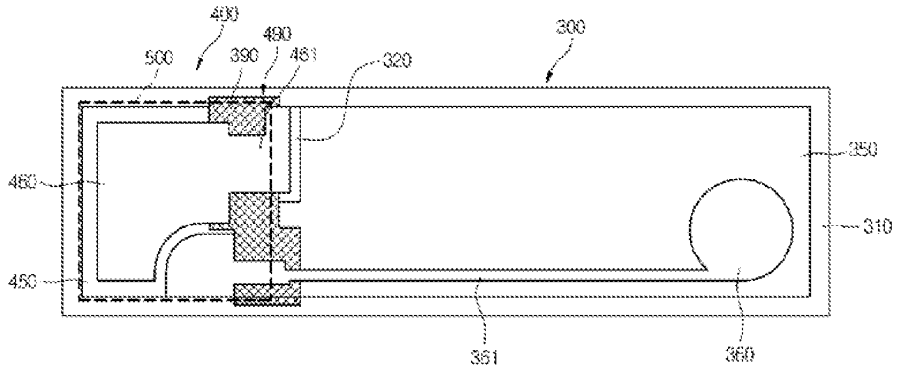
(54) Title: LIGHT-EMITTING DEVICE AND METHOD FOR MANUFACTURING THE SAME



(57) Abstract: Provided are a light-emitting device and a method for manufacturing the same. The light-emitting device includes a substrate, a light-emitting device, a protection device, and a connecting line. The light-emitting device is formed on one part of the substrate, and includes a first semiconductor layer and a second semiconductor layer. The protection device is formed on another part of the substrate, and includes a fourth semiconductor layer and a fifth semiconductor layer. The connecting line electrically connects the light-emitting device and the protection device.

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Description

LIGHT-EMITTING DEVICE AND METHOD FOR MANUFACTURING THE SAME

Technical Field

[1] The embodiment of present invention relates to a light-emitting device and a method for manufacturing the same.

Background Art

[2] Recently, a nitride semiconductor such as gallium nitride (GaN) is in the limelight as an important material for an electronic device and a photoelectric material because of its superior physical and chemical characteristics. Particularly, the development of highly efficient light-emitting diodes (LEDs) of primary colors (Red, Blue, Green) and white color expands an application area of a light-emitting diode. For example, the LED has been applied to a variety of fields such as a keypad, a backlight of a liquid crystal display device, a traffic light, a guide light of a runway in an airport and a lighting apparatus.

[3] Fig. 1 is a sectional view illustrating a related art light-emitting device.

[4] The related art light-emitting device includes a sequentially formed an n-type GaN layer 12, an active layer 13, and a p-type GaN layer 14. Portions of the p-type GaN layer 14, the active layer 13, and the n-type GaN layer 12 are removed using etching to expose a portion of an upper surface of the n-type GaN layer 12. A p-type electrode 15 is formed on an upper surface of the p-type GaN layer 14 and an n-type electrode 16 is formed on the exposed upper surface of the n-type GaN layer 12.

[5] The above described light-emitting device is applied to a variety of fields as a highly efficient light source. However, the related art light-emitting device is very susceptible to an electric shock such as a static electricity. In other words, an electrostatic discharge (ESD) generated in reverse bias in the light-emitting device may damage an internal physical structure of the light-emitting device.

[6] In addition, because the related art ESD-protection device occupies a relatively large area, light efficiency of the light-emitting device is decreased.

[7] Furthermore, because the addition of the ESD-protection device increases a size of the light-emitting device, it is difficult to apply the light-emitting device to a sub-miniature, ultra-thin and ultra-lightweight package.

Disclosure of Invention

Technical Problem

[8] An embodiment of the present invention provides a light-emitting device and a method for manufacturing the same that substantially obviates one or more of the

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problems due to limitations and disadvantages of the related art.

[9] Another embodiment of the present invention provides a light-emitting device including an electrostatic discharge protection device for protecting the device from electrostatic discharge (ESD) applied thereto in reverse bias and a method for manufacturing the same.

[10] Further another embodiment of the present invention provides a light-emitting device of high light efficiency by forming at least one bonding pad in an ESD-protection device and a method for manufacturing the same.

[11] Also, another embodiment of the present invention provides a light-emitting device that includes an ESD-protection device and can be applied to a subminiature, ultra-thin and ultra-lightweight package, and a method for manufacturing the same.

Technical Solution

[12] In one embodiment of the present invention provides a light-emitting device, comprising: a substrate; a light-emitting device on one part of the substrate, the light-emitting device having a first semiconductor layer and a second semiconductor layer; a protection device on another part of the substrate, the protection device having a fourth semiconductor layer and a fifth semiconductor layer; and a connecting line for electrically connecting the light-emitting device and the protection device.

[13] In another embodiment of the present invention provides a light-emitting device comprising: a substrate; a light-emitting device on one part of the substrate, the light-emitting device having a first, a second and a third semiconductor layer; a protection device on another part of the substrate, the protection device having a fourth, a fifth and a sixth semiconductor layer; and a connecting line for electrically connecting the light-emitting device and the protection device.

[14] In further another embodiment of the present invention provides a method for manufacturing a light-emitting device, the method comprising: forming a light-emitting device with a first semiconductor layer and a second semiconductor layer on one part of the substrate; forming a protection device with a fourth semiconductor layer and a fifth semiconductor layer on another part of the substrate; and forming a connecting line for electrically connecting the light-emitting device and the protection device.

Advantageous Effects

[15] According to embodiments of the present invention, it is possible to provide a light-emitting device that has an electrostatic discharge (ESD) protection characteristic, and thus can be applied to a light emitting diode package products requiring a high ESD characteristic.

[16] According to embodiments of the present invention, it is also possible to provide a light-emitting device having a high ESD-protection characteristic without light

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efficiency reduction by forming at least one bonding pad in a protection device.

[17] According to embodiments of the present invention, it is also possible to provide a light-emitting diode that includes an ESD-protection device therein and can be applied to a subminiature, ultra-thin and ultra-lightweight package, and thus can be applied to a variety of package products.

Brief Description of the Drawings

[18] Fig. 1 is a sectional view illustrating a related art light-emitting device;

[19] Fig. 2 is a plan view illustrating a light-emitting device according to a first embodiment of the present invention;

[20] Fig. 3 is a perspective view illustrating the light-emitting device according to the first embodiment of the present invention;

[21] Fig. 4 is a sectional view taken along line B-B in Fig. 3;

[22] Fig. 5 is a sectional view taken along line C-C in Fig. 3;

[23] Fig. 6 is a view illustrating a schematic circuit of the light-emitting device according to the first embodiment of the present invention;

[24] Fig. 7 is a plan view illustrating a light-emitting device according to a second embodiment of the present invention; and

[25] Fig. 8 is a view illustrating a schematic circuit of the light-emitting device according to the second embodiment of the present invention.

Best Mode for Carrying Out the Invention

[26] Hereinafter, embodiments of the present invention will be described in detail with reference to accompanying drawings.

[27] It will be understood that when an element is referred to as being on/under a layer, it can be directly on/under, and one or more intervening elements may also be present.

[28] Although only an NPN type light emitting device will be described in the following embodiments, the embodiments of present invention are not limited thereto, but instead may also be applied to various types of light emitting device such as a PN type light emitting diode.

[29] First Embodiment

[30] Figs. 2 through 6 illustrate a light-emitting device according to a first embodiment of the present invention.

[31] Fig. 2 is a plan view illustrating the light-emitting device according to the first embodiment of the present invention and Fig. 3 is a perspective view illustrating the light-emitting device according to the first embodiment of the present invention.

[32] Referring to Figs. 2 and 3, a light-emitting device 300 and a protection device are formed on a substrate 310 with the same stacking structure.

[33] Here, the protection device 400 may be separated from the light-emitting device

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300 at one part of the light-emitting device 300. The substrate 310 may be an insulating substrate such as a sapphire substrate.

[34] A passivation layer 390 may be formed in a boundary region 490 between the light-emitting device 300 and the protection device 400 to electrically separate them.

[35] The light-emitting device 300 may be an NPN type light-emitting device. The protection device 400 protects the light-emitting device 300 using a voltage applied thereto in a reverse direction. The protection device 400 may also be an NPN type diode, for example. In other words, the light-emitting device 300 and the protection device 400 may have the identical NPN structure.

[36] The light-emitting device 300 may be connected to a first semiconductor layer 420 of the protection device through a first connecting line 361. The protection device 400 may be connected to the first semiconductor layer 320 through a second connecting line 461.

[37] The first and second connecting lines 361 and 461 may be metal layers. The first and second connecting lines 361 and 461 may be formed on ohm-forming layers 350 and 450, first semiconductor layers 320 and 420, and a passivation layer 390.

[38] A first bonding pad 360 may be formed on the ohm-forming layer 350 of the light-emitting device at one side of the first connecting line 361. A second bonding pad 460 may be formed on the ohm-forming layer 450 of the protection device at one side of the second connecting line 461.

[39] The ohm-forming layers 350 and 450 may be transparent electrodes.

[40] According to the first embodiment of the present invention, because a second pad 460 is formed on a protection device 400, it is possible to secure a light-emitting region of the light-emitting device as large as the second bonding pad 460 and to prevent a light efficiency reduction in the light-emitting device with an ESD protection.

[41] A structure of the light-emitting device with a protection device will be described in more detail with reference to Figs. 3 to 6.

[42] Fig. 3 is a perspective view illustrating the light-emitting device according to the first embodiment of the present invention. Fig. 4 is a sectional view taken along line B-B in Fig. 3, and Fig. 5 is a sectional view taken along line C-C in Fig. 3. Fig. 6 is a view illustrating a schematic circuit of the light-emitting device according to the first embodiment of the present invention.

[43] A light-emitting device 300 and a protection device 400 may include first semiconductor layers 320 and 420, active layers 330 and 430, second semiconductor layers 340 and 440, third semiconductor layers 345 and 445, and ohm-forming layers 350 and 450, formed on a substrate 310.

[44] The first semiconductor layers 320 and 420 formed on the substrate 310 may be n-GaN layers. The active layers 330 and 430 formed on the first semiconductor layers

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320 and 420 may include InGaN-QW (quantum well). The second semiconductor layers 340 and 440 formed on the active layers may be p-GaN layers. The third semiconductor layers 345 and 445 formed on the second semiconductor layers 340 and 440 may be n-GaN layers.

[45] The ohm-forming layers 350 and 450 may be formed on the third semiconductor layers 345 and 445. Here, the ohm-forming layers may be transparent oxide layers and may be at least one of ITO, ZnOx, Al doped ZnOx, RuOx, TiOx, IrOx and the like.

[46] The first, second and third semiconductor layers 320, 340 and 345 of the light-emitting device and the first, second and third semiconductor layers 420, 440 and 445 of the protection device may be grown using a process of metal organic chemical vapor deposition (MOCVD) and the like. A buffer layer (not shown) such as AlN/GaN may also be formed on an upper surface of the substrate 310 in order to improve lattice match between the first semiconductor layers 320 and 420 and the substrate. Here, the third semiconductor layers 345 and 445 are layers for ohmic contacts.

[47] A boundary region 490 between the light-emitting device 300 and the protection device 400 may be etched such that a portion of an upper surface of the substrate is exposed and the light-emitting device and the protection device are electrically separated from each other. Also, in the vicinity of the boundary region, portions of the first conductive semiconductor layer 320 in the light-emitting device and the first conductive semiconductor layer 420 in the protection device may be exposed by the etching.

[48] A passivation layer 390 may be formed on the boundary region 490 and a periphery thereof for insulation between the devices and between the layers on the different devices. The passivation layer 390 may be stacked over the boundary region 490, the upper surface of the substrate 310 in the vicinity of the boundary region 490, an exposed portion of the first semiconductor layer 420 and the ohm-forming layer 450 of the protection device 400, and an exposed portion of the first semiconductor layer 320 and the ohm-forming layer 350 of the light-emitting device 300.

[49] A first and a second connecting line 361 and 461 may be formed to electrically connect the light-emitting device 300 with the protection device 400. The first connecting line 361 may be formed on the passivation layer 390, the ohm-forming layer 350 of the light-emitting device and the first semiconductor layer 420 of the protection device. At one side of the first connecting line 361, a first bonding pad 360 of a predetermined size and shape may be formed.

[50] The second connecting line 461 may be formed of a metal layer on the ohm-forming layer 450 of the protection device, the passivation layer 390, and the first semiconductor layer 320 of the light-emitting device. At one side of the second connecting line 461, a second bonding pad 460 of a predetermined size and shape may

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be formed.

[51] The first connecting line 361 or the first bonding pad 360 formed on the ohm-forming layer 350 of the light-emitting device is electrically connected to a third semiconductor layer 345 through the ohm-forming layer 350 of the light-emitting device. Likewise, the second connecting line 461 or the second bonding pad 460 formed on the ohm-forming layer 450 of the protection device is electrically connected to a third semiconductor layer 445 through the ohm-forming layer 450 of the protection device.

[52] Accordingly, the first connecting line 361 is electrically connected to the first semiconductor layer 420 of the protection device and the third semiconductor layer 345 of the light-emitting device, which are n-GaN layers. Likewise, the second connecting line 461 is electrically connected to the first semiconductor layer 320 of the light-emitting device and the third semiconductor layer 445 of the protection device, which are n-GaN layers.

[53] The first bonding pad 360 may be formed at one side of the first connecting line 361 on the light-emitting device 300, and the second bonding pad 460 may be formed at one side of the second connecting line 461 on the protection device. Accordingly, the first and second connecting lines 361 and 461 may be wire-bonded, through the first and second bonding pads 360 and 460, to the light-emitting device including the protection device. The first and second bonding pads 360 and 460 may be formed of metal layers together with the first and second connecting lines 361 and 461.

[54] Referring to Fig. 6, the first connecting line 361 electrically connects the ohm-forming layer 350 of the light-emitting device with the first semiconductor layer 420 of the protection device. The first bonding pad 360 formed at a side of the first connecting line 361 serves as an anode (A) terminal of the light-emitting device.

[55] The second connecting line 461 electrically connects the ohm-forming layer 450 of the protection device with the first semiconductor layer 320 of the light-emitting device. The second bonding pad 460 formed at a side of the second connecting line 461 serves as a cathode (K) terminal of the light-emitting device.

[56] Hereinafter, operations of the first embodiment will be described. Referring to Figs. 4 to 6, the first and second bonding pads 360 and 460 may serve as an anode and a cathode, respectively. In this case, when a p-type carrier flows into the device from the outside, the third semiconductor layer 345 of the light-emitting device forms a reverse grading between the third semiconductor layer 345 and the second semiconductor layer 340 of the light-emitting device to serve as an electrode contact layer.

[57] The light-emitting device 300 operates normally and can be driven at a low voltage. In this case, because an anode is connected to the first semiconductor layer 420 of the protection device to apply a reverse voltage, the device does not work. When a reverse voltage or a reverse voltage of ESD is applied to the light-emitting device 300

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suddenly, the light-emitting device 300 does not work because a reverse voltage is applied thereto. In other words, because of the reverse voltage, the protection device 400 works to safely protect the light-emitting device 300.

[58] The light-emitting device 300 according to the first embodiment of the present invention includes no bonding pad to be connected to the cathode. Accordingly, it is possible to increase the light-emitting device region by a size of the bonding pad 460 formed on the protection device.

[59] In other words, only one bonding pad is formed in the light-emitting device region. Such a light-emitting device 300 with an ESD-protection characteristic can be used in an ultra-thin high brightness package product which a diode cannot be mounted on and a package product which a protection device is needed to be mounted on.

[60] According to another embodiment of the present invention, first and second bonding pads may be realized in a different structure from that of the first embodiment. For example, the first bonding pad may be formed on a first semiconductor of a light-emitting device, and the second bonding pad may be formed on a first semiconductor layer of a protection device.

[61] Second Embodiment

[62] Fig. 7 is a plan view illustrating a light-emitting device according to a second embodiment of the present invention. Fig. 8 is a view illustrating a schematic circuit of the light-emitting device according to the second embodiment of the present invention.

[63] The second embodiment of the present invention illustrates a structure where two bonding pads are formed in a protection device. The characteristics of the first embodiment can be applied thereto.

[64] For example, the light-emitting device according to the second embodiment of the present invention may have the same stacking structure as that of the first embodiment. The only difference of the second embodiment is that two bonding pads are formed in a protection device 400.

[65] Referring to Figs. 7 and 8, a first bonding pad 470a may be formed in one part of a region 500 including a protection device 400, and a second bonding pad 460a may be formed in another part of the region. For example, the first bonding pad 470a may be formed on an ohm-forming layer 450 of the protection device, and the second bonding pad 460a may be formed on a first conductive semiconductor layer 420 of the protection device.

[66] The first and second bonding pads 470a and 460a may be formed to have the identical size or different sizes, and may be electrically connected to the light-emitting device 300 through a first connecting line 361 and a second connecting line 461.

[67] For example, the first connecting line 361 is formed on the first semiconductor layer 420 of the protection device 400 and an ohm-forming layer 350 of the light-

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emitting device 300, to electrically interconnect the first semiconductor layer 420 of the protection device 400 and the third semiconductor layer 345 of the light-emitting device 300. The first bonding pad 470a formed at one side of the first connecting line 361 in the protection device region serves as an anode (A) terminal.

[68] The second connecting line 461 is formed on an ohm-forming layer of the protection device 400 and a first semiconductor layer 320 of the light-emitting device 300, to electrically interconnect the third semiconductor layer 445 of the protection device and the first semiconductor layer 320 of the light-emitting device. The second bonding pad 460a formed at one side of the second connecting line 461 in the protection device region serves as a cathode (K) terminal.

[69] As described above, according to the second embodiment of the present invention, two bonding pads 460a and 470a are formed in an ESD-protection device 400, and both electrodes of the protection device 400 and the light-emitting device 300 are inter-connected in a circuit, respectively. Accordingly, a light-emitting device with a protection device is formed to operate.

[70] According to the second embodiment of the present invention, because a bonding pad is formed on a protection device instead of a light-emitting device, it is possible to increase a light-emitting region.

[71] Furthermore, according to the second embodiment of the present invention, because a bonding pad is formed on a protection device instead of a light-emitting device, an additional bonding pad region except the protection device region is not required.

[72] While the present invention has been described and illustrated herein with reference to the preferred embodiments thereof, it will be apparent to those skilled in the art that various modifications and variations can be made therein without departing from the spirit and scope of the invention. Thus, it is intended that the present invention covers the modifications and variations of this invention that come within the scope of the appended claims and their equivalents.

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Claims

[1] A light-emitting device, comprising:
a substrate;
a light-emitting device on one part of the substrate and including a first semiconductor layer and a second semiconductor layer;
a protection device on another part of the substrate and including a fourth semiconductor layer and a fifth semiconductor layer; and
a connecting line for electrically connecting the light-emitting device with the protection device.

[2] The light-emitting device according to claim 1, comprising:
a first bonding pad on the light-emitting device; and
a second bonding pad on the protection device.

[3] The light-emitting device according to claim 1, comprising:
a first bonding pad on one part of the protection device; and
a second bonding pad on another part of the protection device.

[4] The light-emitting device according to claim 1, comprising:
a first ohm-forming layer on the second semiconductor layer;
a second ohm-forming layer on the fifth semiconductor layer;
a first bonding pad on the first ohm-forming layer; and
a second bonding pad on the second ohm-forming layer.

[5] The light-emitting device according to claim 1, comprising:
a first ohm-forming layer on the second semiconductor layer;
a second ohm-forming layer on the fifth semiconductor layer;
a second bonding pad on the second ohm-forming layer; and
a first bonding pad on the fourth semiconductor layer.

[6] A light-emitting device comprising:
a substrate;
a light-emitting device on one part of the substrate and including a first, a second and a third semiconductor layer;
a protection device on another part of the substrate and including a fourth, a fifth and a sixth semiconductor layer; and
a connecting line for electrically connecting the light-emitting device with the protection device.

[7] The light-emitting device according to claim 6, comprising:
a first bonding pad on the light-emitting device; and
a second bonding pad on the protection device.

[8] The light-emitting device according to claim 6, comprising:

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a first bonding pad on one part of the protection device; and
a second bonding pad on another part of the protection device.

[9] The light-emitting device according to claim 6, comprising:
a first ohm-forming layer on the third semiconductor layer;
a second ohm-forming layer on the sixth semiconductor layer;
a first bonding pad on the first ohm-forming layer; and
a second bonding pad on the second ohm-forming layer.

[10] The light-emitting device according to claim 6, comprising:
a first ohm-forming layer on the third semiconductor layer;
a second ohm-forming layer on the sixth semiconductor layer;
a second bonding pad on the second ohm-forming layer; and
a first bonding pad on the fourth semiconductor layer.

[11] A method for manufacturing a light-emitting device, the method comprising:
forming a light-emitting device including a first semiconductor layer and a second semiconductor layer on one part of a substrate;
forming a protection device including a fourth semiconductor layer and a fifth semiconductor layer on another part of the substrate; and
forming a connecting line for electrically connecting the light-emitting device with the protection device.

[12] The method for manufacturing a light-emitting device according to claim 11, comprising:
forming a first bonding pad on the light-emitting device; and
forming a second bonding pad on the protection device.

[13] The method for manufacturing a light-emitting device according to claim 11, comprising:
forming a first bonding pad on one part of the protection device; and
forming a second bonding pad on another part of the protection device.

[14] The method for manufacturing a light-emitting device according to claim 11, comprising:
forming a first ohm-forming layer on the light-emitting device;
forming a second ohm-forming layer on the protection device;
forming a first bonding pad on the first ohm-forming layer; and
forming a second bonding pad on the second ohm-forming layer.

[15] The method for manufacturing a light-emitting device according to claim 11, comprising:
forming a first ohm-forming layer on the light-emitting device;
forming a second ohm-forming layer on the protection device;
forming a second bonding pad on the second ohm-forming layer; and

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forming a first bonding pad on the fourth semiconductor layer of the protection device.

[16] The method for manufacturing a light-emitting device according to claim 11, comprising:
forming a third semiconductor layer on the second semiconductor layer; and
forming a sixth semiconductor layer on the fifth semiconductor layer.

[17] The method for manufacturing a light-emitting device according to claim 16, comprising:
forming a first ohm-forming layer on the third semiconductor layer;
forming a second ohm-forming layer on the sixth semiconductor layer;
forming a first bonding pad on the first ohm-forming layer; and
forming a second bonding pad on the second ohm-forming layer.

[18] The method for manufacturing a light-emitting device according to claim 16, comprising:
forming a first ohm-forming layer on the third semiconductor layer;
forming a second ohm-forming layer on the sixth semiconductor layer;
forming a second bonding pad on the second ohm-forming layer; and
forming a first bonding pad on the fourth semiconductor layer.

[19] The method for manufacturing a light-emitting device according to claim 11, comprising forming a passivation layer for electrically insulating the light-emitting device from the protection device.

[20] The method for manufacturing a light-emitting device according to claim 11, wherein the first semiconductor layer and the fourth semiconductor layer have the same conductive type and are formed at the same time, and
the second semiconductor layer and the fifth semiconductor layer have the same conductive type and formed at the same time.

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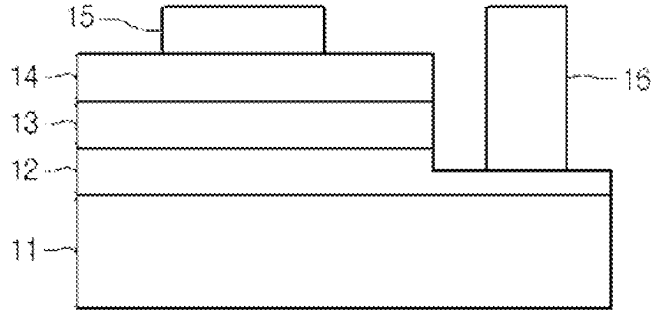
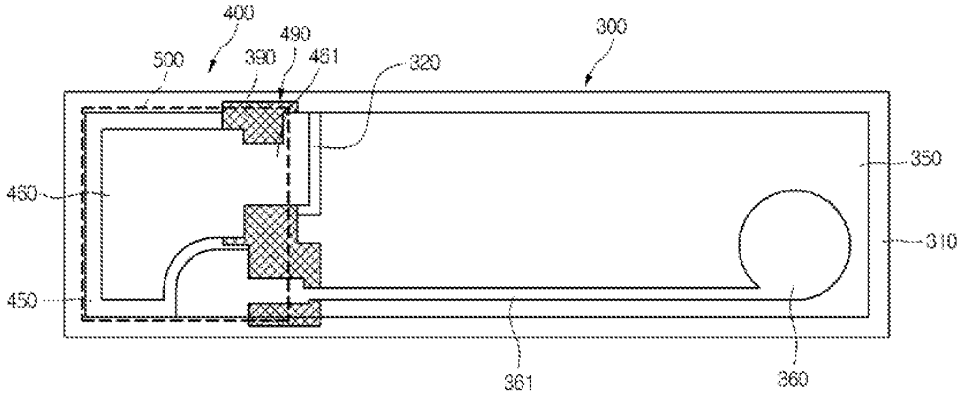
[Fig. 1]

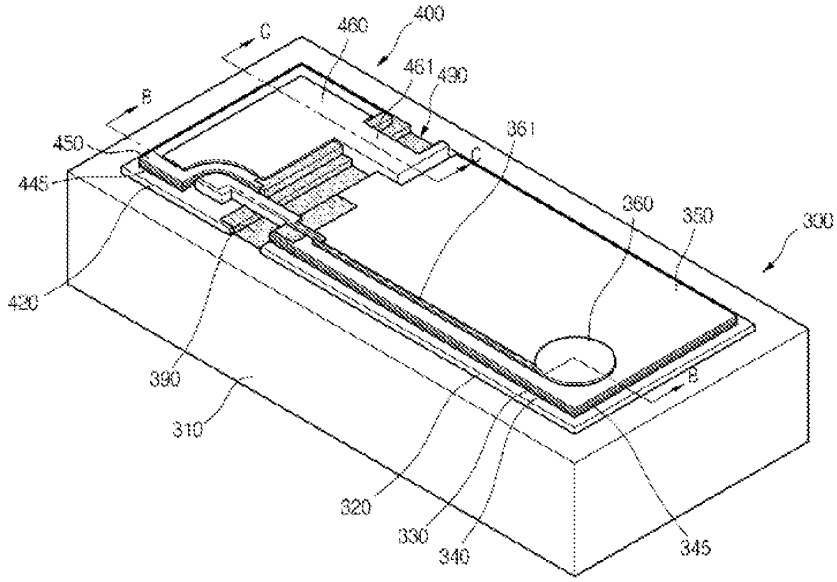
(Related Art)



[Fig. 2]



[Fig. 3]



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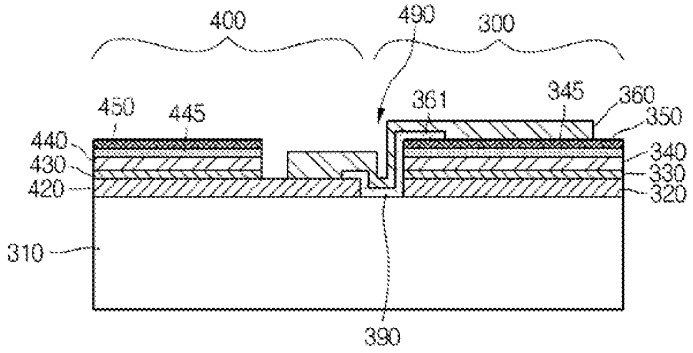
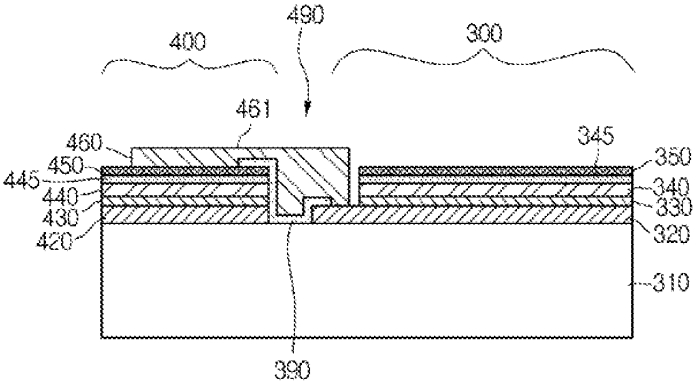
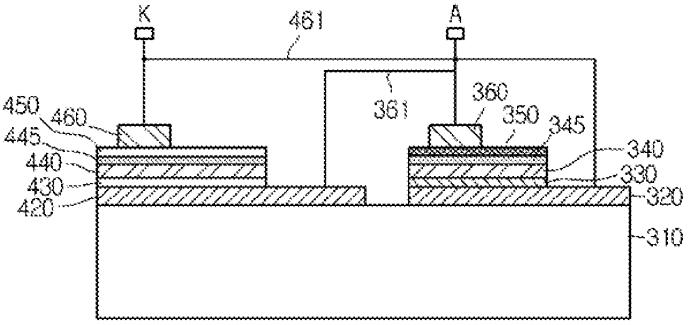
[Fig. 4]



[Fig. 5]



[Fig. 6]



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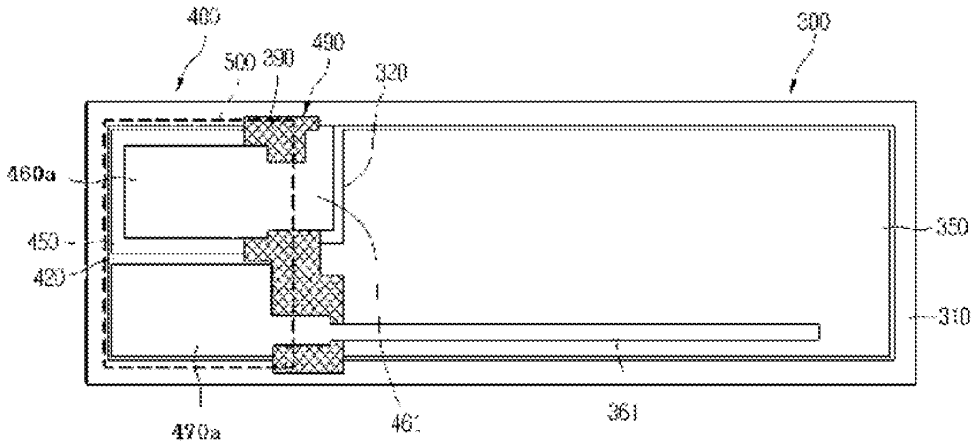
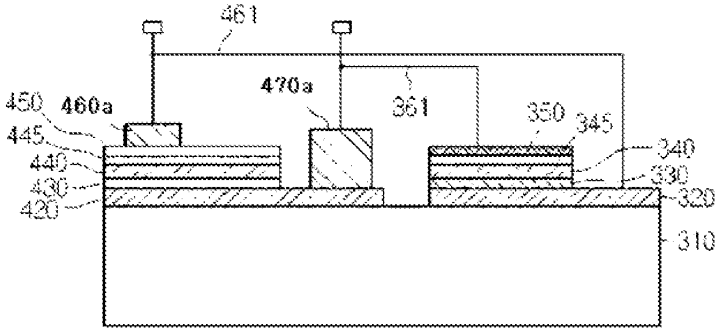
[Fig. 7]



[Fig. 8]



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2007/001392

A. CLASSIFICATION OF SUBJECT MATTER

H01L 33/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC8 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

e-KIPASS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US06547249B2 (COLLINS, III et al.) 15. April. 2003 See abstract, column 2,line 20 - column 4, line56; Figures 6,7	1-20
A	JP15243701A (TOYOTA GOSEI CO., LTD) 29. August. 2003 See abstract, claims 1,3; Figure 8	1-20
A	KR1020050076680A (OPTO TECH Corp.) 26. July. 2005 See abstract, pp.3-4, claim 1; Figures 3-6	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 JUNE 2007 (27.06.2007)	**27 JUNE 2007 (27.06.2007)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office 920 Dunsan-dong, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	KIM, Ki Hyun Telephone No. 82-42-481-8221

Form PCT/ISA/210 (second sheet) (April 2007)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/KR2007/001392

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US06547249 B2	15.04.2003	DE10213464A1	24.10.2002
		JP14359402	13.12.2002
		JP2002359402A2	13.12.2002
		TW540169B	01.07.2003
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		TW223689B	11.11.2004
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		US2005156186AA	21.07.2005

Form PCT/ISA/210 (patent family annex) (April 2007)

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Publication Date: 24.02.2011 International Filing Date: 28.07.2010
IPC: G03B 21/60 (2006.01) ()()

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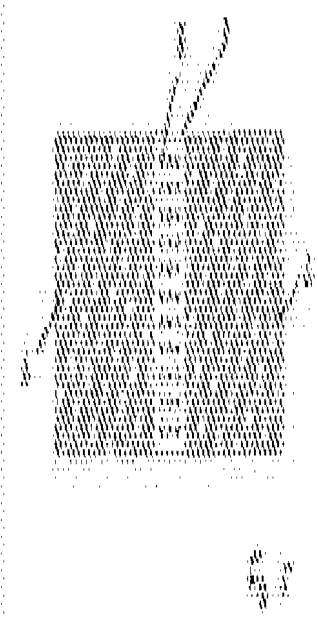
Priority Data: 0903998 18.08.2009 FR

Title (EN) METHOD FOR MANUFACTURING A PROJECTION SCREEN, AND CORRESPONDING SCREEN
(FR) PROCÉDÉ DE FABRICATION D'UN ÉCRAN DE PROJECTION ET ÉCRAN CORRESPONDANT

Abstract: (EN) The invention relates to a method for manufacturing a projection screen (10), preferably pervious to sound waves, by assembling at least two preferably open-worked panels (1, 2) with a partial overlap. According to the invention, said method includes, for the or at least one of the area(s) (3) for linking the panels of the screen together with a partial overlap, at least one step of changing the light reflection characteristics of the partial overlap linking area (3) by treating the surface and/or the body of said area (3).
(FR) L'invention concerne un procédé de fabrication d'un écran de projection (10), de préférence perméable aux ondes sonores, par assemblage à recouvrement partiel d'au moins deux lés (1, 2), de préférence ajourés. Selon l'invention, ledit procédé comprend, pour la, ou au moins l'une des, zone(s) (3) de liaison à recouvrement partiel de lés de l'écran entre eux, au moins une étape de modification des caractéristiques de réflexion lumineuse de la zone (3) de liaison à recouvrement partiel par traitement en surface et/ou dans l'épaisseur de ladite zone (3).



(12) DEMANDE INTERNATIONALE PUBLIÉE EN VERTU DU TRAITÉ DE COOPÉRATION EN MATIÈRE DE BREVETS (PCT)

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0903989 18 août 2009 (18.08.2009) FR

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(74) Mandataires : **GODINEAU, Valérie** et al.; Brema-Loyer, 9, Rue Edmé Mariotte, B.P. 70620, F-44306 Nantes Cedex 3 (FR).

(81) États désignés *(sauf indication contraire, pour tout titre de protection nationale disponible)* : AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) États désignés *(sauf indication contraire, pour tout titre de protection régionale disponible)* : ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), eurasien (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), européen (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Publiée :

— *avec rapport de recherche internationale (Art. 21(3))*

(54) Title : METHOD FOR MANUFACTURING A PROJECTION SCREEN, AND CORRESPONDING SCREEN

(54) Titre : PROCÉDÉ DE FABRICATION D'UN ÉCRAN DE PROJECTION ET ÉCRAN CORRESPONDANT

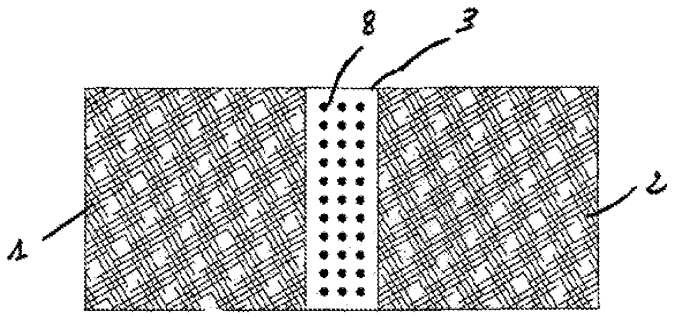

Fig. 5

(57) Abstract : The invention relates to a method for manufacturing a projection screen (10), preferably pervious to sound waves, by assembling at least two preferably open-worked panels (1, 2) with a partial overlap. According to the invention, said method includes, for the or at least one of the area(s) (3) for linking the panels of the screen together with a partial overlap, at least one step of changing the light reflection characteristics of the partial overlap linking area (3) by treating the surface and/or the body of said area (3).

(57) Abrégé : L'invention concerne un procédé de fabrication d'un écran de projection (10), de préférence perméable aux ondes sonores, par assemblage à recouvrement partiel d'au moins deux lés (1, 2), de

[Suite sur la page suivante]

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préférence ajourés. Selon l'invention, ledit procédé comprend, pour la, ou au moins l'une des, zone(s) (3) de liaison à recouvrement partiel de lés de l'écran entre eux, au moins une étape de modification des caractéristiques de réflexion lumineuse de la zone (3) de liaison à recouvrement partiel par traitement en surface et/ou dans l'épaisseur de ladite zone (3).

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1

Procédé de fabrication d'un écran de projection et écran correspondant

La présente invention concerne de manière générale les écrans de projection.

L'invention concerne plus particulièrement un procédé de fabrication d'un écran de projection, de préférence perméable aux ondes sonores, par assemblage à recouvrement partiel d'au moins deux lés, de préférence ajourés.

De manière usuelle, les écrans de projection se présentent sous la forme de lés, de type feuille ou film lisse (par exemple en PVC) ou encore de type toile tissée. On connaît en particulier des écrans perméables aux ondes sonores qui permettent le placement de sources sonores derrière l'écran de manière à favoriser la cohérence perceptible entre l'image projetée et le son. Les écrans perméables aux ondes sonores peuvent être formés de toiles, par exemple en PVC, micro ou macro perforées, ou de toiles tissées. Les perforations peuvent être réalisées par un rouleau perforant en continu la toile de projection. De tels écrans perméables aux ondes sonores sont décrits plus en détail dans le brevet FR-2.810.122.

Les dimensions maximales d'un lé sont limitées par ses moyens de fabrication, ce qui limite également les dimensions de la surface de projection disponible. Le plus souvent, les dimensions maximales du lé en largeur (ou hauteur) sont de l'ordre de 3 m à 4 m. La limitation de la surface de projection est encore plus importante dans le cas d'un écran enroulable, pour lequel une partie du lé reste enroulée autour du support d'enroulement et de déroulement.

Il n'est donc pas possible aujourd'hui d'utiliser un écran formé d'un seul lé pour des applications, en particulier professionnelles nécessitant de projeter des images de taille importante. Pour résoudre ce problème de taille de l'écran, il

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est connu de raccorder plusieurs lés entre eux, horizontalement et/ou verticalement (en configuration d'utilisation de l'écran), afin d'augmenter la surface totale de projection disponible.

Plusieurs modes de raccordement sont usuellement utilisés. Il est connu de raccorder un bord d'un lé au bord d'un autre lé, par exemple par couture. Cependant, un tel assemblage par raccordement bord-à-bord de deux lés n'offre pas une bonne résistance mécanique, en particulier en traction.

Pour obtenir une bonne résistance mécanique en traction au niveau de la zone de liaison entre les deux lés, il est connu d'assembler les deux lés entre eux par une zone de liaison à recouvrement partiel des lés. Ce recouvrement peut s'opérer indifféremment suivant les figures 8 et 9. La figure 8 illustre un recouvrement direct par simple superposition d'un lé sur un lé adjacent. La figure 9 illustre le cas où l'un des lés soit équipé d'une pièce, dite de maintien, de type lèvre ou bavette, rapportée sur une face d'un lé et débordant du lé de manière à venir recouvrir une partie de l'autre lé. Dans ce cas, ladite lèvre du lé et la partie recouverte de l'autre lé forment ladite zone de liaison à recouvrement partiel. Les figures 8 et 9 illustrent par des vues de côté en coupe un assemblage de deux lés 1, 2 par recouvrement partiel, respectivement sans et avec une pièce de maintien 2A rapportée.

Une telle zone de liaison à recouvrement partiel entre les deux lés peut être obtenue par exemple par couture ou collage des deux parties de lés superposées formant ladite zone de liaison à recouvrement.

Cependant, on observe que la zone de liaison à recouvrement partiel présente le plus souvent des caractéristiques de réflexion différentes de celles des parties de lés de l'écran jouxtant cette zone de liaison. Le plus souvent, la zone de liaison présente des caractéristiques de réflexion lumineuse (ou pouvoir de réflexion lumineuse) plus importantes et donc un gain plus élevé.

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En effet, on observe une surépaisseur provoquant, d'une part, une petite ombre projetée le long du bord libre du lé situé côté face de projection et, d'autre part, une augmentation du pouvoir de réflexion lumineuse de la zone de liaison du fait de l'augmentation locale d'épaisseur.

En outre, dans le cas d'utilisation de lés perméables aux ondes sonores, les jours ou interstices sont obturés en totalité ou partiellement par le recouvrement des parties correspondantes des lés qui forment la zone de liaison à recouvrement, ce qui augmente également le pouvoir de réflexion lumineuse de la zone de liaison. D'autre part, la surépaisseur provoque des difficultés importantes en cas de nécessité d'enrouler la toile de projection, par exemple, pour réaliser un écran rétractable, sans marquer l'écran.

Pour résoudre le problème de surépaisseur de la zone de liaison à recouvrement, il est connu de procéder à une soudure, par exemple à haute fréquence ou ultrasons, avec écrasement de la zone de liaison à recouvrement, ce qui permet d'obtenir une épaisseur de la zone de liaison à recouvrement sensiblement égale à celle des parties de lé jouxtant la zone de liaison. La figure 10 illustre une vue en coupe de côté d'un tel raccordement par soudure et écrasement de la zone de liaison 3 à recouvrement de deux lés 1, 2. Cependant, la soudure entraine un changement d'état de surface de la zone de liaison qui devient plus lisse, ce qui augmente le pouvoir de réflexion de ladite zone de liaison 3 par rapport au reste des lés, en particulier pour une vision proche de l'axe perpendiculaire à la zone de liaison. En effet, le «lissage» de la zone de liaison affecte significativement les caractéristiques de diffraction de la lumière dans cette zone, et a tendance à concentrer la lumière diffractée perpendiculairement à la surface de projection, ce qui accentue encore la luminosité dans la zone principale de localisation des «spectateurs».

En outre, dans le cas d'utilisation de lés ajourés pour obtenir un écran perméable aux ondes sonores, l'opération de soudure avec écrasement entraine l'obturation partielle ou totale des jours, ce qui augmente le pouvoir de

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réflexion lumineuse de la zone de liaison par rapport aux autres parties des lés. Les figures 1 et 2 mettent en évidence l'augmentation des propriétés de réflexion de la zone de liaison par rapport aux autres zones des lés dans le cas de lés ajourés et raccordés par soudure et écrasement. La figure 1 illustre en vue de face l'assemblage à recouvrement partiel de deux lés ajourés, par soudure et écrasement de la zone de liaison à recouvrement partiel. La figure 2 est un graphique présentant deux courbes C13 et C11 donnant chacune l'indice de gain de réflectivité IG d'une zone de l'écran en fonction de l'angle de vision ALPHA de ladite zone étudiée par rapport à la direction de projection du flux lumineux (c'est-à-dire de l'image). Les indices de gain des zones de l'écran donnés par les courbes C13 et C11 sont les indices de gains respectivement de la zone de liaison entre les lés et d'une autre zone des lés, par exemple une zone jouxtant la zone de liaison.

Pour un flux lumineux, de température de couleur donnée, projeté sur une zone de l'écran, l'indice de gain de réflectivité de ladite zone correspond à la luminance mesurée au niveau de ladite zone, rapportée à la luminance préalablement mesurée (dans les mêmes conditions) pour une zone de référence dont le gain est considéré comme égal à 1. Plus précisément, le gain d'un écran est défini comme étant le ratio de la luminance de l'écran testé éclairé par un faisceau de lumière blanche issu d'un projecteur, en comparaison à la luminance d'une référence standard de gain 1.0. Cette référence standard pour des essais de gain, est défini dans «British Standard BS 5550-7.2.5:1980 Cinematography», comme étant un carreau de carbonate de magnésium.

Ainsi, l'indice de gain de réflectivité d'une zone est fonction de la luminance de ladite zone qui dépend du pouvoir de réflexion de l'écran.

La figure 2 met ainsi en évidence, en particulier pour une plage d'angle de vision sensiblement égale à [-30 ; +30°], correspondant sensiblement à une vision dans l'axe ou proche de l'axe du projecteur, une augmentation

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importante de l'indice de gain de réflectivité IG au niveau de la zone de liaison par rapport aux autres zones des lés, ce qui traduit une augmentation du pouvoir réflecteur de ladite zone de liaison. Cela se traduit en visionnage par une zone clairement plus lumineuse en projection, ce qui est particulièrement gênant, en particulier sur les couleurs vives ou les images unies claires (ciel, fond blanc).

En outre, un raccordement par soudure est très délicat à mettre en œuvre dans le cas d'un écran perméable aux ondes sonores formé de toiles tissées constituées de fils comprenant une âme de fibres de verre recouvertes de PVC. En effet, l'opération de soudure peut entrainer une modification de la teinte du PVC, ce qui peut modifier la balance des couleurs de l'image visualisée au niveau de la zone de liaison des lés et les propriétés de réflexion lumineuse de ladite zone.

Ainsi, les solutions connues de raccordement à recouvrement partiel des lés entre eux génèrent une augmentation du pouvoir de réflexion de la zone de liaison entre lés, ce qui nuit à la qualité de l'image perçue par le spectateur.

La présente invention a pour but de permettre un raccordement, à recouvrement partiel, des lés entre eux pour lequel l'impact visuel de la zone de liaison entre lés est réduit par rapport aux parties des lés jouxtant ladite zone de liaison.

En particulier, l'invention a pour but de permettre de raccorder des lés en améliorant l'homogénéité des propriétés de réflexion de la lumière entre la zone de liaison des lés et les autres zones des lés, telles que les zones jouxtant ladite zone de liaison.

A cet effet, l'invention a pour objet un procédé de fabrication d'un écran de projection, de préférence perméable aux ondes sonores, par assemblage à recouvrement partiel d'au moins deux lés, lesdits lés étant de préférence

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ajourés, caractérisé en ce que ledit procédé comprend, pour la, ou au moins l'une des, zone(s) de liaison à recouvrement partiel de lés de l'écran, au moins une étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement partiel par traitement en surface et/ou dans l'épaisseur de ladite zone.

La modification des caractéristiques de réflexion, ou pouvoir de réflexion, de la zone de liaison par traitement de surface et/ou dans l'épaisseur de ladite zone permet de ramener l'indice de gain de réflectivité de ladite zone de liaison à une valeur proche de celle des autres zones, en particulier des zones de lés jouxtant ladite zone de liaison. Les propriétés de réflexion de l'écran formé par l'assemblage des lés sont ainsi sensiblement uniformes d'une zone à une autre, en particulier entre la zone de liaison et les zones jouxtant la zone de liaison. Un tel procédé permet ainsi de fabriquer des écrans offrant une surface de projection de grande taille en limitant l'impact visuel de la zone de liaison des lés entre eux pour le spectateur par rapport aux autres zones des lés.

Le procédé de fabrication d'écran selon l'invention permet ainsi d'obtenir une surface de projection de grande taille et dont le pouvoir de réflexion (ou d'indice de gain de réflectivité) est homogène d'une zone à une autre de la surface de projection. Le traitement permet également d'homogénéiser le pouvoir de réflexion de la zone de liaison pour différents angles de vision, en particulier pour des angles de vision compris entre -30 et +30° par rapport à la direction de projection, c'est-à-dire pour des angles de vision correspondant sensiblement à la direction de projection, et aux zones de visionnage les plus usuelles.

Le traitement de la zone de liaison peut également être choisi de manière à obtenir une teinte sensiblement homogène avec la teinte des zones jouxtant la zone de liaison afin de conserver la balance de couleurs souhaitée pour les images (ou flux lumineux) projetées sur l'écran.

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Enfin, le raccordement à recouvrement partiel des lés entre eux offre une résistance mécanique importante permettant d'appliquer une tension suffisante aux lés.

Généralement, l'étape de modification des caractéristiques de réflexion lumineuse s'opère après l'étape d'assemblage à recouvrement partiel des deux lés entre eux.

Selon une caractéristique de l'invention, l'étape de modification des caractéristiques de réflexion de la zone de liaison est une étape de diminution des caractéristiques de réflexion de la zone de liaison.

Ce procédé est particulièrement avantageux pour les lés ajourés pour lesquels la zone de liaison par revêtement partiel présente, avant traitement, un pouvoir réflecteur élevé du fait de l'obturation au moins partielle des jours. En outre, dans le cas d'une fixation par soudure des parties de lés formant ladite zone de liaison, le traitement de la zone de liaison permet de compenser les effets néfastes générés par le changement d'aspect de la zone de liaison dus à la soudure.

Avantageusement, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, on traite en surface et/ou dans l'épaisseur ladite zone, jusqu'à obtention d'un pouvoir de réflexion lumineuse de la zone de liaison à recouvrement sensiblement égal à celui des parties de lés jouxtant ladite zone de liaison.

Selon une caractéristique avantageuse de l'invention, au cours de l'étape de modification des caractéristiques de réflexion pouvoir de réflexion lumineuse de la zone de liaison à recouvrement, par traitement de ladite zone dans l'épaisseur, on perfore ladite zone.

Préférentiellement, chaque lé étant réalisé en un matériau, de préférence de

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type toile, ajouré, on perfore la zone de liaison suivant un motif de perforations rappelant le motif des jours de chaque lé en dehors de la zone de liaison dudit lé.

Selon une caractéristique avantageuse de l'invention, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, par traitement en surface, on applique, côté face de projection dudit écran, un revêtement supplémentaire sur la zone de liaison à recouvrement par rapport aux zones de lés jouxtant la zone de liaison à recouvrement.

Ce revêtement supplémentaire peut avantageusement être en un même matériau que celui formant la surface de projection.

Selon une caractéristique avantageuse de l'invention, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, par traitement en surface, on dessine et/ou on imprime un motif sur la zone de liaison à recouvrement côté face de projection dudit écran.

En d'autres termes, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, on traite en surface, côté face de projection dudit écran, ladite zone de liaison à recouvrement par application d'un revêtement supplémentaire sur la zone de liaison à recouvrement par rapport aux zones de lés jouxtant la zone de liaison à recouvrement et/ou par dessin et/ou impression d'un motif.

Selon une caractéristique avantageuse de l'invention, chaque lé étant réalisé en un matériau, de préférence de type toile, ajouré, on revêt et/ou on forme sur ladite zone de liaison au moins un motif rappelant le motif des jours du lé en dehors de sa zone de liaison. On peut également prévoir d'appliquer à la zone de liaison un traitement de surface pour obtenir une texture de surface selon laquelle les caractéristiques de directivité lumineuse de ladite zone réduisent le

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pouvoir de réflexion de ladite zone de liaison.

Selon une caractéristique avantageuse de l'invention, il est prévu, après l'étape de diminution des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, au moins une étape supplémentaire de traitement de surface de la totalité de l'écran.

L'invention concerne également un écran formé d'au moins deux lés, de préférence ajourés, assemblés l'un à l'autre par recouvrement partiel entre eux, directement et/ou à l'aide d'une pièce de liaison, caractérisé en ce que ledit écran présente, dans la ou au moins l'une des zone(s) de liaison à recouvrement de lés entre eux, des moyens de modification, de préférence de diminution, des caractéristiques de réflexion lumineuse ménagés en surface et/ou dans l'épaisseur de ladite zone de liaison à recouvrement.

Selon une caractéristique avantageuse de l'invention, lesdits moyens de modification du pouvoir de réflexion lumineuse comprennent au moins un motif supplémentaire appliqué en surface de la zone de liaison, côté face de projection de l'écran, et/ou des perforations ménagées dans l'épaisseur de ladite zone.

L'invention sera bien comprise à la lecture de la description suivante d'exemples de réalisation, en référence aux dessins annexés dans lesquels :

- la figure 3 est une vue de détail de l'assemblage par recouvrement partiel de deux lés ajourés entre eux par soudure de la zone de liaison, un motif rappelant les jours des lés étant imprimés sur ladite zone de liaison côté face de projection;
- la figure 4 est un graphique donnant les courbes d'indice de gain de réflectivité de la zone de liaison et d'une autre zone des lés de la figure 3, en fonction de l'angle de vision de ces zones par rapport à la direction de projection de l'image ;
- la figure 5 est une vue de détail de l'assemblage par recouvrement partiel de

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deux lés ajourés entre eux par soudure de la zone de liaison, des perforations étant pratiquées dans l'épaisseur de ladite zone de liaison pour rappeler les jours des lés ;

- la figure 6 est un graphique donnant les courbes d'indice de gain de réflectivité de la zone de liaison et d'une autre zone des lés de la figure 5, en fonction de l'angle de vision de ces zones par rapport à la direction de projection de l'image ;

- la figure 7 est une vue de dessus du matériel utilisé et de son agencement par rapport à l'écran pour réaliser les mesures d'indice de gain dudit écran.

En référence aux figures et comme rappelé ci-dessus, l'invention concerne un procédé de fabrication d'un écran de projection 10, de préférence perméable aux ondes sonores, par assemblage à recouvrement partiel d'au moins deux lés 1, 2 de type toile ou feuille, de préférence ajourés. Comme rappelé ci-avant, l'assemblage à recouvrement partiel de lés peut être réalisé directement par une partie d'un lé venant recouvrir le bord de l'autre lé ou à l'aide d'une pièce de liaison du genre bavette, encore appelée pièce de maintien.

Il doit être rappelé que les lés 1, 2 sont généralement assemblés par soudure, couture ou collage.

De manière caractéristique à l'invention, ledit procédé comprend, pour la, ou au moins l'une des, zone(s) 3 de liaison à recouvrement partiel des lés entre eux, au moins une étape de modification des caractéristiques de réflexion lumineuse (ou pouvoir de réflexion) de la zone 3 de liaison à recouvrement partiel, par traitement en surface et/ou dans l'épaisseur de ladite zone 3, le traitement en surface étant de préférence appliqué côté face de projection dudit écran. Il convient de noter que cette étape de modification du pouvoir de réflexion est réalisée en étant localisée ou restreinte à la zone de liaison, c'est-à-dire indépendamment des autres zones des lés, et de manière spécifique à ladite zone de liaison, ce qui n'empêche pas de prévoir d'autres étapes de modifications supplémentaires du pouvoir de réflexion appliquées à l'ensemble

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de la surface de projection.

En outre, cette étape de modification est généralement réalisée après l'assemblage des lés.

Dans l'exemple illustré aux figures, on s'intéresse en particulier à diminuer le pouvoir de réflexion lumineuse, c'est-à-dire la réflectance (ou réflectivité) lumineuse de la zone de liaison, dans le domaine du spectre de lumière visible pour l'œil humain. Le pouvoir de réflexion peut encore être appelé facteur de réflexion et correspond au rapport du flux lumineux réfléchi au flux incident pour une longueur d'onde ou une gamme de longueurs d'onde donnée.

Préférentiellement, le traitement de la ou des parties de lé formant la zone de liaison est réalisé après assemblage des lés. On pourrait cependant prévoir d'effectuer le traitement d'une ou des parties des lés destinées à être assemblées, avant l'assemblage.

Comme rappelé ci-dessus, il doit être noté que l'indice de gain de réflectivité est fonction de la luminance qui est elle-même fonction du pouvoir de réflexion de la zone étudiée de l'écran. Ainsi, dans des conditions opératoires identiques, la réduction du pouvoir de réflexion entraine la réduction de l'indice de gain de réflectivité.

La figure 7 illustre les conditions opératoires dans lesquelles sont réalisées les mesures de l'indice de gain. Un flux lumineux (ou image), correspondant à une gamme de longueurs d'ondes données, par exemple un blanc neutre de température de couleur de l'ordre de 5600 K, est émis par un vidéoprojecteur 6 selon une direction de projection sensiblement orthogonale à l'écran 10 formé de l'assemblage de lés. Un appareil de mesure de luminance 5 permet de mesurer pour différents angles de vision ALPHA par rapport à la direction de projection, la luminance de la zone de liaison des lés et la luminance d'autres zones des lés. Comme expliqué ci-avant, pour un angle de vision donné,

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l'indice de gain de réflectivité est obtenu en rapportant la luminance ainsi mesurée en une zone donnée de l'écran, à la luminance mesurée préalablement (dans les mêmes conditions) pour une zone de référence d'un autre écran dont le gain est considéré égal à 1.

L'étape de réduction de l'indice de gain de réflectivité de la zone de liaison à recouvrement, s'effectue en traitant en surface et/ou dans l'épaisseur au moins une partie d'un lé participant à la formation de la zone de liaison (encore appelée zone d'assemblage), de préférence au moins la partie de lé de ladite zone de liaison venant côté face de projection de l'écran à recouvrement de l'autre lé. L'étape de traitement en surface et/ou dans l'épaisseur d'au moins la partie de lé venant côté face de projection de l'écran à recouvrement de l'autre lé, permet de diminuer l'indice de gain de réflectivité de ladite zone de liaison à recouvrement côté face de projection dudit écran en vue d'obtenir un indice de gain de réflectivité de la zone de liaison à recouvrement, côté face de projection dudit écran, similaire à celui des parties de lés jouxtant ladite zone de liaison.

Avantageusement, on traite en surface et/ou dans l'épaisseur ladite zone 3 jusqu'à obtention d'un pouvoir de réflexion lumineuse (ou encore d'un indice de gain de réflectivité lumineuse) de la zone de liaison à recouvrement sensiblement égal à celui des parties de lés 1, 2 jouxtant ladite zone de liaison.

L'étape de diminution du pouvoir de réflexion lumineuse de la zone de liaison à recouvrement peut être réalisée de différentes manières.

Selon un premier mode d'exécution illustré aux figures 5 et 6, l'étape de diminution du pouvoir de réflexion lumineuse de la zone 3 de liaison à recouvrement, par traitement de ladite zone dans l'épaisseur, comprend une étape de perforation de ladite zone. L'ensemble des perforations ménagées permet de réduire la surface de réflexion de la zone de liaison.

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En outre, dans le cas de lés réalisés en un matériau, de préférence de type toile, ajouré, pour être perméable aux sons, les perforations ménagées dans la zone de liaison assurent la présence d'orifices traversant la zone de liaison qui rendent ladite zone de liaison perméable au son, ce qui améliore l'homogénéité de la transparence acoustique de l'ensemble de l'écran. Avantageusement, dans ce cas de lés ajourés, on perfore la zone de liaison 3 suivant un motif de perforations rappelant le motif des jours de chaque lé 1, 2 en dehors de la zone d'assemblage dudit lé. Ainsi, grâce aux perforations pratiquées dans la zone de liaison à recouvrement, la zone de liaison présente des jours supplémentaires et/ou des jours de dimensions différentes par rapport aux jours d'origine des lés.

Le diamètre des orifices de perforation pratiqués lors du traitement est choisi en fonction des dimensions des interstices du maillage pour les lés en toile tissée ou du diamètre des perforations d'origine pour les lés en feuille micro ou macro-perforée. Préférentiellement le diamètre des orifices de perforation est compris entre 0,2 et 1,0 mm pour les écrans de moyenne taille (correspondant à une image projetée dont la base mesure entre 2 et 5 m environ) et entre 0,4 et 2 mm pour les écrans de grande taille (correspondant à une image projetée de base supérieure à 5 m environ). Avantageusement, les orifices de perforation ont une densité de l'ordre 10 à 30 % de la surface de la zone de liaison.

Les perforations peuvent être obtenues notamment par poinçonnage, découpe au laser, découpe au jet d'eau, ou découpe au cutter.

La densité et le diamètre des perforations sont choisis de manière à diminuer l'indice de gain de réflectivité de la zone de liaison jusqu'à obtenir un indice de gain de réflectivité au niveau de la zone de liaison sensiblement égal à l'indice de gain de réflectivité au niveau d'une autre zone des lés. Autrement dit, comme illustré à la figure 6, la densité et le diamètre des perforations sont choisis de manière à faire correspondre le mieux possible la courbe C53

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d'indice de gain de réflectivité de la zone de liaison avec la courbe C51 d'indice de gain de réflectivité d'une autre zone des lés.

Ainsi, par comparaison des figures 2 et 6, on constate que les perforations 8, pratiquées dans la zone de liaison 3 de l'assemblage de lés de la figure 5, ont permis de rapprocher la courbe C53 d'indice de gain de la zone de liaison 3, de la courbe C51 d'indice de gain d'une autre zone des lés (figure 6), par rapport aux courbes d'indice de gain correspondantes C13 et C11 pour un assemblage de lés dont la zone de liaison par soudure n'est pas traitée. En particulier dans la plage angulaire de vision [- 30°, + 30°], correspondant sensiblement à une vision dans l'axe de projection, la courbe C53 reprend par rapport à la courbe C13 une allure plus régulière. Ainsi, le traitement de la zone de liaison par perforations permet d'homogénéiser le pouvoir de réflexion et donc l'indice de gain de réflectivité de la zone de liaison par rapport aux autres zones des lés, en particulier par rapport aux zones des lés jouxtant la zone de liaison.

Selon un deuxième mode d'exécution illustré aux figures 3 et 4, l'étape de diminution du pouvoir de réflexion lumineuse de la zone de liaison à recouvrement, par traitement en surface, comprend une étape de dessin et/ou d'impression, sur la zone de liaison à recouvrement côté face de projection dudit écran, d'un motif 4 supplémentaire par rapport aux zones des lés jouxtant la zone de liaison. Dans le cas de lés ajourés, ledit motif supplémentaire est bien entendu distinct du motif formé par la superposition des jours d'origine des deux lés.

Dans l'exemple illustré à la figure 3, le motif est formé de traits gris ou noir rappelant le motif des interstices ou jours des parties des lés non superposées. Ainsi, par comparaison des figures 2 et 4, on constate que le motif formé sur la zone de liaison des lés, côté face de projection, a permis de rapprocher la courbe C33 d'indice de gain de la zone de la liaison, de la courbe C31 d'indice de gain des autres zones. En particulier dans la plage angulaire de vision [-

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30°, +30°], correspondant sensiblement à la direction de projection, la courbe C33 présente par rapport à la courbe C13 une allure plus régulière. Ainsi, le traitement de la zone de liaison par formation d'un motif en surface rappelant le motif des jours des autres zones des lés permet d'homogénéiser le pouvoir de réflexion et donc l'indice de gain de réflectivité de la zone de liaison par rapport aux autres zones des lés, en particulier par rapport aux zones des lés jouxtant la zone de liaison.

L'étape de diminution du pouvoir de réflexion lumineuse de la zone 3 de liaison à recouvrement, par traitement en surface de ladite zone, peut également comprendre une étape d'application sur la zone 3 de liaison à recouvrement côté face de projection dudit écran d'un revêtement supplémentaire par rapport aux zones des lés jouxtant la zone de liaison.

Le revêtement, par exemple un film autocollant, peut présenter une bande de teinte uniforme sur toute la surface de la zone de liaison ou être formé de plusieurs morceaux de tailles, formes et/ou couleurs différentes permettant de diminuer la luminosité de la surface de la zone de liaison sur laquelle est apposé le revêtement. Ce revêtement peut également être formé d'une bande en un matériau de même nature que le matériau constitutif des lés.

En variante, le revêtement peut être formé d'un ensemble de particules projetées en surface de la zone de liaison côté face de projection du flux lumineux. Le traitement de surface appliqué à la zone de liaison côté face de projection peut également comprendre une étape de modification de la texture de la zone de liaison, notamment en augmentant sa rugosité pour diminuer son pouvoir de réflexion.

Le revêtement, le dessin et/ou l'impression appliqués sur la zone de liaison sont conçus de manière à assombrir ladite zone de liaison, c'est-à-dire réduire la luminosité de ladite zone.

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Préférentiellement, dans le cas de lés réalisés en un matériau, de préférence de type toile, ajouré, pour être perméable aux sons, le motif formé sur ladite zone de liaison par impression, et/ou dessin et/ou application d'un revêtement équipé d'un tel motif, est choisi de manière à rappeler le motif des jours du lé en dehors de sa zone d'assemblage.

Le motif peut être formé d'un ensemble de petits points noirs et/ou d'une bande de couleur, par exemple plus sombre que le reste des lés, et/ou d'une bande rappelant le motif du reste des lés. Le motif peut également être conçu de manière à présenter une ou plusieurs couleurs permettant d'obtenir des propriétés chromatiques souhaitées au niveau de ladite zone de liaison.

Il est ainsi possible de traiter la zone de liaison des lés de manière à, d'une part, obtenir un indice de gain de réflexion homogène par rapport aux autres zones des lés, et, d'autre part, obtenir des propriétés chromatiques permettant de conserver la balance de couleurs souhaitée pour les images ou flux lumineux projetés.

Avantageusement, quel que soit le mode de traitement mis en œuvre, le traitement effectué présente une régularité et une homogénéité suffisante pour rendre le traitement de la zone de liaison quasiment invisible par l'œil humain en configuration d'utilisation à partir, d'une part, d'une distance d'environ 3m pour des écrans de moyenne taille correspondant à une image projetée dont la base mesure entre 2 et 4 m environ et, d'autre part, d'une distance d'environ 6 à 8m pour des écrans de grande taille correspondant à une image projetée de base supérieure à 6m environ.

L'étape de diminution du pouvoir de réflexion lumineuse de la zone 3 de liaison à recouvrement, peut être suivie d'une étape supplémentaire de traitement de surface de la totalité de l'écran 10 par exemple pour augmenter l'indice de gain sur l'ensemble de l'écran, et d'homogénéiser les différentes zones (écran et zone(s) de liaison). L'étape supplémentaire peut également consister à

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appliquer un niveau de gris donné à l'ensemble de l'écran pour une utilisation en milieu semi-éclairé, ou encore appliquer une couche de surface sur l'écran permettant une projection en trois dimensions.

Le procédé de fabrication décrit ci-dessus et les différents traitements correspondant de la zone de liaison s'appliquent également à un assemblage de lés par une liaison à recouvrement par couture et non pas par soudure, afin d'homogénéiser le pouvoir de réflexion de la zone de liaison à recouvrement par rapport aux autres zones des lés.

La présente invention n'est nullement limitée aux modes de réalisation décrits et représentés, mais l'homme du métier saura y apporter toute variante conforme à son esprit.

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REVENDICATIONS

1. Procédé de fabrication d'un écran de projection (10), de préférence perméable aux ondes sonores, par assemblage à recouvrement partiel d'au moins deux lés (1, 2), lesdits lés étant de préférence ajourés,
caractérisé en ce que ledit procédé comprend, pour la, ou au moins l'une des, zone(s) (3) de liaison à recouvrement partiel de lés de l'écran, au moins une étape de modification des caractéristiques de réflexion lumineuse de la zone (3) de liaison à recouvrement partiel par traitement en surface et/ou dans l'épaisseur de ladite zone (3).

2. Procédé selon la revendication 1, caractérisé en ce que l'étape de modification des caractéristiques de réflexion de la zone de liaison est une étape de diminution des caractéristiques de réflexion de la zone de liaison.

3. Procédé selon l'une des revendications précédentes, caractérisé en ce que, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, on traite en surface et/ou dans l'épaisseur ladite zone (3), jusqu'à obtention de caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement sensiblement égale à celles des parties de lés (1, 2) jouxtant ladite zone de liaison.

4. Procédé selon l'une des revendications précédentes, caractérisé en ce que, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone (3) de liaison à recouvrement, par traitement de ladite zone dans l'épaisseur, on perfore ladite zone.

5. Procédé selon la revendication 4, caractérisé en ce que, chaque lé (1, 2) étant réalisé en un matériau, de préférence de type toile, ajouré, on perfore la zone de liaison (3) suivant un motif de perforations (8) rappelant le motif des jours de chaque lé (1, 2) en dehors de la zone (3) de liaison dudit lé.

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6. Procédé selon l'une des revendications précédentes, caractérisé en ce que, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, par traitement en surface, on applique, côté face de projection dudit écran, un revêtement supplémentaire sur la zone (3) de liaison à recouvrement par rapport aux zones de lés jouxtant la zone (3) de liaison à recouvrement.

7. Procédé selon l'une des revendications précédentes, caractérisé en ce que, au cours de l'étape de modification des caractéristiques de réflexion lumineuse de la zone de liaison à recouvrement, par traitement en surface, on dessine et/ou on imprime un motif (4) sur la zone (3) de liaison à recouvrement, côté face de projection dudit écran.

8. Procédé selon l'une des revendications 6 et 7, caractérisé en ce que, chaque lé étant réalisé en un matériau, de préférence de type toile, ajouré, on revêt et/ou on forme sur ladite zone (3) de liaison au moins un motif (4) rappelant le motif des jours du lé en dehors de sa zone de liaison.

9. Procédé selon l'une des revendications précédentes, caractérisé en ce qu'il comprend, après l'étape de diminution des caractéristiques de réflexion lumineuse de la zone (3) de liaison à recouvrement, au moins une étape supplémentaire de traitement de surface de la totalité de l'écran (10).

10. Ecran (10) de projection, de préférence perméable aux ondes sonores, ledit écran, obtenu de préférence par mise en œuvre d'un procédé conforme à l'une des revendications 1 à 9, étant formé d'au moins deux lés (1, 2), de préférence ajourés, assemblés l'un à l'autre par recouvrement partiel entre eux, caractérisé en ce que ledit écran présente, dans la ou au moins l'une des zone(s) (3) de liaison à recouvrement de lés (1, 2) entre eux, des moyens de modification, de préférence de diminution, des caractéristiques de réflexion lumineuse ménagés en surface et/ou dans l'épaisseur de ladite zone (3) de liaison à recouvrement.

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11. Ecran (10) de projection selon la revendication 10, caractérisé en ce que lesdits moyens de modification du pouvoir de réflexion lumineuse comprennent au moins un motif supplémentaire (4) appliqué en surface de la zone (3) de liaison, côté face de projection de l'écran, et/ou des perforations (4') ménagées dans l'épaisseur de ladite zone (3).

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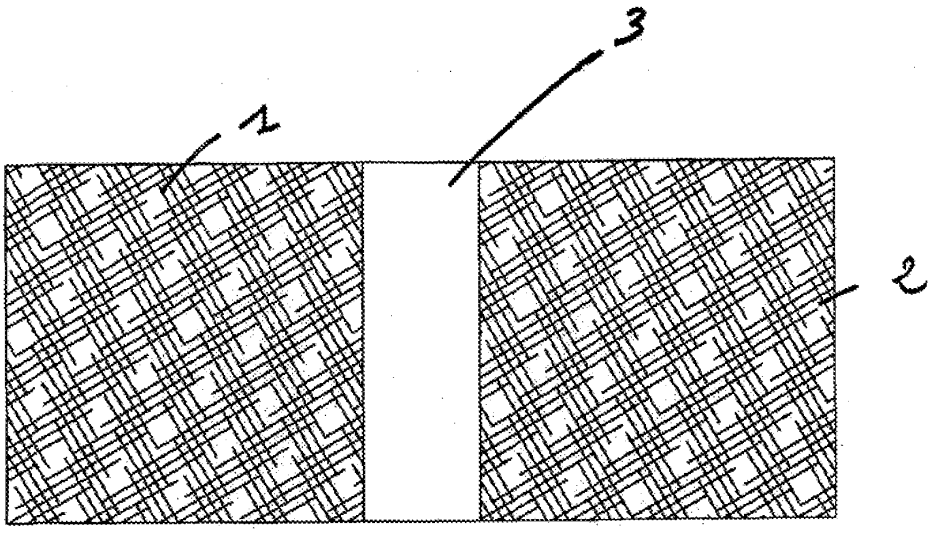

Fig. 1

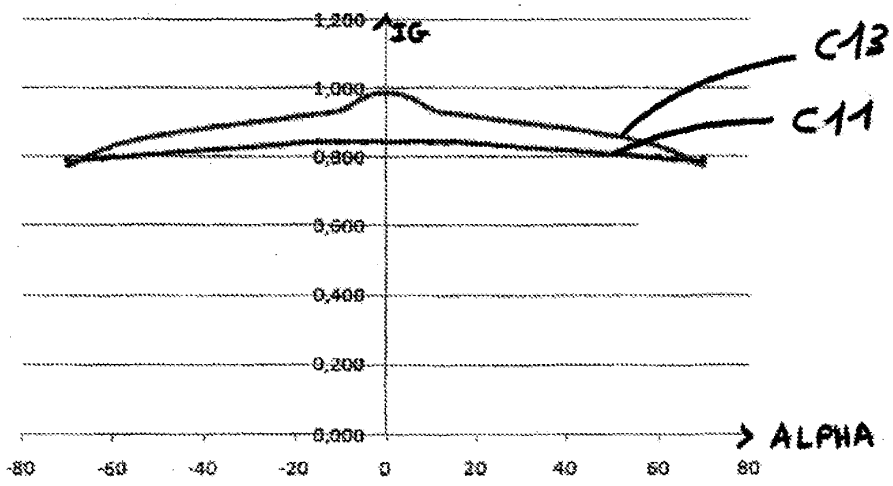

Fig. 2

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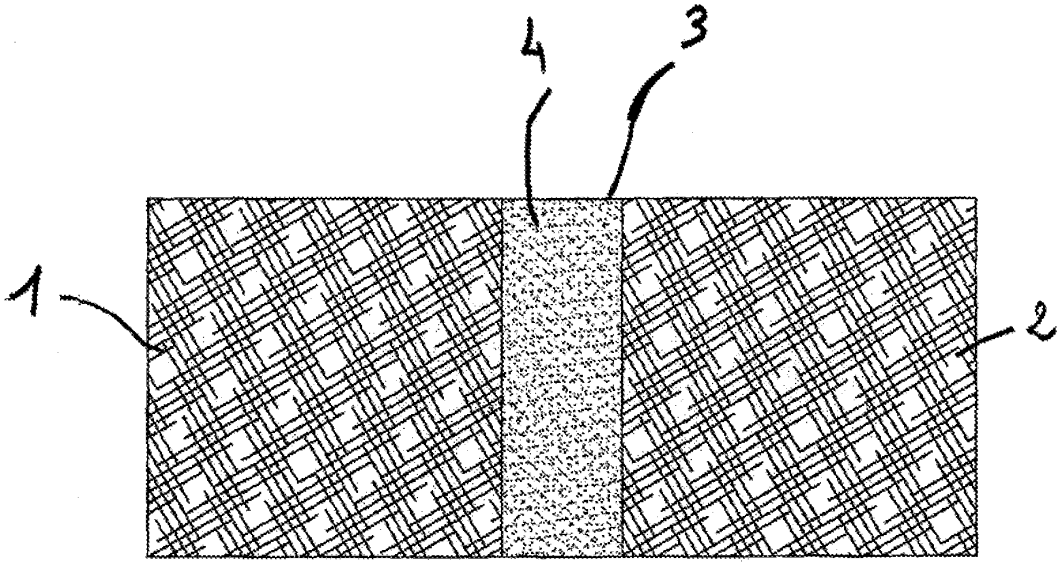

Fig. 3

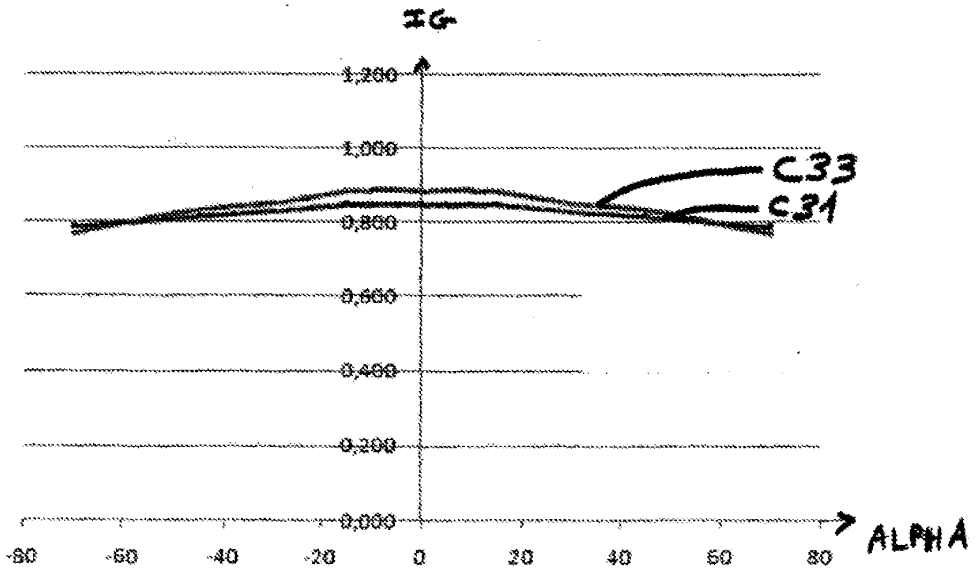

Fig. 4

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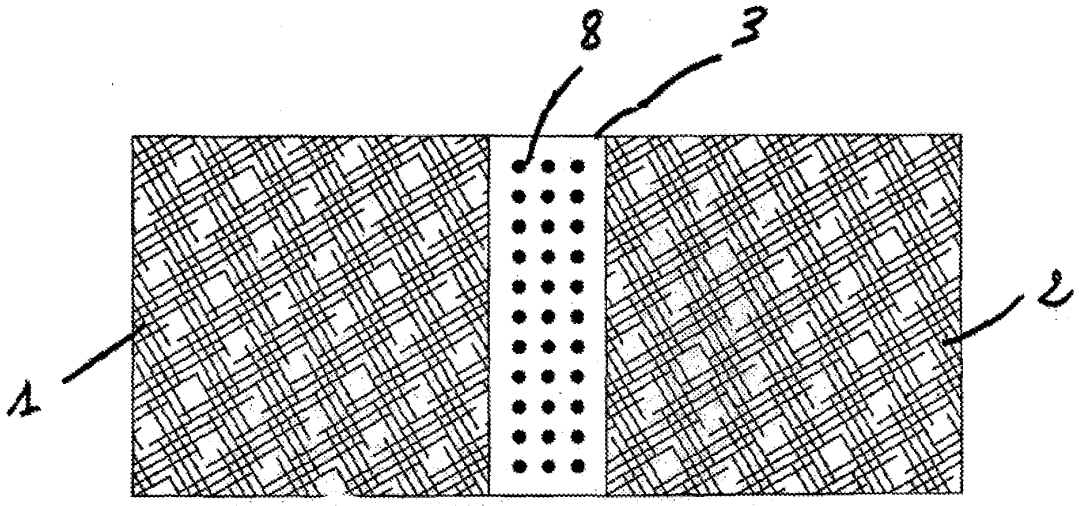

Fig. 5

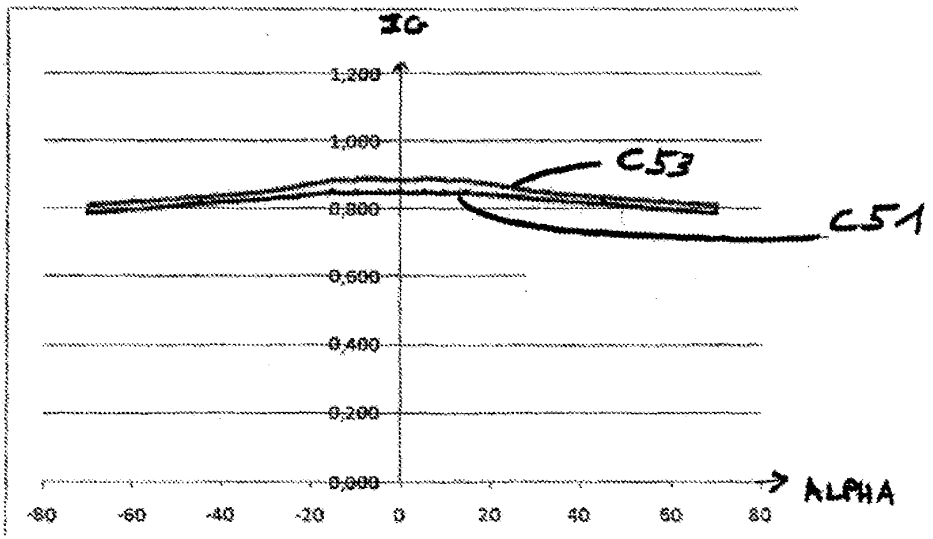

Fig. 6

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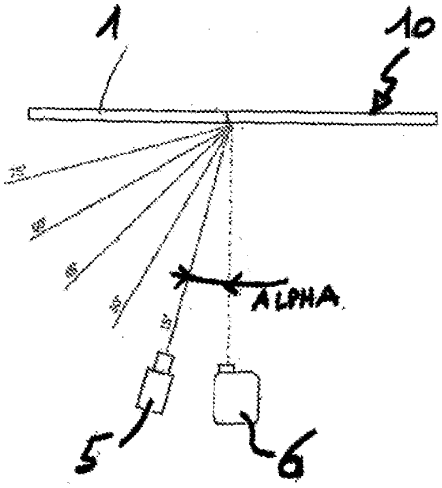

Fig. 7

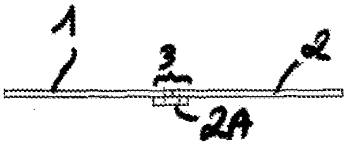

Fig. 8

Fig. 9

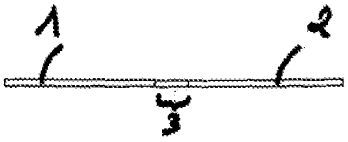

Fig. 10

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INTERNATIONAL SEARCH REPORT

International application No
PCT/FR2010/051593

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03B21/60
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	GB 375 640 A (CLIFFORD FANSHAWE PEMBER) 30 June 1932 (1932-06-30) page 1, line 84 - line 91	1-3,7,8, 10 6,9,11
Y A	GB 813 847 A (ANDREW SMITH HARKNESS LTD) 27 May 1959 (1959-05-27) page 1, line 70 - page 2, line 26	6,9 1,10
Y A	EP 1 162 499 A1 (AVANCE ENGINEERING [FR]) 12 December 2001 (2001-12-12) cited in the application paragraph [0003] - paragraph [0008] figure 1	11 1-3,10
A	US 5 140 460 A (FUKUHARA SUEMEI [JP] ET AL) 18 August 1992 (1992-08-18) column 4, line 12 - line 38 figure 8	1,10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2010	23/11/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Breccia, Luca

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/FR2010/051593

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 375640 A	30-06-1932	NONE	
GB 813847 A	27-05-1959	NONE	
EP 1162499 A1	12-12-2001	FR 2810122 A1 US 2002051289 A1	14-12-2001 02-05-2002
US 5140460 A	18-08-1992	NONE	

Form PCT/ISA/210 (patent family annex) (April 2005)

RAPPORT DE RECHERCHE INTERNATIONALE

Demande internationale n°
PCT/FR2010/051593

A. CLASSEMENT DE L'OBJET DE LA DEMANDE
INV. G03B21/60
ADD.

Selon la classification internationale des brevets (CIB) ou à la fois selon la classification nationale et la CIB

B. DOMAINES SUR LESQUELS LA RECHERCHE A PORTE

Documentation minimale consultée (système de classification suivi des symboles de classement)
G03B

Documentation consultée autre que la documentation minimale dans la mesure où ces documents relèvent des domaines sur lesquels a porté la recherche

Base de données électronique consultée au cours de la recherche internationale (nom de la base de données, et si cela est réalisable, termes de recherche utilisés)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie*	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
X Y	GB 375 640 A (CLIFFORD FANSHAWE PEMBER) 30 juin 1932 (1932-06-30) page 1, ligne 84 - ligne 91	1-3,7,8, 10 6,9,11
Y A	GB 813 847 A (ANDREW SMITH HARKNESS LTD) 27 mai 1959 (1959-05-27) page 1, ligne 70 - page 2, ligne 26	6,9 1,10
Y A	EP 1 162 499 A1 (AVANCE ENGINEERING [FR]) 12 décembre 2001 (2001-12-12) cité dans la demande alinéa [0003] - alinéa [0008] figure 1	11 1-3,10
A	US 5 140 460 A (FUKUHARA SUEMEI [JP] ET AL) 18 août 1992 (1992-08-18) colonne 4, ligne 12 - ligne 38 figure 8	1,10

☐ Voir la suite du cadre C pour la fin de la liste des documents

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"A" document définissant l'état général de la technique, non considéré comme particulièrement pertinent

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Date à laquelle la recherche internationale a été effectivement achevée	Date d'expédition du présent rapport de recherche internationale
16 novembre 2010	23/11/2010

Nom et adresse postale de l'administration chargée de la recherche internationale	Fonctionnaire autorisé
Office Européen des Brevets, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Breccia, Luca

Formulaire PCT/ISA/210 (deuxième feuille) (avril 2005)

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RAPPORT DE RECHERCHE INTERNATIONALE

Renseignements relatifs aux membres de familles de brevets

Demande internationale n°
PCT/FR2010/051593

Document brevet cité au rapport de recherche	Date de publication	Membre(s) de la famille de brevet(s)	Date de publication
GB 375640 A	30-06-1932	AUCUN	
GB 813847 A	27-05-1959	AUCUN	
EP 1162499 A1	12-12-2001	FR 2810122 A1 US 2002051289 A1	14-12-2001 02-05-2002
US 5140460 A	18-08-1992	AUCUN	

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G02F 1/1335 (2006.01)

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12 May 2012 (12.05.2012)

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13/300,293 18 November 2011 (18.11.2011) US

(71) Applicant *(for all designated States except US)*: **REALD INC.** [US/US]; 100 North Crescent Drive, Suite 200, Beverly Hills, CA 90210 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **ROBINSON, Michael, G.** [GB/US]; 100 North Crescent Drive, Suite 200, Beverly Hills, CA 90210 (US).

(74) Agents: **MOTHEW, Neil, G.J.** et al.; Baker & McKenzie LLP, 2001 Ross Avenue, Suite 2300, Dallas, TX 75201 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: EFFICIENT POLARIZED DIRECTIONAL BACKLIGHT

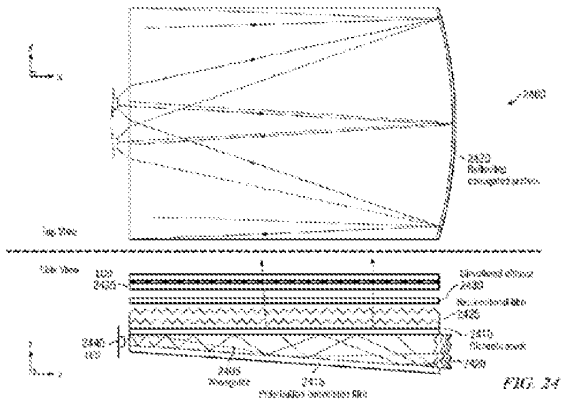

FIG. 24

(57) Abstract: By introducing a stack of alternating high and low index dichroic material layers on the exit surface of a waveguide for a wedge type directional backlight, natural reflectivity differences between polarized components can be increased, effectively reflecting the vast proportion of S-polarized light rays, while at the same time transmitting the P-polarized light rays, of light impacting the exit surface of the waveguide at an angle sufficient to exit the waveguide. This recovers polarization in wedge type backlight systems, increasing illumination exiting the waveguide. Also, on the back reflecting surface of the waveguide, a birefringent material can be added to efficiently transform S-polarized reflected light from the dichroic stack, into returning P-polarized light. Because returning rays that are now P-polarized by the birefringent material have already achieved the critical angle for exiting the waveguide, the rays transformed to P-polarization can now also exit the waveguide, increasing waveguide illumination.

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Efficient polarized directional backlight

TECHNICAL FIELD

[0001] The present disclosure generally relates to displays, and more specifically, to two dimensional and three dimensional display technologies and components.

BACKGROUND

[0002] Generally, current display technologies may include functionality to deploy, view and/or display three dimensional (3D) content. Recently, the increased demand for such functionality has driven the need for enhanced performance of display technology. Display technology may employ the use of plasma and liquid crystal displays (LCDs). Directional backlighting of LCDs provides efficient, private, large viewing angle, autostereoscopic and conventional 2D viewing. However, it may be difficult to use conventional approaches such as, 3M's Vikuiti™ Dual Brightness Enhancement Film (DBEF), to efficiently polarize output light for illuminating LCDs on top of the added complexity that directionality demands.

BRIEF SUMMARY

[0003] Display backlights in general employ waveguides and edge emitting sources. Certain imaging directional backlights have the additional capability of directing the illumination through a display panel into viewing windows. An imaging system may be formed between multiple sources and the respective window images. One example of an imaging directional backlight is an optical valve that may employ a folded optical system and hence may also be an example of a folded imaging directional backlight. Light may propagate substantially without loss in one direction through the optical valve while counter-propagating light may be extracted by reflection off tilted facets as described in Pat. App. Ser. No. 13/300,293, which is herein incorporated by reference, in its entirety.

[0004] Polarization selective transmission of the highly collimated extracted light from a wedge type directional backlight element, such as the type disclosed in U.S. Patent No. 7,970,246, which is incorporated herein by reference, can be enhanced by dichroic layers coated onto the exit surface performing a similar manner to a conventional polarizing beam splitter (PBS), as described in U.S. Patent No. 2,403,731, entitled "Beam Splitter," which is also hereby incorporated by reference in its entirety. Physics naturally favors the transmission of P-polarized over S-polarized light; the former having its oscillating electric field in the incident plane. By introducing a stack of alternating high and low index dichroic material layers in accordance with the disclosed principles, the natural reflectivity differences between polarized components can be increased, effectively reflecting the vast proportion of S--polarized light rays, while at the same time transmitting the P--polarized light rays, of light impacting the exit surface of the waveguide at an angle sufficient to exit the waveguide. The more dichroic layers, the greater the angular and wavelength range over which both high P-transmission and S-reflection is achieved. Unlike a conventional PBS, few layers, for example, approximately three, may be employed to achieve approximately 90% polarized transmission due to the high collimation and large incident angles of light rays that exit the wedge type directional backlight system.

[0005] In addition to the above principles, on the back reflecting surface of the waveguide, a birefringent material can be added to efficiently transform the S-polarized reflected light from the dichroic stack, into returning P-polarized light. Because the returning rays that are now P-polarized by the birefringent material have already achieved the critical angle for exiting the waveguide, the rays transformed to P-polarization can now also exit the waveguide. This is preferred currently over any introduction of birefringence into, or any residual birefringence in, the wedge waveguide's substrate material as it can be tightly controlled. The prescription for the birefringent material is determined by the critical angle of the waveguide material, as will be discussed later.

[0006] Thus, in accordance with the above-mentioned principles, one aspect of the present disclosure provides an illumination system for use with an electronic display system. In one embodiment, the illumination system may comprise an optical waveguide having a near end and a reflecting far end, wherein a thickness of the waveguide at the reflecting end is greater than a

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thickness at the near end. In addition, the waveguide may further comprise an exit surface extending between the near and far ends, and have a critical angle above which light rays may exit the waveguide. The reflecting far end preferably includes at least one corrugation or similar facet, as well as being curved along a plane substantially parallel to a plane of the exit surface. Exemplary illumination systems may also comprise at least one dichroic layer located on the exit surface of the waveguide, where the at least one dichroic layer is configured to pass exiting light rays having a first polarization and to reflect exiting light rays having a second polarization, different than the first polarization, back through the exit surface. Additionally, such embodiments may also include a polarization conversion film located on a surface of the waveguide that is opposite the exit surface. Such a polarization conversion film may be configured to transform the polarization of at least some of the light rays having the second polarization that are reflected by the at least one dichroic layer into light rays having the first polarization. The polarization conversion film may be configured to reflect the transformed light rays having the first polarization back into the waveguide such that at least a portion of the transformed light rays having the first polarization back into the waveguide such that they may exit the waveguide and pass through the at least one dichroic layer.

[0007] In other embodiments, an electronic display system is provided. In exemplary embodiments, such a display system may comprise an optical waveguide having a near end and a reflecting far end, where a thickness of the waveguide at the reflecting end is greater than a thickness at the near end. The waveguide may further comprise an exit surface extending between the near and far ends and have a critical angle above which light rays may exit the waveguide. The reflecting far end preferably includes at least one corrugation, as well as being curved along a plane substantially parallel to a plane of the exit surface. Such display systems may include at least one illumination unit configured to transmit lights rays into the waveguide through the near end. Moreover, such display systems may include at least one dichroic layer located on the exit surface of the waveguide, wherein the at least one dichroic layer is configured to pass P-polarized light rays exiting the waveguide and to reflect S-polarized light rays exiting the waveguide back through the exit surface. In addition, a polarization conversion film may be located on a surface of the waveguide that is opposite the exit surface, where the polarization

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conversion film is configured to transform the polarization of at least some of the S-polarized light rays reflected by the at least one dichroic layer to P-polarized light rays, and to reflect the transformed P-polarized light rays back into the waveguide such that at least a portion of the transformed P-polarized light rays may exit the waveguide and pass though the at least one dichroic layer. Furthermore, in such exemplary embodiments, the display system may include a display panel for providing images for display to a viewer of the display system, and configured to receive the P-polarized light rays passing through the at least one dichroic layer.

[0008] In other aspects, methods for illuminating an electronic display system are provided by the disclosed principles. In one embodiment, such a method may comprise transmitting light rays into a waveguide comprising an exit surface having a critical angle above which light rays may exit the waveguide, wherein a portion of the transmitted light rays exit the waveguide through the exit surface. Such a method may further include passing exiting light rays having a first polarization towards a display panel, while reflecting exiting light rays having a second polarization, different than the first polarization, back into the waveguide through the exit surface. Moreover, such exemplary method may include transforming the polarization of at least some of the reflected light rays having the second polarization into light rays having the first polarization, and reflecting the transformed light rays back towards the exit surface such that at least a portion of the transformed light rays exit the waveguide. Then such methods may provide for passing at least some of the transformed light rays exiting the waveguide towards the display panel to illuminate the display panel.

[0009] In other embodiments, methods for illuminating an electronic display system may comprise generating light rays using at least one illumination unit located proximate an optical waveguide comprising an exit surface having a critical angle above which light rays may exit the waveguide. Then such methods may comprise transmitting the generated light rays into the waveguide, wherein a portion of the transmitted light rays exit the waveguide through the exit surface. In addition, such methods may then provide for passing exiting P-polarized light rays while reflecting exiting S-polarized light rays back into the waveguide through the exit surface. Then such methods may comprise transforming at least some of the reflected S-polarized light rays into P-polarized light rays, and reflecting the transformed P-polarized light rays back

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towards the exit surface such that at least a portion of the transformed P-polarized light rays exit the waveguide. Afterwards, such exemplary methods may provide for passing at least some of the transformed P-polarized light rays exiting the waveguide, and illuminating a display panel, configured to provide images for display to a viewer, with at least a portion of the passed P-polarized light rays and transformed P-polarized light rays.

[0010] Embodiments herein may provide an autostereoscopic display with large area and thin structure. Further, as will be described, the optical valves of the present disclosure may achieve thin optical components with large back working distances. Such components can be used in directional backlights, to provide directional displays including autostereoscopic displays. Further, embodiments may provide a controlled illuminator for the purposes of an efficient autostereoscopic display.

[0011] Embodiments of the present disclosure may be used in a variety of optical systems. The embodiment may include or work with a variety of projectors, projection systems, optical components, displays, microdisplays, computer systems, processors, self-contained projector systems, visual and/or audiovisual systems and electrical and/or optical devices. Aspects of the present disclosure may be used with practically any apparatus related to optical and electrical devices, optical systems, presentation systems or any apparatus that may contain any type of optical system. Accordingly, embodiments of the present disclosure may be employed in optical systems, devices used in visual and/or optical presentations, visual peripherals and so on and in a number of computing environments.

[0012] Before proceeding to the disclosed embodiments in detail, it should be understood that the disclosure is not limited in its application or creation to the details of the particular arrangements shown, because the disclosure is capable of other embodiments. Moreover, aspects of the disclosure may be set forth in different combinations and arrangements to define embodiments unique in their own right. Also, the terminology used herein is for the purpose of description and not of limitation.

[0013] Directional backlights offer control over the illumination emanating from substantially the entire output surface controlled typically through modulation of independent LED light

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sources arranged at the input aperture side of an optical waveguide. Controlling the emitted light directional distribution can achieve single person viewing for a security function, where the display can only be seen by a single viewer from a limited range of angles; high electrical efficiency, where illumination is only provided over a small angular directional distribution; alternating left and right eye viewing for time sequential stereoscopic and autostereoscopic display; and low cost.

[0014] These and other advantages and features of the present disclosure will become apparent to those of ordinary skill in the art upon reading this disclosure in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Embodiments are illustrated by way of example in the accompanying figures, in which like reference numbers indicate similar parts, and in which:

[0016] **FIGURE 1A** is a schematic diagram illustrating a front view of light propagation in one embodiment of an optical valve apparatus, in accordance with the present disclosure;

[0017] **FIGURE 1B** is a schematic diagram illustrating a side view of light propagation in one embodiment of the optical valve apparatus of FIGURE 1A, in accordance with the present disclosure;

[0018] **FIGURE 2A** is a schematic diagram illustrating in a top view of light propagation in another embodiment of an optical valve apparatus, in accordance with the present disclosure;

[0019] **FIGURE 2B** is a schematic diagram illustrating light propagation in a front view of the optical valve apparatus of FIGURE 2A, in accordance with the present disclosure;

[0020] **FIGURE 2C** is a schematic diagram illustrating light propagation in a side view of the optical valve apparatus of FIGURE 2A, in accordance with the present disclosure;

[0021] **FIGURE 3** is a schematic diagram illustrating in a side view of an optical valve apparatus, in accordance with the present disclosure;

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[0022] **FIGURE 4A** is schematic diagram illustrating in a front view, generation of a viewing window in an optical valve apparatus and including curved light extraction features, in accordance with the present disclosure;

[0023] **FIGURE 4B** is a schematic diagram illustrating in a front view, generation of a first and a second viewing window in an optical valve apparatus and including curved light extraction features, in accordance with the present disclosure;

[0024] **FIGURE 5** is a schematic diagram illustrating generation of a first viewing window in an optical valve apparatus including linear light extraction features, in accordance with the present disclosure;

[0025] **FIGURE 6A** is a schematic diagram illustrating one embodiment of the generation of a first viewing window in a time multiplexed imaging directional backlight apparatus, in accordance with the present disclosure;

[0026] **FIGURE 6B** is a schematic diagram illustrating another embodiment of the generation of a second viewing window in a time multiplexed optical valve apparatus in a second time slot, in accordance with the present disclosure;

[0027] **FIGURE 6C** is a schematic diagram illustrating another embodiment of the generation of a first and a second viewing window in a time multiplexed optical valve apparatus, in accordance with the present disclosure;

[0028] **FIGURE 7** is a schematic diagram illustrating an observer tracking autostereoscopic display apparatus including a time multiplexed optical valve apparatus, in accordance with the present disclosure;

[0029] **FIGURE 8** is a schematic diagram illustrating a multi-viewer display apparatus including a time multiplexed optical valve apparatus, in accordance with the present disclosure;

[0030] **FIGURE 9** is a schematic diagram illustrating a privacy display apparatus including an optical valve apparatus, in accordance with the present disclosure;

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[0031] **FIGURE 10** is a schematic diagram illustrating in side view, the structure of a time multiplexed optical valve apparatus, in accordance with the present disclosure;

[0032] **FIGURE 11A** is a schematic diagram illustrating a front view of an optical inline directional backlight apparatus as another example of an imaging directional backlight apparatus, in accordance with the present disclosure;

[0033] **FIGURE 11B** is a schematic diagram illustrating a front view of a wedge type directional backlight apparatus, in accordance with the present disclosure;

[0034] **FIGURE 11C** is a schematic diagram illustrating a side view of a wedge type directional backlight apparatus, in accordance with the present disclosure;

[0035] **FIGURE 12** is a close up view a backlight system which includes a wedge type waveguide constructed according to the principles disclosed herein;

[0036] **FIGURE 13** is a schematic diagram illustrating a diagram for internal angle definitions, in accordance with the present disclosure;

[0037] **FIGURE 14** is a schematic diagram illustrating a standard polar emission plot of an exemplary white LED;

[0038] **FIGURE 15** is a schematic diagram illustrating a schematic showing flared beam expander waveguide extensions for LED angular tailoring;

[0039] **FIGURE 16** is a schematic diagram illustrating a schematic representation of a compressed angular light input profile following expansion of LED output;

[0040] **FIGURE 17** is a schematic diagram illustrating a *zx* angle profile as light propagates forward and backward through a wedge with reflection from a corrugated end reflector, in accordance with the present disclosure;

[0041] **FIGURE 18** is a schematic diagram illustrating collimation of light on reflection in the *xy* plane;

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[0042] **FIGURE 19** is a schematic diagram illustrating a geometrical image forming construction diagram for determining reflector radius of curvature, in accordance with the present disclosure;

[0043] **FIGURE 20** is a schematic diagram illustrating one embodiment of a conventional wedge type directional backlight illuminator with an equivalent Fresnel structure;

[0044] **FIGURE 21** is a schematic diagram illustrating a graph of reflectivity off the dichroic layer stack, in accordance with the present disclosure;

[0045] **FIGURE 22** is a schematic diagram illustrating incidence geometry of a ray entering a polarization transforming retarder layer from the waveguide, in accordance with the present disclosure;

[0046] **FIGURE 23** is a schematic diagram illustrating an extraction film profile used to redirect illuminating light, in accordance with the present disclosure;

[0047] **FIGURE 24** is a schematic diagram illustrating one embodiment of a waveguide structure, in accordance with the present disclosure;

[0048] **FIGURE 25** is a schematic diagram illustrating one embodiment of the operation of directional backlight for selective eye viewing and time sequential stereoscopic operation, in accordance with the present disclosure; and

[0049] **FIGURE 26** is a schematic diagram illustrating one embodiment of an eyewear-free stereoscopic display system using a directional backlight, in accordance with the present disclosure.

DETAILED DESCRIPTION

[0050] Time multiplexed autostereoscopic displays can advantageously improve the spatial resolution of autostereoscopic display by directing light from all of the pixels of a spatial light modulator to a first viewing window in a first time slot, and all of the pixels to a second viewing window in a second time slot. Thus an observer with eyes arranged to receive light in first and

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second viewing windows will see a full resolution image across the whole of the display over multiple time slots. Time multiplexed displays can advantageously achieve directional illumination by directing an illuminator array through a substantially transparent time multiplexed spatial light modulator using directional optical elements, wherein the directional optical elements substantially form an image of the illuminator array in the window plane.

[0051] The uniformity of the viewing windows may be advantageously independent of the arrangement of pixels in the spatial light modulator. Advantageously, such displays can provide observer tracking displays which have low flicker, with low levels of cross talk for a moving observer.

[0052] To achieve high uniformity in the window plane, it is desirable to provide an array of illumination elements that have a high spatial uniformity. The illuminator elements of the time sequential illumination system may be provided, for example, by pixels of a spatial light modulator with size approximately 100 micrometers in combination with a lens array. However, such pixels suffer from similar difficulties as for spatially multiplexed displays. Further, such devices may have low efficiency and higher cost, requiring additional display components.

[0053] High window plane uniformity can be conveniently achieved with macroscopic illuminators, for example, an array of LEDs in combination with homogenizing and diffusing optical elements that are typically of size 1 mm or greater. However, the increased size of the illuminator elements means that the size of the directional optical elements increases proportionately. For example, a 16 mm wide illuminator imaged to a 65 mm wide viewing window may require a 200 mm back working distance. Thus, the increased thickness of the optical elements can prevent useful application, for example, to mobile displays, or large area displays.

[0054] Addressing the aforementioned shortcomings, optical valves as described in commonly-owned U.S. Patent Application No. 13/300,293 advantageously can be arranged in combination with fast switching transmissive spatial light modulators to achieve time multiplexed autostereoscopic illumination in a thin package while providing high resolution images with flicker free observer tracking and low levels of cross talk. Described is a one dimensional array

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of viewing positions, or windows, that can display different images in a first, typically horizontal, direction, but contain the same images when moving in a second, typically vertical, direction.

[0055] As used herein, an optical valve is an optical structure that may be a type of light guiding structure or device referred to as, for example, a light valve, an optical valve directional backlight, and a valve directional backlight ("v-DBL"). As used herein for discussion purposes only, and not of limitation, examples of an imaging directional backlight include a stepped imaging directional backlight, a folded imaging directional backlight, a wedge type directional backlight, an optical valve, or an optical inline directional backlight. Additionally, as used herein for discussion purposes only and not of limitation, a stepped imaging directional backlight may be at least one of an optical valve or an optical inline directional backlight. Moreover, as used herein for discussion purposes only and not of limitation, a folded imaging directional backlight may be at least one of a wedge type directional backlight, or an optical valve.

[0056] In operation, light may propagate within an exemplary optical valve in a first direction from an input side to a reflective side and may be transmitted substantially without loss. Light may be reflected at the reflective side and propagates in a second direction substantially opposite the first direction. As the light propagates in the second direction, the light may be incident on light extraction features, which are operable to redirect the light outside the optical valve. Stated differently, the optical valve generally allows light to propagate in the first direction and may allow light to be extracted while propagating in the second direction.

[0057] The optical valve may achieve time sequential directional illumination of large display areas. Additionally, optical elements may be employed that are thinner than the back working distance of the optical elements to direct light from macroscopic illuminators to a window plane. Such displays may use an array of light extraction features arranged to extract light counter propagating in a substantially parallel waveguide.

[0058] Thin directional backlight implementations for use with LCDs have been proposed and demonstrated by 3M, for example U.S. Patent No. 7,528,893; by Microsoft, for example U.S. Patent No. 7,970,246 which may be referred to herein as a "wedge type directional backlight;"

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by RealD, for example U.S. Patent Application No. 13/300,293 which may be referred to herein as an "optical valve" or "optical valve directional backlight," all of which are herein incorporated by reference in their entirety. Edge lit waveguide backlight illumination structures may be used in liquid crystal display systems such as those seen in 2D Laptops, Monitors and TVs. Light propagates from the edge of a lossy waveguide which may include sparse features; typically local indentations in the surface of the guide which cause light to be lost regardless of the propagation direction of the light.

[0059] The present disclosure provides stepped imaging directional backlights in which light may reflect back and forth between the internal faces of, for example, a stepped waveguide which may include a first side and a first set of features. As the light travels along the length of the stepped waveguide, the light may not substantially change angle of incidence with respect to the first side and first set of surfaces and so may not reach the critical angle of the medium at these internal faces. Light extraction may be advantageously achieved by a second set of surfaces (the step "risers") that are inclined to the first set of surfaces (the step "treads"). Note that the second set of surfaces may not be part of the light guiding operation of the stepped waveguide, but may be arranged to provide light extraction from the structure. By contrast, a wedge type directional backlight may allow light to guide within a wedge profiled waveguide having continuous internal surfaces. The optical valve is thus not a wedge type directional backlight.

[0060] **FIGURE 1A** is a schematic diagram illustrating a front view of light propagation in one embodiment of an optical valve structure, and **FIGURE 1B** is a schematic diagram illustrating a side view of light propagation in the optical valve structure of FIGURE 1A.

[0061] FIGURE 1A illustrates a front view in the *xy* plane of an optical valve, and includes an illuminator array 15 which may be used to illuminate a stepped waveguide 1. Illuminator array 15 includes illuminator elements 15a through illuminator element 15n (where n is an integer greater than one). In one example, the stepped waveguide 1 of FIGURE 1A may be a stepped, display sized waveguide 1. Illumination elements 15a through 15n may be light emitting diodes (LEDs). Although LEDs are discussed herein as illuminator elements 15a – 15n, other light

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sources may be used such as, but not limited to, diode sources, semiconductor sources, laser sources, local field emission sources, organic emitter arrays, and so forth. Additionally, FIGURE 1B illustrates a side view in the *xz* plane, and includes illuminator array 15, LCD 48, extraction features 12, guiding features 10, and stepped waveguide 1, arranged as shown. The side view provided in FIGURE 1B is an alternative view of the front view shown in FIGURE 1A. Accordingly, the illuminator array 15 of FIGURES 1A and 1B corresponds to one another and the stepped waveguide 1 of FIGURES 1A and 1B may correspond to one another. Further, in FIGURE 1B, the stepped waveguide 1 may have a thin end 2 and a thick end 4. Although the LCD 48 may be referred to herein for discussion purposes, other spatial light modulators or displays may be used including LCOS, DLP devices, and so forth, as this illuminator may work in reflection.

[0062] The operation of an optical valve that may provide a one dimensional array of viewing windows is illustrated in front view in FIGURE 1A, with its side profile shown in FIGURE 1B. In operation, in FIGURES 1A and 1B, light may be emitted from an illuminator array 15, such as an array of illuminator elements 15a through 15n, located at different positions, y, along the surface of thin end side 2, x=0, of the stepped waveguide 1. The light may propagate along +x in a first direction, within the stepped waveguide 1, while at the same time, the light may fan out in the *xy* plane and upon reaching the far curved end side 4, may substantially or entirely fill the curved end side 4. While propagating, the light may spread out to a set of angles in the *xz* plane up to, but not exceeding the critical angle of the guide material. The extraction features 12 that link the guiding features 10 of the bottom side of the stepped waveguide 1 may have a tilt angle greater than the critical angle and hence may be missed by substantially all light propagating along +x in the first direction, ensuring the substantially lossless forward propagation.

[0063] Continuing the discussion of FIGURES 1A and 1B, the curved end side 4 of the stepped waveguide 1 may be made reflective, typically by being coated with a reflective material such as, for example, silver, although other reflective techniques may be employed. Light may therefore be redirected in a second direction, back down the guide in the direction of $-x$ and may be substantially collimated in the *xy* or display plane. The angular spread may be substantially preserved in the *xz* plane about the principal propagation direction, which may allow light to hit

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the riser edges and reflect out of the guide. In an embodiment with approximately 45 degree tilted extraction features 12, light may be effectively directed approximately normal to the *xy* display plane with the *xz* angular spread substantially maintained relative to the propagation direction. This angular spread may be increased when light exits the stepped waveguide 1 through refraction, but may be decreased somewhat dependent on the reflective properties of the extraction features 12.

[0064] In some embodiments with uncoated extraction features 12, reflection may be reduced when total internal reflection (TIR) fails, squeezing the *xy* angular profile and shifting off normal. However, in other embodiments having silver coated or metallized extraction features, the increased angular spread and central normal direction may be preserved. Continuing the description of the embodiment with silver coated extraction features, in the *xz* plane, light may exit the stepped waveguide 1 approximately collimated and may be directed off normal in proportion to the y-position of the respective illuminator element 15a – 15n in illuminator array 15 from the input edge center. Having independent illuminator elements 15a – 15n along the input edge 2 then enables light to exit from the entire first light directing side 6 and propagate at different external angles, as illustrated in FIGURE 1A.

[0065] Illuminating a spatial light modulator (SLM) 48 such as a fast liquid crystal display (LCD) panel with such a device may achieve autostereoscopic 3D as shown in top view or *yz*-plane viewed from the illuminator array 15 end in **FIGURE 2A**, front view in **FIGURE 2B** and side view in **FIGURE 2C**. FIGURE 2A is a schematic diagram illustrating in a top view, propagation of light in an optical valve system, FIGURE 2B is a schematic diagram illustrating in a front view, propagation of light in an optical valve system, and FIGURE 2C is a schematic diagram illustrating in side view propagation of light in an optical valve system. As illustrated in FIGURES 2A, 2B, and 2C, a stepped waveguide 1 may be located behind a fast (e.g., greater than 100Hz) LCD panel SLM 48 that displays sequential right and left eye images. In synchronization, specific illuminator elements 15a through 15n of illuminator array 15 (where n is an integer greater than one) may be selectively turned on and off, providing illuminating light that enters right and left eyes substantially independently by virtue of the system's directionality. In the simplest case, sets of illuminator elements of illuminator array 15 are turned on together,

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providing a one dimensional viewing window 26 or an optical pupil with limited width in the horizontal direction, but extended in the vertical direction, in which both eyes horizontally separated may view a left eye image, and another viewing window 44 in which a right eye image may primarily be viewed by both eyes, and a central position in which both the eyes may view different images. In this way, 3D may be viewed when the head of a viewer is approximately centrally aligned. Movement to the side away from the central position may result in the scene collapsing onto a 2D image.

[0066] **FIGURE 3** is a schematic diagram illustrating in side view an optical valve. Further, FIGURE 3 illustrates additional detail of a side view of the operation of a stepped waveguide 1, which may be a transparent material. The stepped waveguide 1 may include an illuminator input side 2, a reflective side 4, a first light directing side 6 which may be substantially planar, and a second light directing side 8 which includes guiding features 10 and light extraction features 12. In operation, light rays 16 from an illuminator element 15c of an illuminator array 15 (not shown in FIGURE 3), that may be an addressable array of LEDs for example, may be guided in the stepped waveguide 1 by means of total internal reflection by the first light directing side 6 and total internal reflection by the guiding feature 10, to the reflective side 4, which may be a mirrored surface. Although reflective side 4 may be a mirrored surface and may reflect light, it may in some embodiments also be possible for light to pass through reflective side 4.

[0067] Continuing the discussion of FIGURE 3, light ray 18 reflected by the reflective side 4 may be further guided in the stepped waveguide 1 by total internal reflection at the reflective side 4 and may be reflected by extraction features 12. Light rays 18 that are incident on extraction features 12 may be substantially deflected away from guiding modes of the stepped waveguide 1 and may be directed, as shown by ray 20, through the side 6 to an optical pupil that may form a viewing window 26 of an autostereoscopic display. The width of the viewing window 26 may be determined by at least the size of the illuminator, output design distance and optical power in the side 4 and extraction features 12. The height of the viewing window may be primarily determined by the reflection cone angle of the extraction features 12 and the illumination cone angle input at the input side 2.

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[0068] **FIGURE 4A** is a schematic diagram illustrating in front view an optical valve which may be illuminated by a first illuminator element and including curved light extraction features. Further, FIGURE 4A shows in front view further guiding of light rays from illuminator element 15c of illuminator array 15, in the stepped waveguide 1. Each of the output rays are directed towards the same viewing window 26 from the respective illuminator 14. Thus light ray 30 may intersect the ray 20 in the window 26, or may have a different height in the window as shown by ray 32. Additionally, in various embodiments, sides 22, 24 of the optical valve may be transparent, mirrored, or blackened surfaces. Continuing the discussion of FIGURE 4A, light extraction features 12 may be elongate, and the orientation of light extraction features 12 in a first region 34 of the light directing side 8 (light directing side 8 shown in FIGURE 3, but not shown in FIGURE 4A) may be different to the orientation of light extraction features 12 in a second region 36 of the light directing side 8.

[0069] **FIGURE 4B** is a schematic diagram illustrating in front view an optical valve which may illuminated by a second illuminator element. Further, FIGURE 4B shows the light rays 40, 42 from a second illuminator element 15h of the illuminator array 15. The curvature of the reflective surface on the side 4 and the light extraction features 12 cooperatively produce a second viewing window 44 laterally separated from the viewing window 26 with light rays from the illuminator element 15h.

[0070] Advantageously, the arrangement illustrated in FIGURE 4B may provide a real image of the illuminator element 15c at a viewing window 26 in which the real image may be formed by cooperation of optical power in reflective side 4 and optical power which may arise from different orientations of elongate light extraction features 12 between regions 34 and 36, as shown in FIGURE 4A. The arrangement of FIGURE 4B may achieve improved aberrations of the imaging of illuminator element 15c to lateral positions in viewing window 26. Improved aberrations may achieve an extended viewing freedom for an autostereoscopic display while achieving low cross talk levels.

[0071] **FIGURE 5** is a schematic diagram illustrating in front view an embodiment of an optical valve having substantially linear light extraction features. Further, FIGURE 5 shows a similar

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arrangement of components to FIGURE 1 (with corresponding elements being similar), with one of the differences being that the light extraction features 12 are substantially linear and parallel to each other. Advantageously, such an arrangement may provide substantially uniform illumination across a display surface and may be more convenient to manufacture than the curved extraction features of FIGURE 4A and FIGURE 4B.

[0072] **FIGURE 6A** is a schematic diagram illustrating one embodiment of the generation of a first viewing window in a time multiplexed imaging directional backlight apparatus, namely an optical valve apparatus in a first time slot, **FIGURE 6B** is a schematic diagram illustrating another embodiment of the generation of a second viewing window in a time multiplexed imaging directional backlight apparatus in a second time slot, and **FIGURE 6C** is a schematic diagram illustrating another embodiment of the generation of a first and a second viewing window in a time multiplexed imaging directional backlight apparatus. Further, FIGURE 6A shows schematically the generation of illumination window 26 from stepped waveguide 1. Illuminator element group 31 in illuminator array 15 may provide a light cone 17 directed towards a viewing window 26. FIGURE 6B shows schematically the generation of illumination window 44. Illuminator element group 33 in illuminator array 15 may provide a light cone 19 directed towards viewing window 44. In cooperation with a time multiplexed display, windows 26 and 44 may be provided in sequence as shown in FIGURE 6C. If the image on a spatial light modulator 48 (not shown in FIGURES 6A, 6B, 6C) is adjusted in correspondence with the light direction output, then an autostereoscopic image may be achieved for a suitably placed viewer. Similar operation can be achieved with all imaging optical valve systems or imaging directional backlights. Note that illuminator element groups 31, 33 each include one or more illumination elements from illumination elements 15a to 15n, where n is an integer greater than one.

[0073] **FIGURE 7** is a schematic diagram illustrating one embodiment of an observer tracking autostereoscopic display apparatus including a time multiplexed optical valve apparatus. As shown in FIGURE 7, selectively turning on and off illuminator elements 15a to 15n along axis 29 provides for directional control of viewing windows. The head 45 position may be monitored with a camera, motion sensor, motion detector, or any other appropriate optical, mechanical or electrical means, and the appropriate illuminator elements of illuminator array 15 may be turned

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on and off to provide substantially independent images to each eye irrespective of the head 45 position. The head tracking system (or a second head tracking system) may provide monitoring of more than one head 45, 47 (head 47 not shown in FIGURE 7) and may supply the same left and right eye images to each viewers' left and right eyes providing 3D to all viewers. Again similar operation can be achieved with all imaging optical valve systems or imaging directional backlights.

[0074] **FIGURE 8** is a schematic diagram illustrating one embodiment of a multi-viewer display apparatus which includes a time multiplexed optical valve apparatus as an example of an imaging directional backlight. As shown in FIGURE 8, at least two 2D images may be directed towards a pair of viewers 45, 47 so that each viewer may watch a different image on the spatial light modulator 48. The two 2D images of FIGURE 8 may be generated in a similar manner as described with respect to FIGURE 7 in that the two images would be displayed in sequence and in synchronization with sources whose light is directed toward the two viewers. One image is presented on the spatial light modulator 48 in a first phase, and a second image is presented on the spatial light modulator 48 in a second phase different from the first phase. In correspondence with the first and second phases, the output illumination is adjusted to provide first and second viewing windows 26, 44 respectively. An observer with both eyes in window 26 will perceive a first image while an observer with both eyes in window 44 will perceive a second image.

[0075] **FIGURE 9** is a schematic diagram illustrating a privacy display apparatus which includes an imaging directional backlight apparatus, and as illustrated, an optical valve. 2D display systems may also utilize directional backlighting for security and efficiency purposes in which light may be primarily directed at the eyes of a first viewer 45 as shown in FIGURE 9. Further, as illustrated in FIGURE 9, although first viewer 45 may be able to view an image on device 50, light is not directed towards second viewer 47. Thus second viewer 47 is prevented from viewing an image on device 50. Each of the embodiments of the present disclosure may advantageously provide autostereoscopic, dual image or privacy display functions.

[0076] **FIGURE 10** is a schematic diagram illustrating in side view the structure of a time multiplexed optical valve apparatus as an example of an imaging directional backlight. Further,

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FIGURE 10 shows in side view an autostereoscopic display, which may include the stepped waveguide 1 and a Fresnel lens 62 arranged to provide the viewing window 26 for a substantially collimated output across the stepped waveguide 1 output surface. A vertical diffuser 68 may be arranged to extend the height of the window 26 further. The light may then be imaged through the spatial light modulator 48. The illuminator array 15 may include light emitting diodes (LEDs) that may, for example, be phosphor converted blue LEDs, or may be separate RGB LEDs. Alternatively, the illuminator elements in illuminator array 15 may include a uniform light source and spatial light modulator arranged to provide separate illumination regions. Alternatively the illuminator elements may include laser light source(s). The laser output may be directed onto a diffuser by means of scanning, for example, using a galvo or MEMS scanner. In one example, laser light may thus be used to provide the appropriate illuminator elements in illuminator array 15 to provide a substantially uniform light source with the appropriate output angle, and further to provide reduction in speckle. Alternatively, the illuminator array 15 may be an array of laser light emitting elements. Additionally in one example, the diffuser may be a wavelength converting phosphor, so that illumination may be at a different wavelength to the visible output light.

[0077] **FIGURE 11A** is a schematic diagram illustrating a front view of an optical inline directional backlight apparatus as another example of an imaging directional backlight apparatus. Further, FIGURE 11A shows another imaging directional backlight apparatus described herein as an optical inline directional backlight. The optical inline directional backlight may operate in a similar manner to the optical valve, with the difference that light may not be reversed at the end interface. Instead, the optical inline directional backlight may allow light to fan out in a guiding region before refracting light approximately half way down its length into a region containing extraction features 12 and in which light may be directed out of the guide and toward a viewer. Light emitted from an illuminator element 15d (e.g., LED) may expand within a guiding region 9 before being redirected with a refractive imaging element 119, which may include in this case, a Fresnel lens surface between dissimilar refractive index materials 111 and 113. Extraction features 12 may extract the light between guiding regions 10 to provide directed rays 5, which may converge to form viewing windows in a similar manner to the optical valve. Effectively, the

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optical inline directional backlight can be constructed and may operate as an unfolded optical valve in which the reflecting mirror 4 may be replaced by the refractive cylindrical lens 119.

[0078] **FIGURE 11B** is a schematic diagram illustrating a front view of another imaging directional backlight apparatus, as illustrated, a wedge type directional backlight, and **FIGURE 11C** is a schematic diagram illustrating a side view of the same wedge type directional backlight apparatus. A wedge type directional backlight is generally discussed by U.S. Patent No. 7,660,047 and entitled "Flat Panel Lens," which is herein incorporated by reference in its entirety. The structure may include a wedge type waveguide 1104 with a bottom surface which may be preferentially coated with a reflecting layer 1106 and with an end corrugated surface 1102, which may also be preferentially coated with a reflecting layer 1106. As shown in FIGURE 11C, light may enter the wedge type waveguide 1104 from local sources 1101 and the light may propagate in a first direction before reflecting off the end surface. Light may exit the wedge type waveguide 1104 while on its return path and may illuminate a display panel 1110. By way of comparison with an optical valve, a wedge type waveguide provides extraction by a taper that reduces the incidence angle of propagating light so that when the light is incident at the critical angle on an output surface, it may escape. Escaping light at the critical angle in the wedge type waveguide propagates substantially parallel to the surface until extracted by a redirection layer 1108 such as a prism array. Errors or dust on the wedge type waveguide output surface may change the critical angle, creating stray light and uniformity errors. Further, an imaging directional backlight that uses a mirror to fold the beam path in the wedge type directional backlight may employ a faceted mirror that biases the light cone directions in the wedge type waveguide. Such faceted mirrors are generally complex to fabricate and may result in illumination uniformity errors as well as stray light.

[0079] The wedge type directional backlight and optical valve further process light beams in different ways. In the wedge type waveguide, light input at an appropriate angle will output at a defined position on a major surface, but light rays will exit at substantially the same angle and substantially parallel to the major surface. By comparison, light input to a stepped waveguide of an optical valve at a certain angle may output from points across the first side, with output angle determined by input angle. Advantageously, the stepped waveguide of the optical valve may not

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require further light re-direction films to extract light towards an observer and angular non-uniformities of input may not provide non-uniformities across the display surface.

[0080] Generally, one embodiment in accordance with the present disclosure may take the form of adding a dichroic layer stack and a polarization rotation film respectively to the exiting and reflecting surfaces of a wedge type directional backlight which performs efficient polarization conversion without compromising directional performance. Useful polarized illumination output may be increased by approximately 80%.

[0081] It should be noted that embodiments of the present disclosure may be used in a variety of optical systems and projection systems. The embodiment may include or work with a variety of projectors, projection systems, optical components, computer systems, processors, self-contained projector systems, visual and/or audiovisual systems and electrical and/or optical devices. Aspects of the present disclosure may be used with practically any apparatus related to optical and electrical devices, optical systems, presentation systems or any apparatus that may contain any type of optical system. Accordingly, embodiments of the present disclosure may be employed in optical systems, devices used in visual and/or optical presentations, visual peripherals and so on and in a number of computing environments including the Internet, intranets, local area networks, wide area networks and so on.

[0082] Before proceeding to the disclosed embodiments in detail, it should be understood that the disclosure is not limited in its application or creation to the details of the particular arrangements shown, because the disclosure is capable of other embodiments. Moreover, aspects of the disclosure may be set forth in different combinations and arrangements to define inventions unique in their own right. Also, the terminology used herein is for the purpose of description and not of limitation.

[0083] An exemplary embodiment of the general concept of the disclosed principles is illustrated in **FIGURE 12**. FIGURE 12 illustrates a close up view a backlight system 1200 which includes a wedge type waveguide 1205 constructed according to the principles disclosed herein. In FIGURE 12, a cross section of the waveguide 1205 illustrates a plurality of dichroic layers 1210

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positioned on the exit surface 1215 of the waveguide 1205, and a birefringent layer 1220 positioned on the bottom surface of the waveguide 1205.

[0084] A collimated unpolarized ray of light 1225 is illustrated that back propagates at angles just steeper than the critical angle of the waveguide 1205. Unpolarized light 1225 at such an angle is incident on the dichroic layer stack 1210, which has high transmission of P-polarized light 1230 while reflecting most light that is S-polarized 1235. The S-polarized reflected light 1235 is shown as a hashed line in FIGURE 12. This reflected S-polarized light 1235 then passes through a birefringent layer 1220, as illustrated in FIGURE 12, which may be a film optically bonded to the back surface of the waveguide 1205 before being totally internally reflected back toward the exit surface 1215. Suitable orientation of the birefringent material's 1220 optic axis, together with the retardance value, efficiently transforms the lights 1235 S-polarization state into P-polarized light 1240. When the transformed P-polarized light 1240 encounters the dichroic layers 1210 for a second time, it passes through with minimal reflection since this light was already at or exceeded the critical exit angle of the waveguide 1205. In the ideal case, all the exiting light becomes P-polarized suitable for modulation by an LCD panel. In practice, the 1000:1 polarization purity is difficult to achieve, an thus the use of a clean-up polarizer after the dichroic layers 1201 may be employed. Nevertheless, significant polarization purity can be achieved, which provides system efficiencies greater than that resulting from conventional approaches, such as the use of dual brightness enhancement film (DBEF) for light exiting a waveguide.

[0085] One embodiment of a backlight system 1200 constructed in accordance with the disclosed principles may include at least some of the following design parameters: the wedge waveguide and reflector corrugation angle, the radius of curvature of the end reflector of the waveguide, the dichroic layer number and thicknesses, the orientation and retardance of the birefringent film, and the design of any extraction film employed with the waveguide. Each of these design parameters will be discussed in further detail herein. The design parameters may be determined in any order and are discussed accordingly.

Wedge Angle of the Waveguide

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[0086] **FIGURE 13** is a schematic diagram illustrating a close up diagram that illustrates internal angle definitions for backlight system 1300 constructed in accordance with the disclosed principles. The illustrated system 1300 includes a wedge type waveguide 1305 and a cladding material 1310 located above the exit side of the waveguide 1305. For light to propagate down a wedge waveguide 1305, few to no initial internal rays 1320 may have angles greater than approximately the critical incident angle θc from the waveguide exiting surface 1315, as shown in FIGURE 13. Rays 1325 with angles less than the critical incident angle θc from the waveguide 1305 can exit the waveguide, also as shown in FIGURE 13. This critical angle θc is determined by the refractive indices of the waveguide 1305 material ($nw \sim 1.492$ for the example material acrylic) and the exiting surface cladding material 1310 ($nc \sim 1.41$ for the example material silicone), where:

$$\theta c = \sin^{-1}\left(\frac{nc}{nw}\right) \approx 71^\circ$$

[0087] The related propagation angles θp, which may be defined primarily from the principal propagation direction, may adhere to the following criterion for the exemplary materials mentioned above:

$$|\theta p| < \theta pc = 90^\circ - \theta \approx 19^\circ$$

where θpc is defined as the confinement angle.

[0088] Most LED backlights use white emitters that comprise a blue (~450nm peak wavelength) diode encapsulated in a yellow phosphor. Packages for backlights are often approximately 2.5mm x 1mm, with an angular emission profile similar to that shown in **FIGURE 14**. FIGURE 14 is a schematic diagram illustrating a standard polar emission plot of an exemplary white LED. The profile of FIGURE 14 assumes emission into air, whereas entering a waveguide of the approximate index 1.492 may reduce the angular extent through refraction. As shown in FIGURE 14, most of the light, and in some cases approximately 90 percent, may be contained within an azimuthally symmetric, approximately 50° cone, which equates to approximately 30°

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within the waveguide. To avoid losing light, a simple input wedge beam expander for each LED can be provided as part of the overall molded waveguide structure.

[0089] **FIGURE 15** is a schematic diagram illustrating top and side views of one embodiment of a wedge type directional backlight system 1500. The exemplary backlight system 1500 includes a waveguide 1505 and a cladding layer 1510 located over the exit surface of the waveguide 1505, similar to embodiments discussed above. The system 1500 also includes flared beam expander waveguide extensions (a non-imaging optical element) for angular tailoring of LEDs 1515 used in the backlight system 1500. FIGURE 15 shows a schematic of beam expander extensions 1520 to the waveguide 1505 that may limit the input ray angles to approximately ±19°, which may be approximately equal to $\pm\theta pc$, in the plane substantially normal to the waveguide 1505 (side view in FIGURE 15), and avoids gaps between the LEDs 1515 in the waveguide plane itself. The juxtaposition of the LEDs 1515 may reduce or prevent dark viewing regions in the final overall system 1500.

[0090] The effect of a wedge expander 1520 may be to compress the light and also to substantially homogenize the rays, thus producing an angular profile similar to that shown in **FIGURE 16**. FIGURE 16 is a schematic diagram illustrating a compressed angular light input profile 1600 following expansion of LED output. Most or all of the light may then be guided with little to no loss down the wedge waveguide, along the *x*-axis. The light may be confined in the *z*--axis direction through total internal reflection (TIR), but may expand in the *xy* plane of the guide consistent with the launch angles. Each reflection of the light from the non-parallel exit and bottom surfaces of a wedge-shaped waveguide may act to reduce the propagation angles. In a physically long waveguide, such as one which is significantly longer than its thickness, the angle spread may be compressed in accordance with the conservation of etendue. For small angles, the product: $d.\Delta\phi$ may be conserved, where d is the thickness of the waveguide at a given position along the *x-axis*, and $\Delta\phi$ is the total angular spread. Assuming the waveguide's thickness at the thicker or reflecting end is D, then the angular spread, $\Delta\phi'$, of the rays hitting the surface may be compressed by a factor: d/D.

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[0091] On reflection, rays counter-propagate down the waveguide, and the angle spread of the rays may increase in a substantially symmetrical manner. Any rays that exceed the confinement angle θpc may escape the waveguide. With normal reflection, the angles may be within the confinement regime and, from the symmetry of the system, may reach the escape condition when they encounter the thin end of the wedge. Little to no light will therefore exit in this case. By introducing horizontal corrugations with apex angles of approximately $90°-(d/D)\theta pc$ onto the end reflection surface of the waveguide, the angular profile of the reflected light can be separated to provide two symmetric angular distribution lobes, as shown in **FIGURE 17**. FIGURE 17 is a schematic diagram illustrating a zx angle profile 1700 as light propagates forward and backward through a wedge waveguide 1705 with reflection from a corrugated end reflector 1710.

[0092] The number of corrugations on the end reflector 1710 may affect the distance taken to substantially homogenize the ray angles within the waveguide 1705 following reflection, with more corrugations providing a shorter distance for mixing. A guideline to the number of corrugations can be determined by realizing the size c of each corrugation may produce an angular *hole* in the ray distribution at a single first exit point at a distance z from the corrugated end reflector 1710, which may be equivalent to approximately c/z radians. To avoid a significant impact on illumination uniformity, the *hole* may not be larger than the spread of ray angles ($=2\theta w \approx 2°$) that escape the waveguide 1705 at any one position. A suitable homogenizing distance zh might be approximately ten millimeters in the case of a monitor, making a guideline number of corrugations of approximately $D/c \approx D/(zh.2\theta w) \approx 20$, in which θw is expressed in radians.

[0093] As illustrated in FIGURE 17, the angles may expand during the backward propagation, and may gradually exceed the confinement criterion causing light to exit and form an illumination beam. By the time the light gets back to the thin end of the waveguide 1705, most to all light may have escaped. The condition depicted by FIGURE 17 is one in which the angular spread of the input light may closely match with the initial confinement condition and may minimize the input wedge thickness. The corresponding thickness of the reflecting end 1710 may then become approximately 3x the input width. For the approximately one millimeter

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LED expanded to approximately 2.5 millimeter input considered in this exemplary embodiment, the reflecting end 1710 may be approximately 7.5 millimeters. This may be feasible for a laptop/monitor/TV implementation. Assuming an approximately 23 inch monitor platform, the wedge angle θw, which may be associated with an approximately five millimeter change in thickness over a vertical height of approximately 300 millimeters, may be approximately 5/300 radians or approximately one degree. Physically smaller LEDs may be considered for hand-held display implementations which may reduce this angle and overall thicknesses.

[0094] In summary, the wedge angle in radians may be the product of: the LED size, *Le*, the input angular contraction factor *2.5*, the wedge contraction factor, *3*, divided by the length of the wedge, *L*, or :

$$\theta w = \frac{7.5Le}{L}$$

Reflector Curvature Radius

[0095] A similar analysis to that above can be considered for ray angles in the *xy* plane of a waveguide in accordance with the disclosed principles. Initial ray angular profile may be determined by the light expander as in the case above. Freedom to choose the exit size and expander length allows for somewhat controlled angular profile of the type shown on the left side of **FIGURE 18**. FIGURE 18 is a schematic diagram illustrating an angular profile 1800 of the collimation of light on reflection in the *xy* plane in wedge type waveguides. This angular profile may be retained in the unconfined waveguide plane, but may be collimated on reflection, as shown in the right side of FIGURE 18. The extent to which the rays may be collimated, and therefore the curvature of the end reflector 1810, may be determined through geometrical optical analysis. A valid construction may consider conventional ray tracing in the *xy* plane, and then may introduce a rotation of coordinates where the light departs from the waveguide. It may be assumed that the central rays forming the LED image, for example, the final exit pupils, exit approximately halfway along the waveguide. The coordinate rotation may unfold the rays that would head toward the viewer, allowing them to be plotted with a substantially similar familiar geometric image formation construction. The resulting diagram is shown in **FIGURE 19**.

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FIGURE 19 is a schematic diagram illustrating a geometrical image forming construction diagram 1900 for determining reflector radius of curvature 1910. First exemplary light rays (e.g., red rays) and second exemplary light rays (e.g., blue rays) are plotted in FIGURE 19 to help illustrate the determination of the radius of curvature for the reflecting end of a waveguide constructed as disclosed herein. Similar triangles may provide the source magnification M as:

$$\frac{P}{Le} = \frac{n \cdot V + \frac{L}{2} - \frac{r}{2}}{\frac{r}{2}}$$

for the rays labeled red rays; and

$$\frac{P}{Le} = \frac{n \cdot V + \frac{L}{2}}{L}$$

for the rays labeled blue rays (e.g., the remaining rays).

[0096] Combining the above yields the following solution for the radius curvature of the end reflector:

$$r = 2 \cdot L \cdot \frac{(2 \cdot n \cdot V + L)}{(3 \cdot L + 2 \cdot n \cdot V)}$$

[0097] In the monitor example, L may be approximately 300 millimeter, and the viewing distance V may be approximately 750 millimeters. The waveguide index $n = nw \approx 1.492$ may be consistent with optical grade acrylic, thus providing the radius of curvature $r \approx 485$ millimeters. The pupil magnification M may then be approximately 4.2, making the physical size of an extended LED source corresponding to a single eye light box approximately 65/4.2 or approximately 15 millimeters.

[0098] The illuminator region defined within the curved edge may be outside the viewing region, which may be impractical in many cases where edge bevels may be minimal. To reduce the

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illuminator overhang, the curved surface can be replaced with a Fresnel equivalent as shown in **FIGURE 20**. FIGURE 20 sets forth a schematic diagram illustrating one embodiment of a wedge type directional backlight waveguide illuminator 2010 with an equivalent Fresnel waveguide structure 2020.

Dichroic Layer Thicknesses

[0099] The design of a polarization selective reflecting dichroic layer stack may be somewhat dependent on the angular extent of the light incident on the stack. In this case, light that exceeds the confinement angle θpc may be considered as all other light may be substantially to completely reflected regardless of polarization. Also, to provide the desired output collimation, most or all light that exceeds the confinement angle may exit the waveguide as soon as possible with minimal bouncing within the waveguide. This may limit the incident angles to be considered. The extent of the collimation of the light exiting the waveguide may be approximately determined by the number of bounces before total extraction, together with the angle increase between bounces. For a perfect system, where light exits with no reflection after exceeding the confinement condition, the angular spread of exiting rays incident on the dichroic stack within the waveguide is simply twice the wedge angle. With good polarization conversion it may be expected that the light may exit after two bounces, making the ray angle spread at the dichroic stack equal to approximately $4.\theta w$ or approximately 4 degrees for the exemplary embodiment herein.

[0100] Standard optimization techniques can be used to determine a suitable dichroic stack, such as those employed in software like TFCalc, a thin film design software package supplied by Software Spectra Inc., of Portland, OR. Optimizing for a cost effective three layer solution with a typical cladding material index may yield the following exemplary solutions set forth in TABLE 1, in which dispersion is included in the optimization:

Material	Refractive index	Thickness (nm)

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Acrylic (Waveguide)	1.492	
TiO_2	2.4	140
MgF_2	1.38	240
TiO_2	2.4	21
Cladding	1.41	

TABLE 1

[0101] **FIGURE 21** is a schematic diagram illustrating one embodiment of a graph 2100 of reflectivity off an exemplary dichroic layer stack in accordance with the disclosed principles. FIGURE 21 illustrates the transmission of the aforementioned coating for an average exiting ray incident at approximately 2° larger than the confinement angle. Assuming the reflected S-polarized ray is transformed into P-polarization before next hitting the exit surface of the waveguide, the double bounce polarization efficiency may be calculated at approximately 80%.

Polarization Transformation Layer

[0102] In general, a method of transforming or converting polarization may be to use a half-wave retarder film oriented such that its optic axis is approximately 45° to the light's polarization direction in the plane approximately perpendicular to propagation. The determination of the correct orientation and retardance value of a uniaxially stretched film attached to the bottom of the waveguide in question can be done geometrically. Relevant angle definitions are illustrated in **FIGURE 22**. FIGURE 22 is a schematic diagram 2200 illustrating incidence geometry of a ray entering a polarization transforming retarder layer from a waveguide.

[0103] A ray incident at angle θi ($\approx \theta c$ -2° ≈ 69°) on the waveguide/retarder interface enters the retarder at the approximate angle θr in which:

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$$\theta r = a\sin\left(\frac{nw}{nr}\cdot\sin(\theta i)\right)$$

[0104] Thus, inside the retarder the ray may have a propagation vector (k-vector) described as:

$$\vec{k} = \begin{pmatrix} \sin(\theta r) \\ 0 \\ -\cos(\theta r) \end{pmatrix} = \begin{bmatrix} \frac{nw}{nr}\sin(\theta i) \\ 0 \\ -\sqrt{1-\left(\frac{nw}{nr}\cdot\sin(\theta i)\right)^2} \end{bmatrix}$$

[0105] and the retarder's optic axis by:

$$\vec{O} = \begin{pmatrix} \cos(\theta\gamma) \\ \sin(\theta\gamma) \\ 0 \end{pmatrix}$$

[0106] The ordinary polarization axis may then be approximately parallel to:

$$\vec{k}\,x\,\vec{O} = \begin{pmatrix} \sin(\theta r) \\ 0 \\ -\cos(\theta r) \end{pmatrix} x \begin{pmatrix} \cos(\theta\gamma) \\ \sin(\theta\gamma) \\ 0 \end{pmatrix} = \begin{pmatrix} \cos(\theta r).\sin(\theta\gamma) \\ -\cos(\theta r).\cos(\theta\gamma) \\ \sin(\theta r).\sin(\theta\gamma) \end{pmatrix}$$

[0107] For efficient polarization conversion, this vector may need to be approximately 45° from the S-polarization direction in which:

$$\vec{S} = \begin{pmatrix} 0 \\ -1 \\ 0 \end{pmatrix}$$

The negative option described as the positive value may yield an imaginary solution. This may imply solving:

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$$\frac{\left(\vec{k} x \vec{O}\right) \cdot \vec{S}}{\left|\vec{k} x \vec{O}\right|} = \cos(45\,\mathrm{deg})$$

Algebraic manipulation may yield the following solutions:

$$\theta\gamma = \begin{pmatrix} a\tan(\cos(\theta\cdot)) \\ -a\tan(\cos(\theta\cdot)) \end{pmatrix}$$

which, in this example case may lead to $\theta\gamma \approx \pm 22.5°$.

[0108] The effective ordinary and extraordinary refractive indices may first be calculated and used to determine the retardance value Γ of the transforming film. Assuming a cost effective uniaxially stretched film is used, the ordinary index, *no*, may remain substantially unchanged for any incident ray. The extraordinary index *ne* may, however, be determined by the ray's propagation direction ($\theta = a\cos\left(\vec{k} \cdot \vec{O}\right)$) relative to the film optic axis, and may be determined by:

$$\frac{1}{ne^2} = \frac{\cos(\theta)^2}{no^2} + \frac{\sin(\theta)^2}{(no + \Delta n)^2}$$

Replacing *ne* with (*no* + $\Delta n'$) and recognizing Δn and $\Delta n' << no$, this expression can be expanded to give:

$$\Delta n' = \sin(\theta)^2 \cdot \Delta n$$

For a film of thickness *d*, the retardance value may be $\Gamma = \Delta n.d$.

[0109] In one example of a reflective case, the net retardance experienced by a double pass though the film may be:

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$$\frac{2 \cdot \Delta n' \cdot d}{\cos(\theta_r)},$$

which can be re-expressed in the following ways:

$$\frac{2 \cdot \sin\left(\frac{\rightarrow}{k} \cdot \frac{\rightarrow}{O}\right)^2 \cdot \Gamma}{\cos(\theta_r)} = \frac{2 \cdot \sin(a\cos(\sin(\theta_r) \cdot \cos(\theta_y)))^2 \cdot \Gamma}{\cos(\theta_r)} = \frac{2 \cdot \left(1 - \sin(\theta_r)^2 \cdot \cos(\theta_y)^2\right) \cdot \Gamma}{\cos(\theta_r)}$$

[0110] Equating this last expression to a half-wave or $\lambda/2$, the result is:

$$\Gamma = \frac{\lambda \cdot \cos(\theta_r)}{4 \cdot \left(1 - \sin(\theta_r)^2 \cdot \cos(\theta_y)^2\right)}$$

Substituting the values obtained above for θ_r (≈65.5°) and θ_y (≈25.5°) may provide a film retardance value that yields a half-wave at approximately λ=589 nanometers of approximately 187 nanometers.

Extraction Film

[0111] As determined above, the light that may be extracted from the breakdown of the TIR condition may be incident on the extraction surface of the waveguide at angles between approximately θc and θc-4.θw. This may translate through Snell's law into angles ϕ within the cladding layer, in which:

$$a\sin\left(\frac{nc}{nw} \sin(\theta c)\right) > \phi > a\sin\left(\frac{nc}{nw} \sin(\theta c - 4 \cdot \theta w)\right)$$

or $90° > \phi > 76.7°$ for $\theta w = 1°$

[0112] To provide normal illumination, these angles may be redirected by approximately 80°. This may be achieved by both reflecting and refracting by using a double-sided, one dimensional

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'sawtooth' redirection film 2310 located on the cladding layer 2320, as well as an additional directional diffuser 2330, as shown in **FIGURE 23**. FIGURE 23 is a schematic diagram illustrating a close up side view of an extraction film profile 2300 used to redirect illuminating light 2340 exiting from a waveguide that may be constructed in accordance with the disclosed principles.

[0113] Another embodiment for provide normal illumination is illustrated in **FIGURE 24** and the corresponding method to provide separate panel illumination for each eye is illustrated in **FIGURE 25**. FIGURE 24 is a schematic diagram illustrating top and side views of another embodiment of a waveguide structure 2400 constructed in accordance to the disclosed principles, and which includes directional layers for exiting rays. In this embodiment, a wedge waveguide 2405 again includes a dichroic stack 2410 on its exit surface, and a polarization conversion film 2415 on its bottom surface, as discussed above. This embodiment also includes a corrugated reflecting end 2420 on the waveguide 2405 for redirecting lights rays during backward propagation as discussed above. Additionally, a redirection film 2425 is employed above the dichroic stack 2410, and which may include two or more patterns therein for redirecting rays exiting from the waveguide 2405 to a more normal angle. A directional diffuser 2430 may also be employed to more evenly distribute the substantially normal rays for more uniform illumination of, for example, an LCD panel 2435 having alternating stereoscopic left eye and right eye imagery of a scene. LEDs 2440 in an LED array provide the initial lights rays into the waveguide 2405, as discussed above.

[0114] FIGURE 25 is a schematic diagram 2500 illustrating the operation of directional backlighting for selective eye viewing and time sequential stereoscopic operation, in accordance with the disclosed principles. In such embodiments, as the LCD panel presents alternating left eye and right eye imagery, directional backlighting may be provided by an efficient illumination system as disclosed herein in synchronization with the left and right eye images. A final auto-stereoscopic system is shown in **FIGURE 26**. More specifically, FIGURE 26 sets forth a schematic diagram illustrating an eyewear-free stereoscopic display system 2600 using a directional backlight in accordance with the principles disclosed herein.

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[0115] Other advantages of directional backlighting, discussed in further detail herein, may include secure viewing, in which only the viewer sees the image on the display due to the narrow viewing window and efficiency. Modest illumination power may be employed since the illumination may be directed substantially toward the viewer's eyes and not elsewhere. Yet further advantageous features of this technology can be exhibited by incorporating more than two independent LEDs (or LED arrays) along with head tracking. These include the freedom of head position and multiple viewers of stereoscopic imagery.

[0116] As may be used herein, the terms "substantially" and "approximately" provide an industry-accepted tolerance for its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to ten percent and corresponds to, but is not limited to, component values, angles, etc. Such relativity between items ranges between less than one percent to ten percent.

[0117] While various embodiments in accordance with the principles disclosed herein have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of this disclosure should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with any claims and their equivalents issuing from this disclosure. Furthermore, the above advantages and features are provided in described embodiments, but shall not limit the application of such issued claims to processes and structures accomplishing any or all of the above advantages.

[0118] Additionally, the section headings herein are provided for consistency with the suggestions under 37 CFR 1.77 or otherwise to provide organizational cues. These headings shall not limit or characterize the invention(s) set out in any claims that may issue from this disclosure. Specifically and by way of example, although the headings refer to a "Technical Field," the claims should not be limited by the language chosen under this heading to describe the so-called field. Further, a description of a technology in the "Background" is not to be construed as an admission that certain technology is prior art to any embodiment(s) in this disclosure. Neither is the "Summary" to be considered as a characterization of the embodiment(s) set forth in issued claims. Furthermore, any reference in this disclosure to

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"invention" in the singular should not be used to argue that there is only a single point of novelty in this disclosure. Multiple embodiments may be set forth according to the limitations of the multiple claims issuing from this disclosure, and such claims accordingly define the embodiment(s), and their equivalents, that are protected thereby. In all instances, the scope of such claims shall be considered on their own merits in light of this disclosure, but should not be constrained by the headings set forth herein.

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CLAIMS

What is claimed is:

1. An illumination system for use with an electronic display system, the illumination system comprising:

an optical waveguide having a near end and a reflecting far end, a thickness of the waveguide at the reflecting end greater than a thickness at the near end, the waveguide further comprising an exit surface extending between the near and far ends and having a critical angle above which light rays may exit the waveguide; and

at least one dichroic layer located on the exit surface of the waveguide, the at least one dichroic layer configured to pass exiting light rays having a first polarization and to reflect exiting light rays having a second polarization, different than the first polarization, back through the exit surface.

2. An illumination system in accordance with claim 1, wherein the at least one dichroic layer comprises a dichroic stack of at least three dichroic materials, stacked in alternating high and low refractive indices.

3. An illumination system in accordance with claim 1, further comprising a polarization conversion film located on a surface of the waveguide opposite the exit surface, the polarization conversion film configured to transform the polarization of at least some of the light rays having the second polarization reflected by the at least one dichroic layer to light rays having the first polarization, and to reflect the transformed light rays having the first polarization back into the waveguide such that at least a portion of the transformed light rays having the first polarization may exit the waveguide and pass through the at least one dichroic layer.

4. An illumination system in accordance with claim 3, wherein the polarization conversion film comprises a birefringent film.

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5. An illumination system in accordance with claim 1, further comprising a cladding layer located proximate the at least one dichroic layer, the cladding layer configured to redirect at least some exiting light rays to an angle approximately normal to the exit surface.

6. An illumination system in accordance with claim 1, wherein the reflecting end further comprises a curvature extending along a plane substantially parallel to the exit surface's plane.

7. An illumination system in accordance with claim 1, wherein the reflecting end comprises at least one corrugation on an internal surface thereof.

8. A method of illuminating an electronic display system, the method comprising:

transmitting light rays into a waveguide comprising an exit surface having a critical angle above which light rays may exit the waveguide, wherein a portion of the transmitted light rays exit the waveguide through the exit surface;

passing exiting light rays having a first polarization towards a display panel, while reflecting exiting light rays having a second polarization, different than the first polarization, back into the waveguide through the exit surface; and

passing at least some of the light rays exiting the waveguide towards the display panel.

9. A method in accordance with claim 8, wherein the method comprises passing exiting light rays having the first polarization towards a display panel, and reflecting exiting light rays having the second polarization back through the exit surface, using at least one dichroic layer located on the exit surface.

10. A method in accordance with claim 9, wherein the at least one dichroic layer comprises a dichroic stack of at least three dichroic materials, stacked in alternating high and low refractive indices.

11. A method in accordance with claim 8, wherein the method further comprises:

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transforming the polarization of at least some of the reflected light rays having the second polarization into light rays having the first polarization; and

reflecting the transformed light rays back towards the exit surface such that at least a portion of the transformed light rays exit the waveguide.

12. A method in accordance with claim 11, wherein transforming the polarization of at least some of the reflected light rays having the second polarization into light rays having the first polarization comprises employing a birefringent film.

13. A method in accordance with claim 8, further comprising redirecting at least some light rays passing towards the display panel to an angle approximately normal to the exit surface.

14. A method in accordance with claim 13, wherein redirecting comprises redirecting the at least some light rays passing towards the display panel using a cladding material.

15. A method in accordance with claim 8, wherein the waveguide comprises a near end and a reflecting far end, a thickness of the waveguide at the reflecting end being greater than a thickness at the near end, wherein at least a portion of the lights rays exiting the waveguide reflected off of the reflecting end.

16. A method in accordance with claim 15, wherein the reflecting end comprises a curvature extending along a plane substantially parallel to the exit surface's plane.

17. A method in accordance with claim 15, wherein the reflecting end comprises at least one corrugation on an internal surface thereof.

18. An electronic display system, comprising:

an optical waveguide having a near end and a reflecting far end, a thickness of the waveguide at the reflecting end greater than a thickness at the near end, the waveguide further

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comprising an exit surface extending between the near and far ends and having a critical angle above which light rays may exit the waveguide;

at least one illumination unit configured to transmit lights rays into the waveguide through the near end;

at least one dichroic layer located on the exit surface of the waveguide, the at least one dichroic layer configured to pass P-polarized light rays exiting the waveguide and to reflect S-polarized light rays exiting the waveguide back through the exit surface; and

a display panel for providing images for display to a viewer of the display system, and configured to receive the P-polarized light rays passing through the at least one dichroic layer.

19. An electronic display system in accordance with claim 18, wherein the at least one dichroic layer comprises a dichroic stack of at least three dichroic materials, stacked in alternating high and low refractive indices.

20. An electronic display system in accordance with claim 18, further comprising a polarization conversion film located on a surface of the waveguide opposite the exit surface, the polarization conversion film configured to transform the polarization of at least some of the S-polarized light rays reflected by the at least one dichroic layer to P-polarized light rays, and to reflect the transformed P-polarized light rays back into the waveguide such that at least a portion of the transformed P-polarized light rays may exit the waveguide and pass though the at least one dichroic layer.

21. An electronic display system in accordance with claim 20, wherein the polarization conversion film comprises a birefringent film.

22. An electronic display system in accordance with claim 18, further comprising a cladding layer located between the at least one dichroic layer and the display panel, the cladding layer configured to redirect at least some exiting light rays to an angle approximately normal to the exit surface.

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23. An electronic display system in accordance with claim 18, wherein the reflecting end further comprises a curvature extending along a plane substantially parallel to the exit surface's plane.

24. An electronic display system in accordance with claim 18, wherein the reflecting end comprises at least one corrugation on an internal surface thereof.

25. A method of illuminating an electronic display system, the method comprising:

generating light rays using at least one illumination unit located proximate an optical waveguide comprising an exit surface having a critical angle above which light rays may exit the waveguide;

transmitting the generated light rays into the waveguide, wherein a portion of the transmitted light rays exit the waveguide through the exit surface;

passing exiting P-polarized light rays while reflecting exiting S-polarized light rays back into the waveguide through the exit surface; and

illuminating a display panel, configured to provide images for display to a viewer, with at least a portion of the passed P-polarized light rays.

26. A method in accordance with claim 25, wherein the method comprises passing exiting P-polarized light rays, and reflecting exiting S-polarized light rays, using at least one dichroic layer located on the exit surface.

27. A method in accordance with claim 25, wherein the method further comprises transforming at least some of the reflected S-polarized light rays into P-polarized light rays, and reflecting the transformed P-polarized light rays back towards the exit surface such that at least a portion of the transformed P-polarized light rays exit the waveguide, the method further comprising passing at least some of the transformed P-polarized light rays exiting the waveguide, and illuminating the display panel with at least a portion of the passed transformed P-polarized light rays.

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28. A method in accordance with claim 25, wherein the waveguide comprises a near end and a reflecting far end, a thickness of the waveguide at the reflecting end being greater than a thickness at the near end, wherein at least a portion of the lights rays exiting the waveguide reflected off of the reflecting end.

29. A method in accordance with claim 28, wherein the reflecting end comprises a curvature extending along a plane substantially parallel to the exit surface's plane.

30. A method in accordance with claim 28, wherein the reflecting end comprises at least one corrugation on an internal surface thereof.

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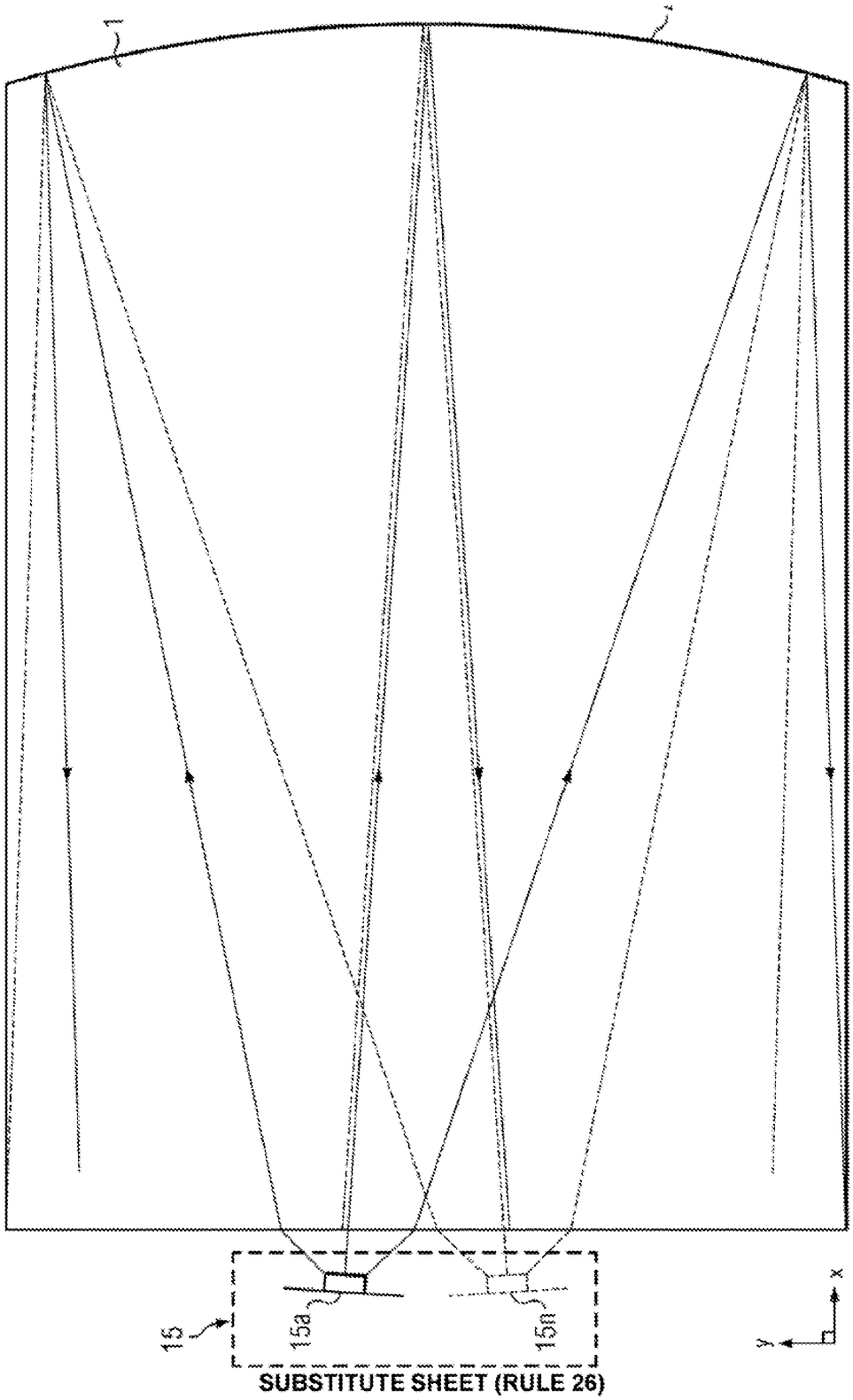

FIG. 1A

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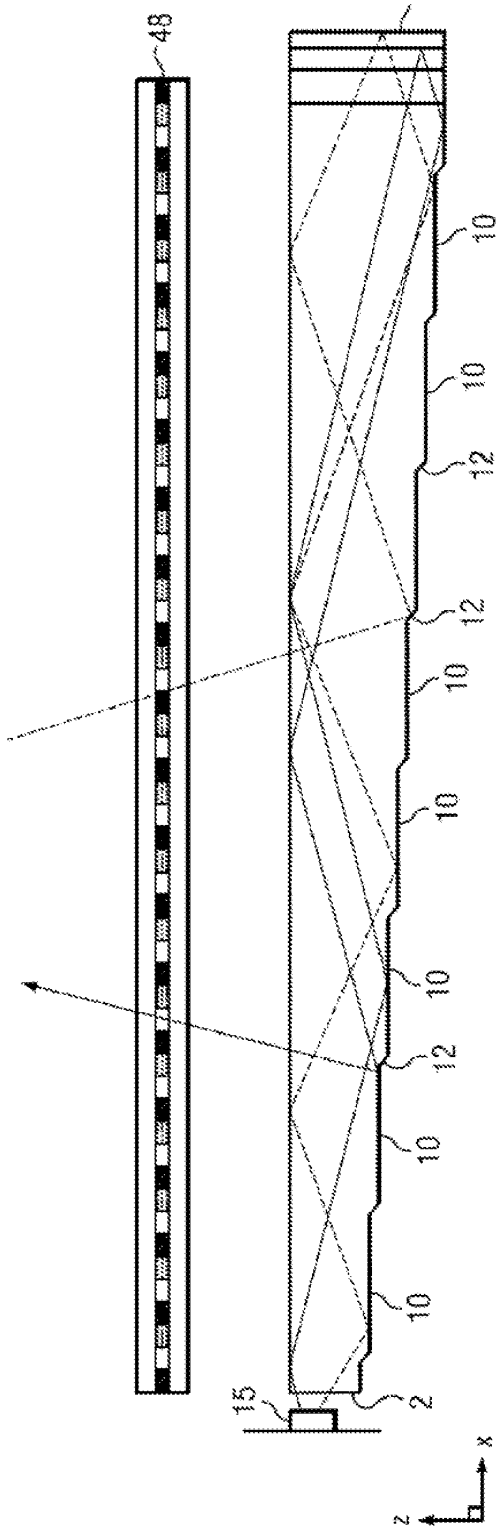

FIG. 1B

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

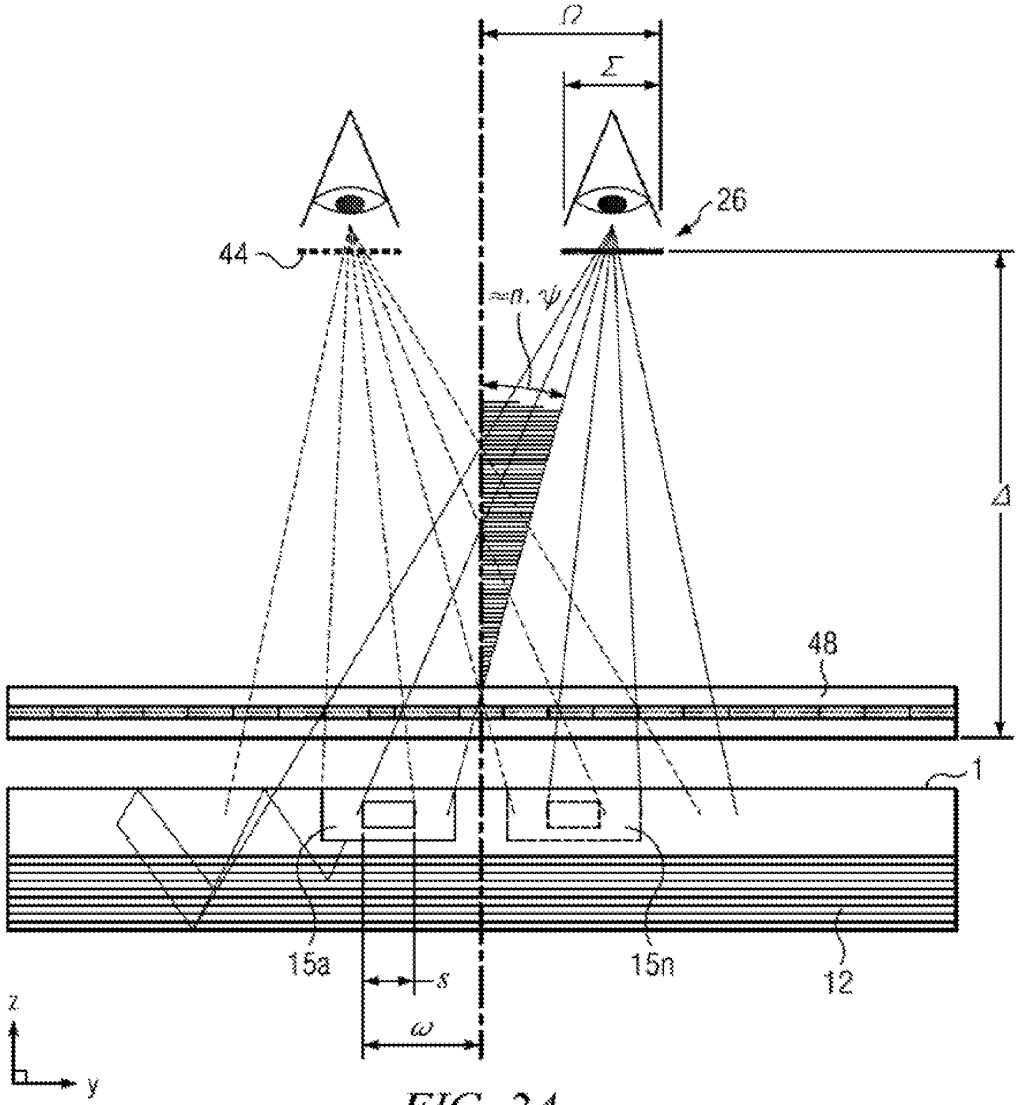

FIG. 2A

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

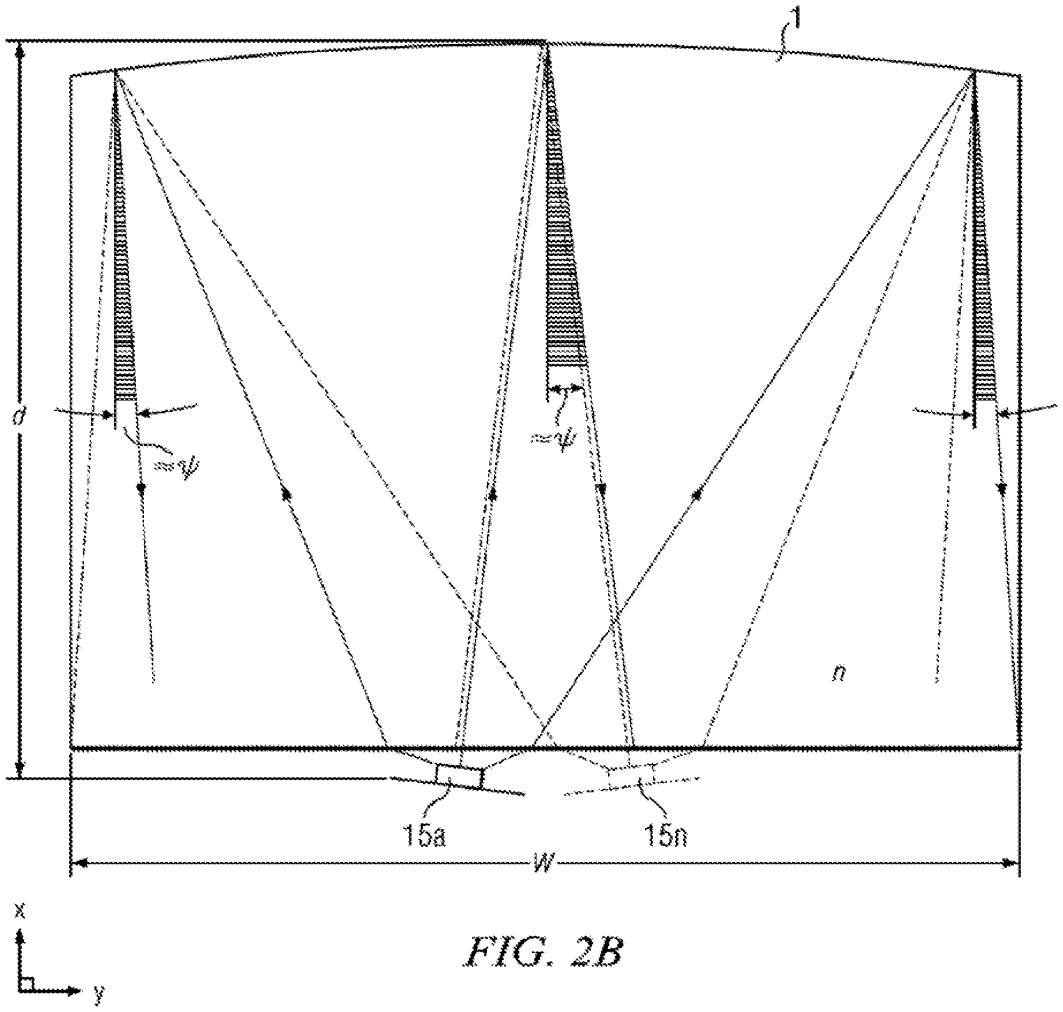

FIG. 2B

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Microsoft Corporation v. RealD Spark, LLC
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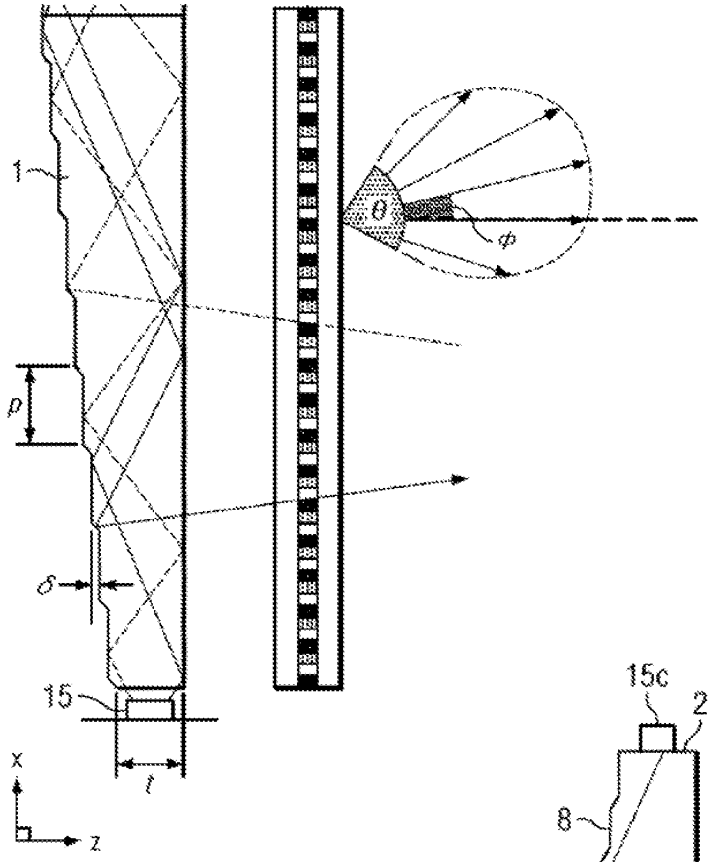

FIG. 2C

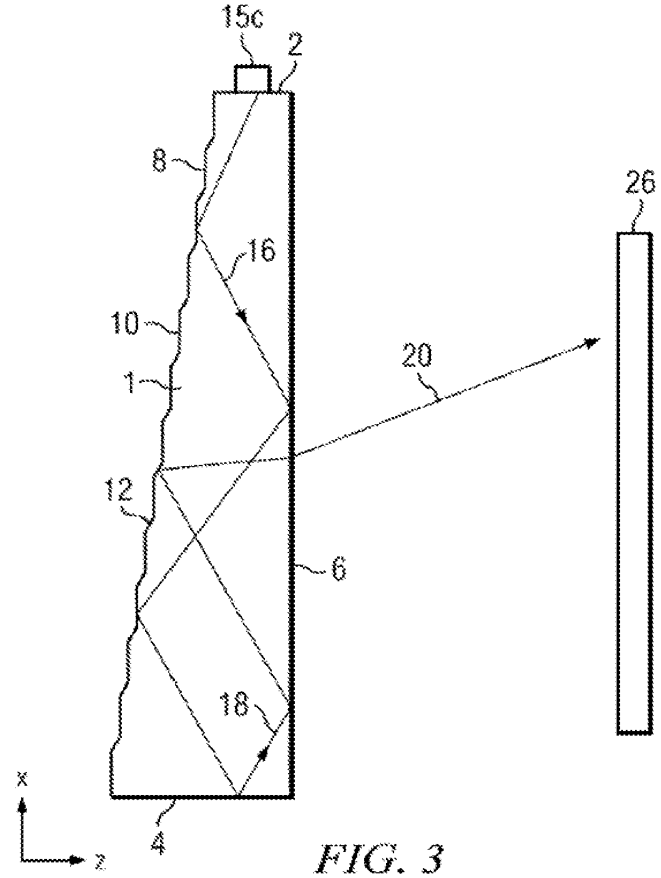

FIG. 3

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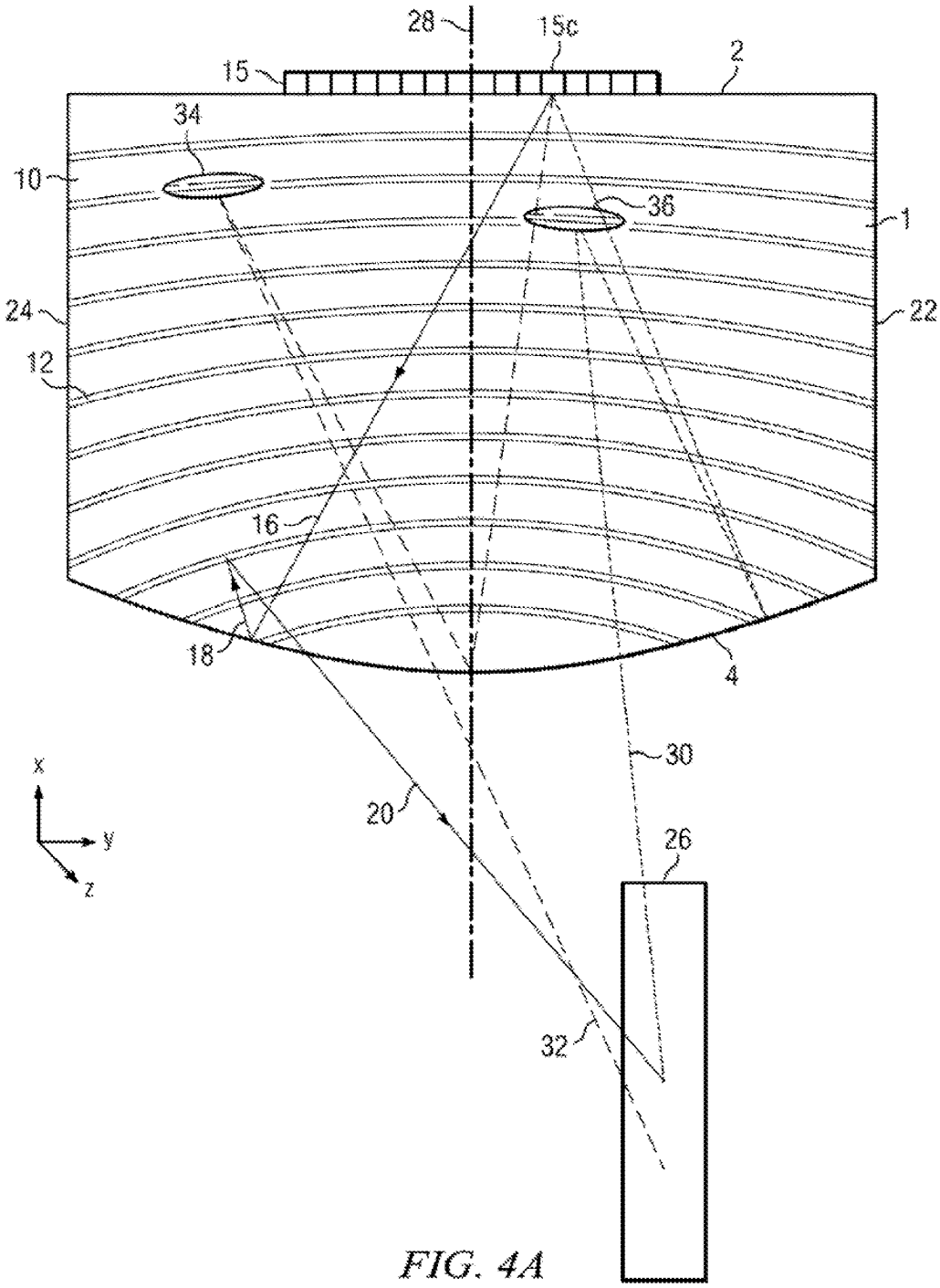

FIG. 4A

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

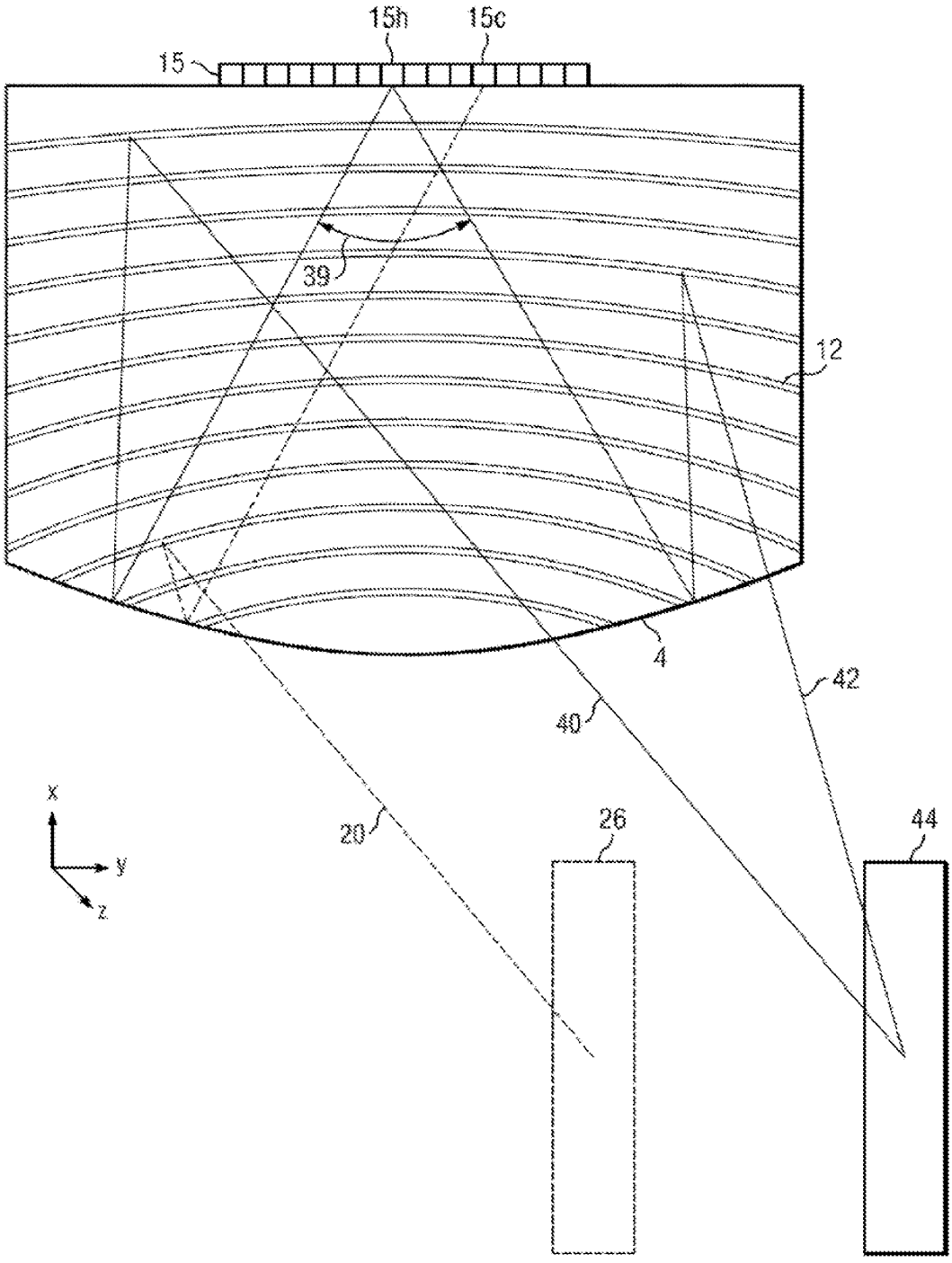

FIG. 4B

Microsoft Exhibit 1002 - Page 1686
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

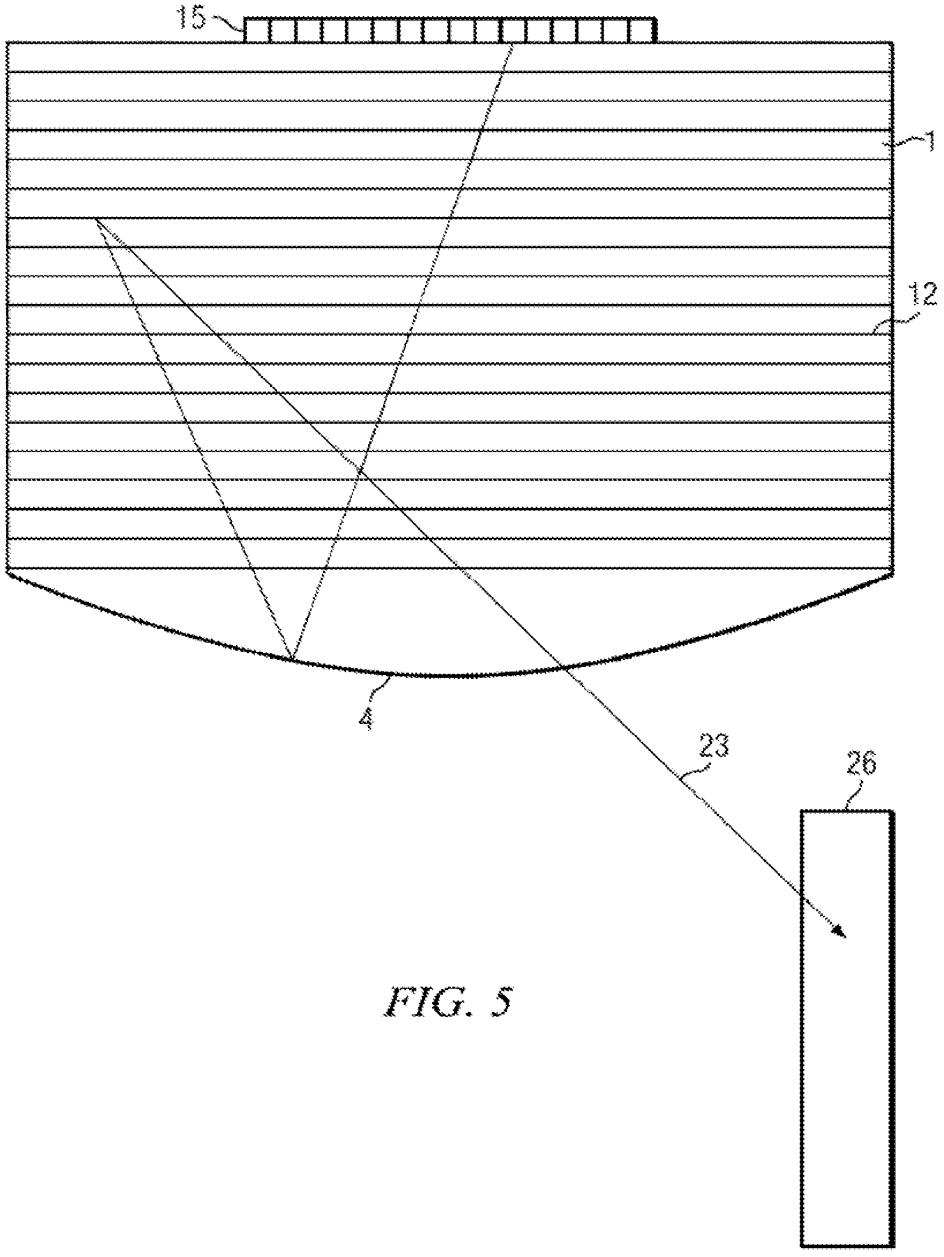

FIG. 5

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

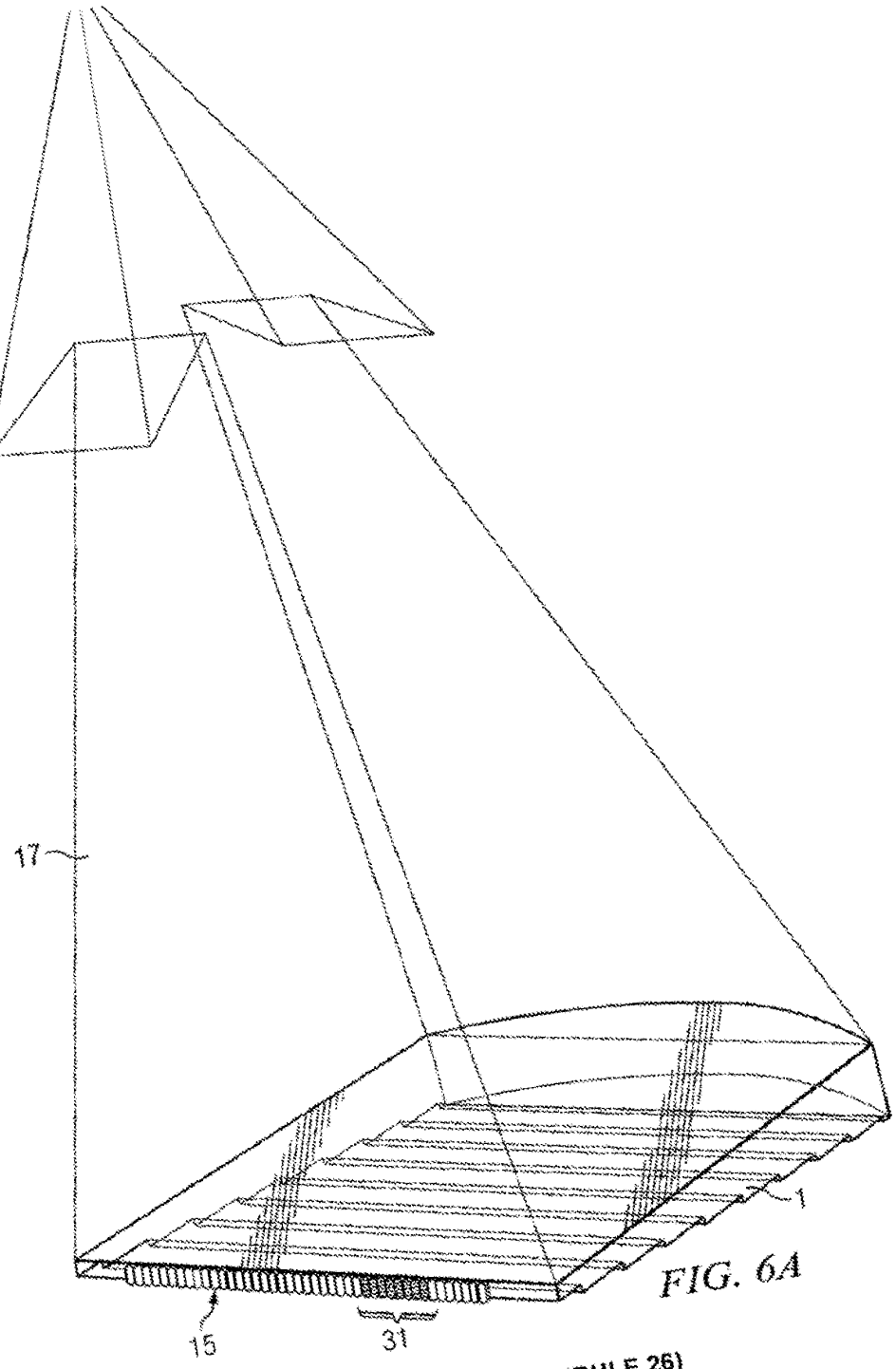

FIG. 6A

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Microsoft Corporation v. RealD Spark, LLC
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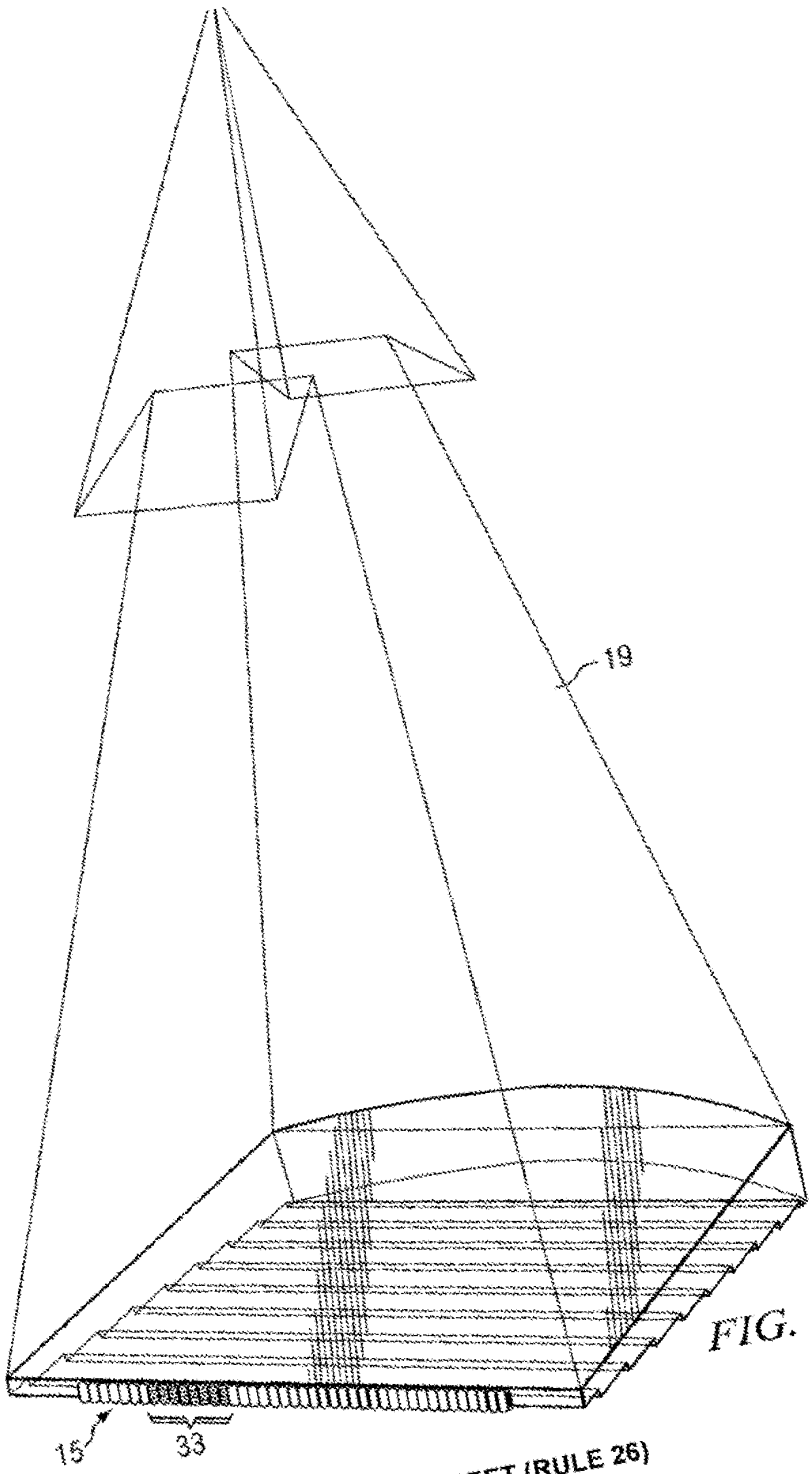

FIG. 6B

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

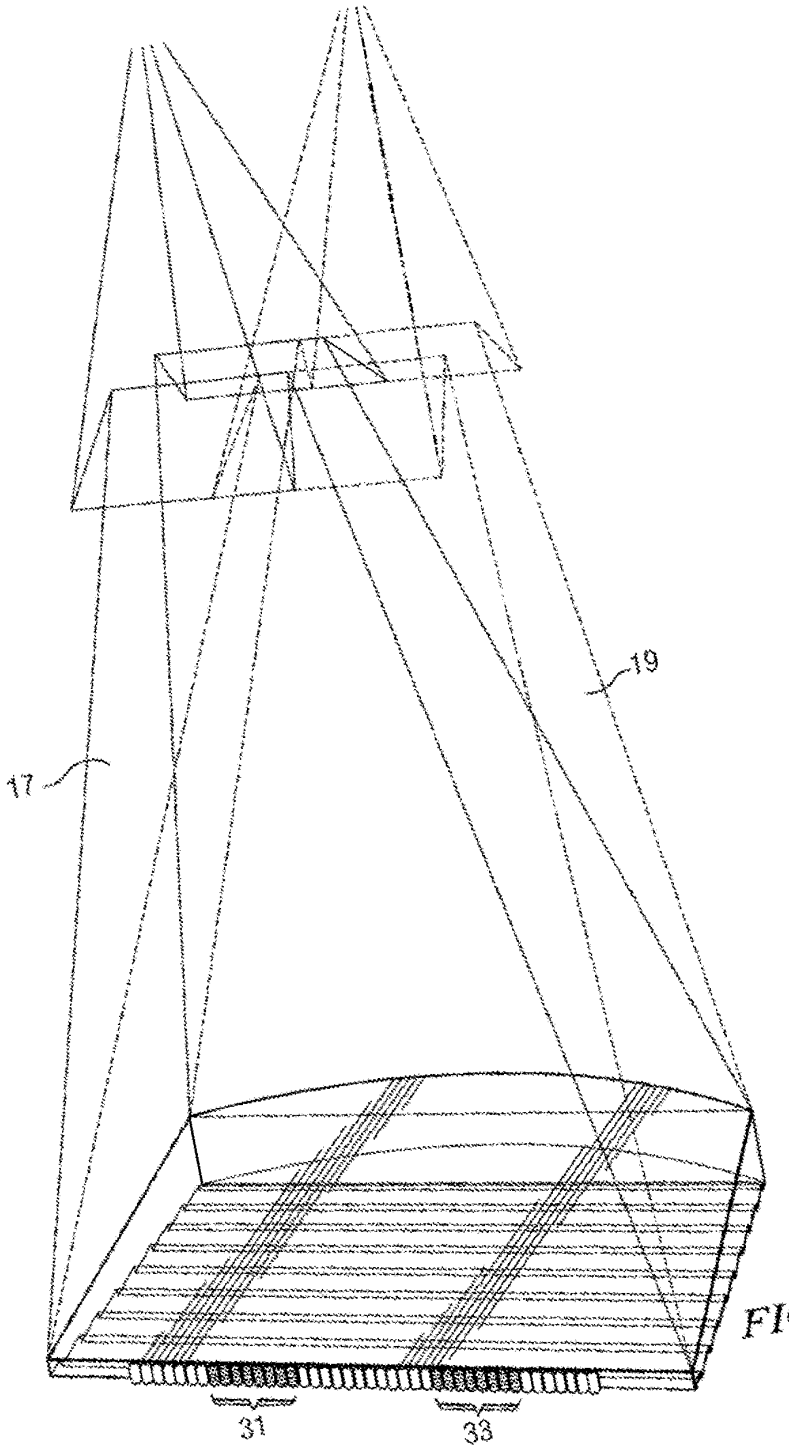

FIG. 6C

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Microsoft Corporation v. RealD Spark, LLC
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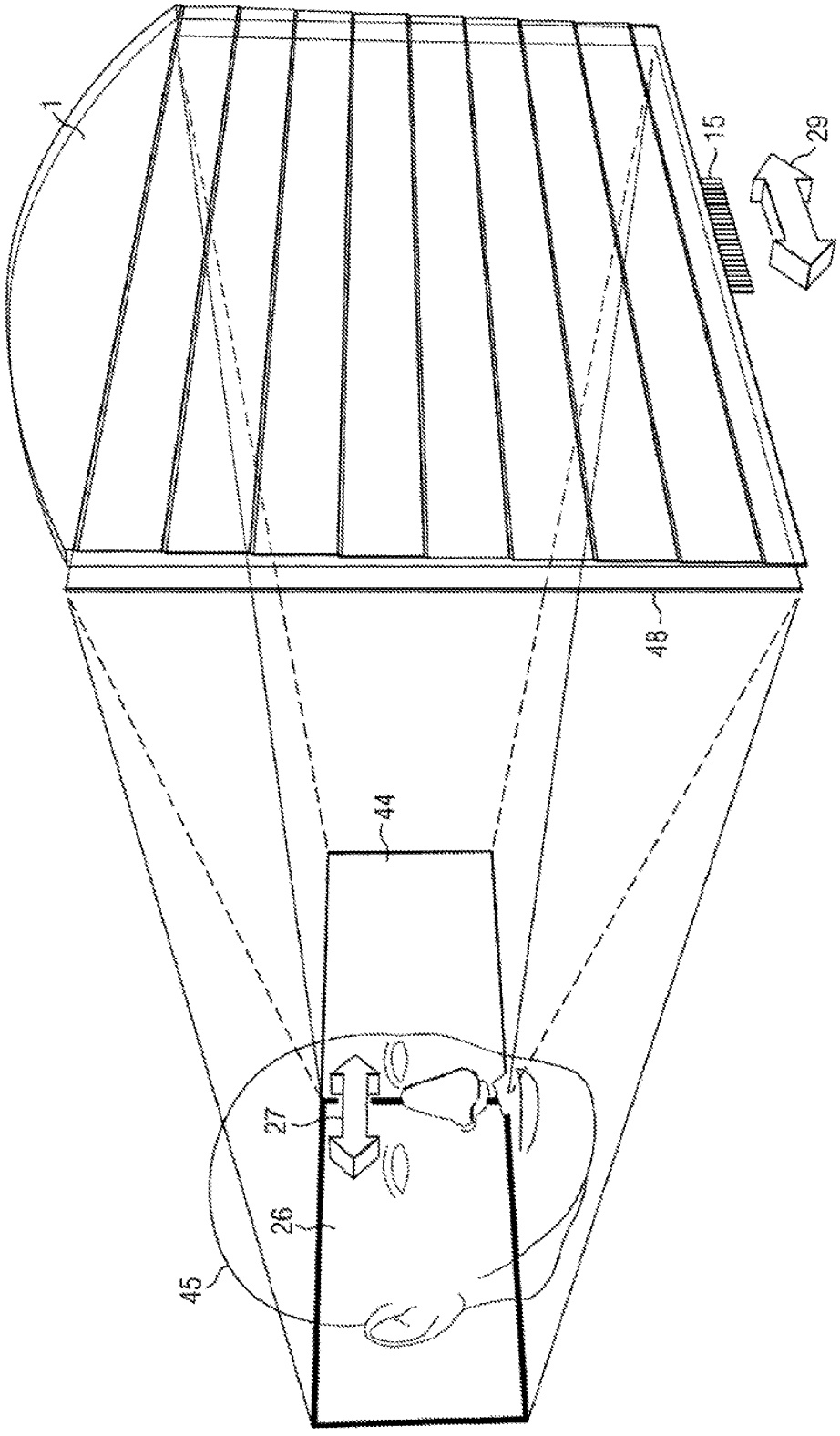

FIG. 7

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Microsoft Corporation v. RealD Spark, LLC
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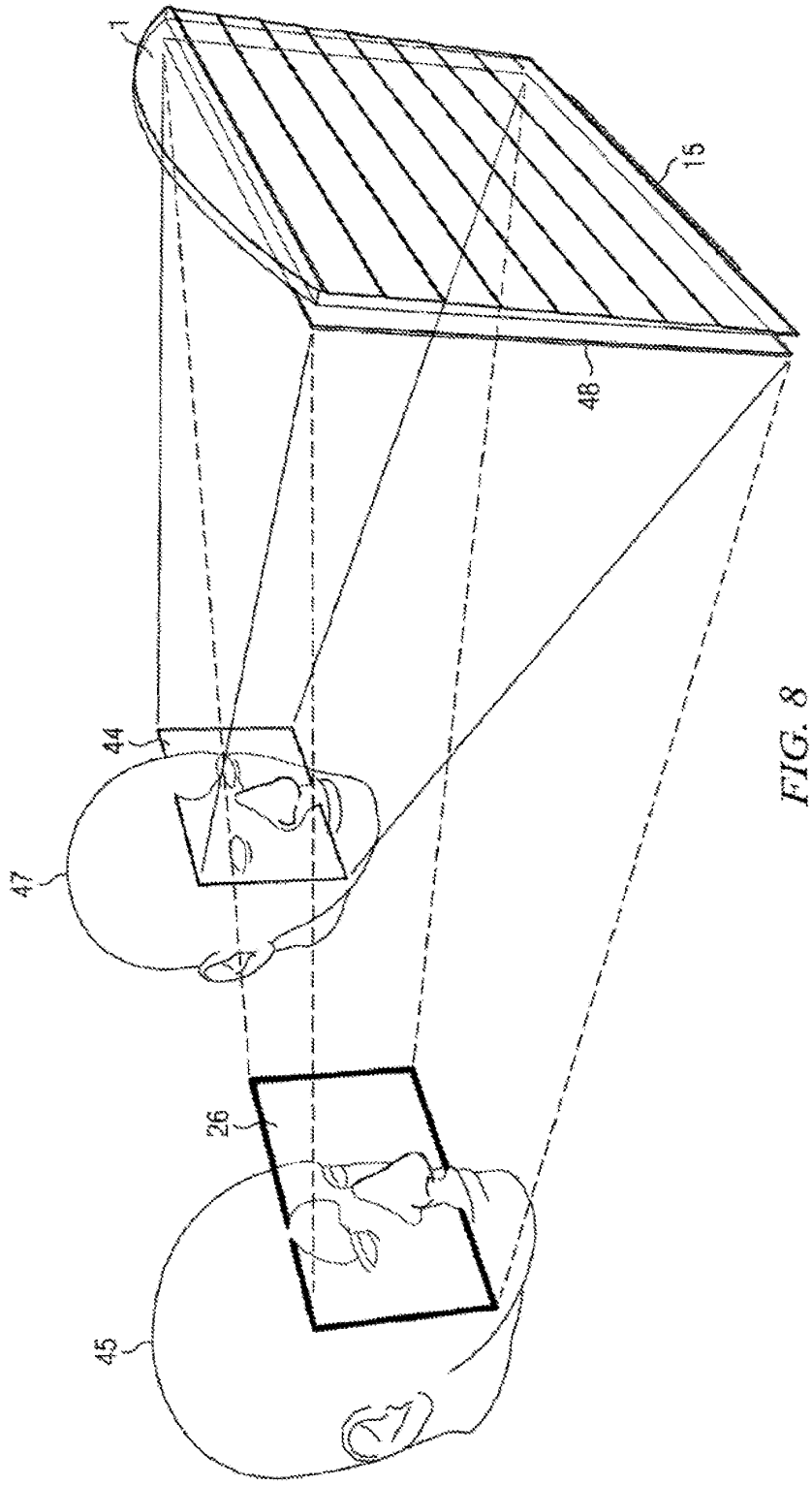

FIG. 8

Microsoft Exhibit 1002 - Page 1692
Microsoft Corporation v. RealD Spark, LLC
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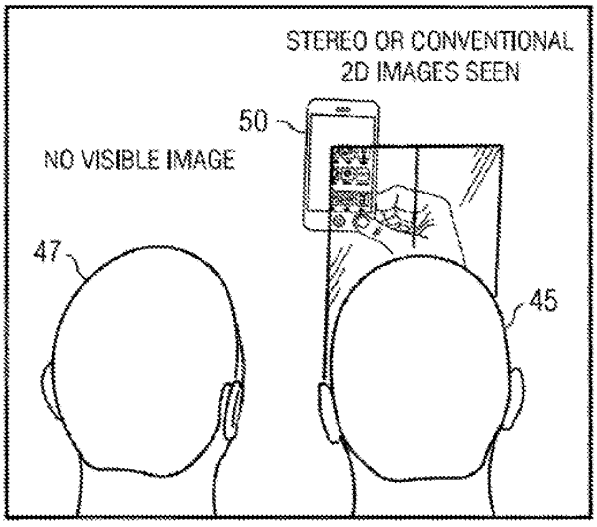

FIG. 9

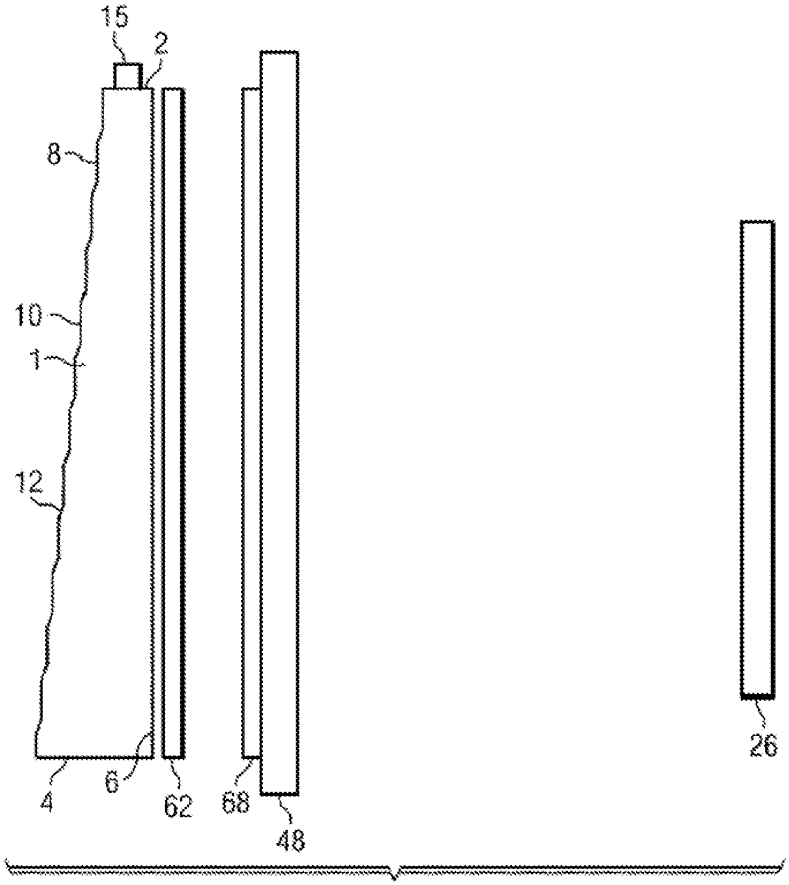

FIG. 10

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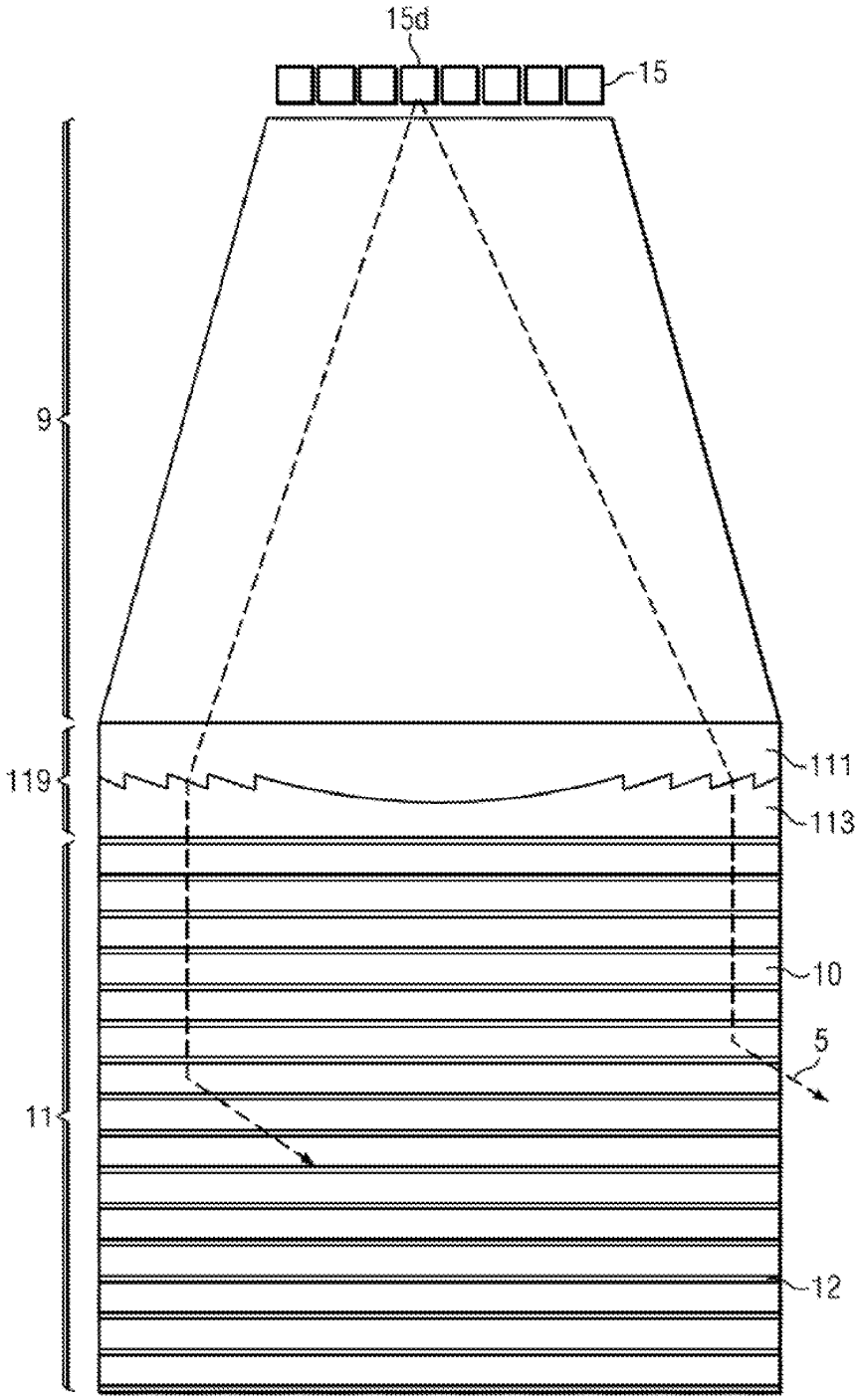

FIG. 11A

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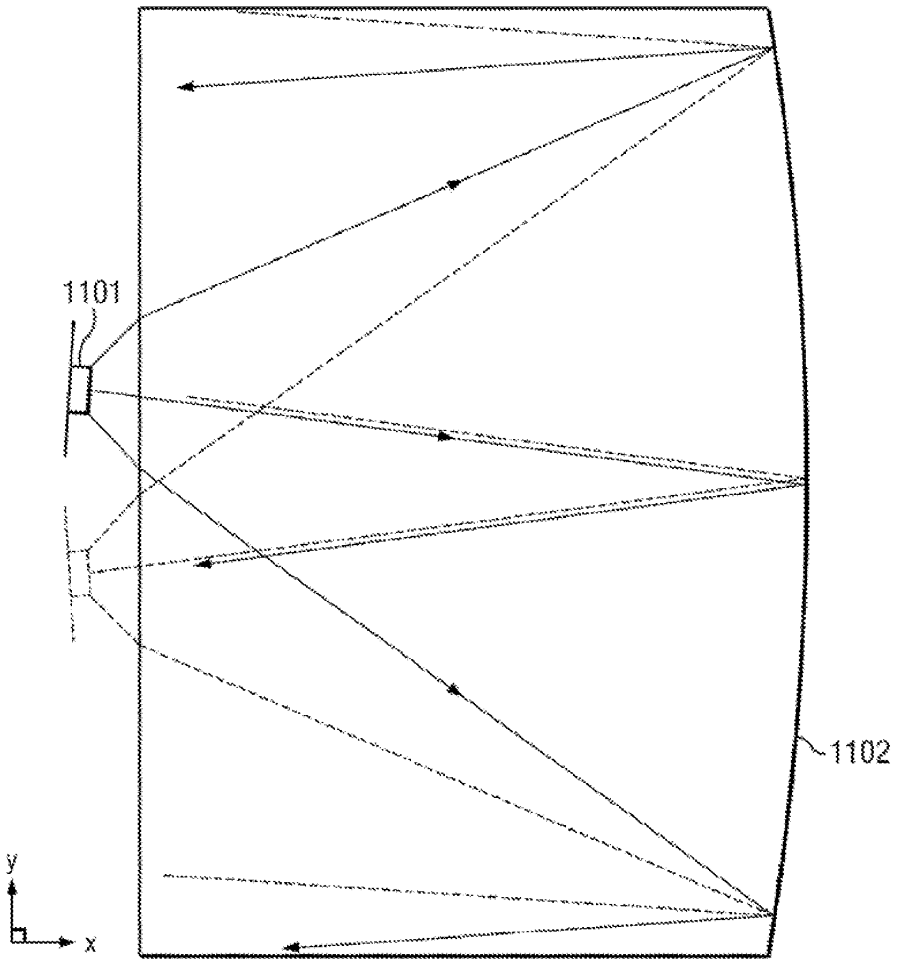

FIG. 11B

Microsoft Exhibit 1002 - Page 1695
Microsoft Corporation v. RealD Spark, LLC
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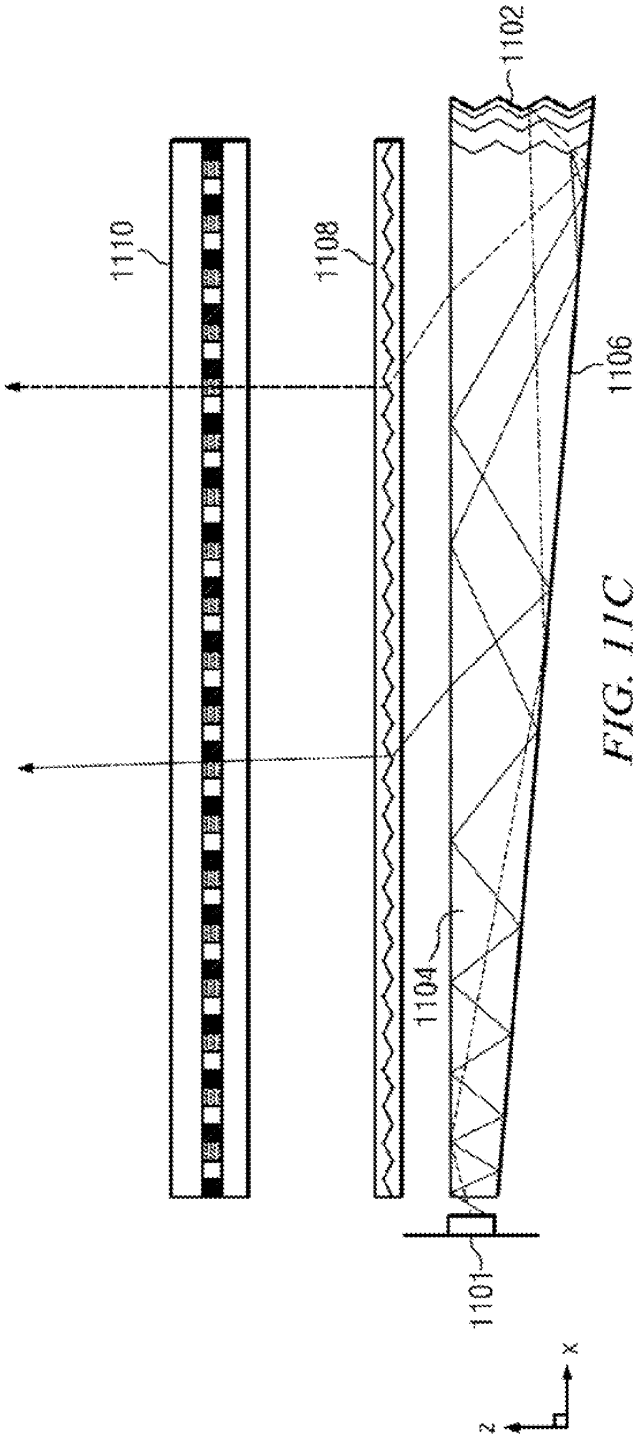

FIG. 11C

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

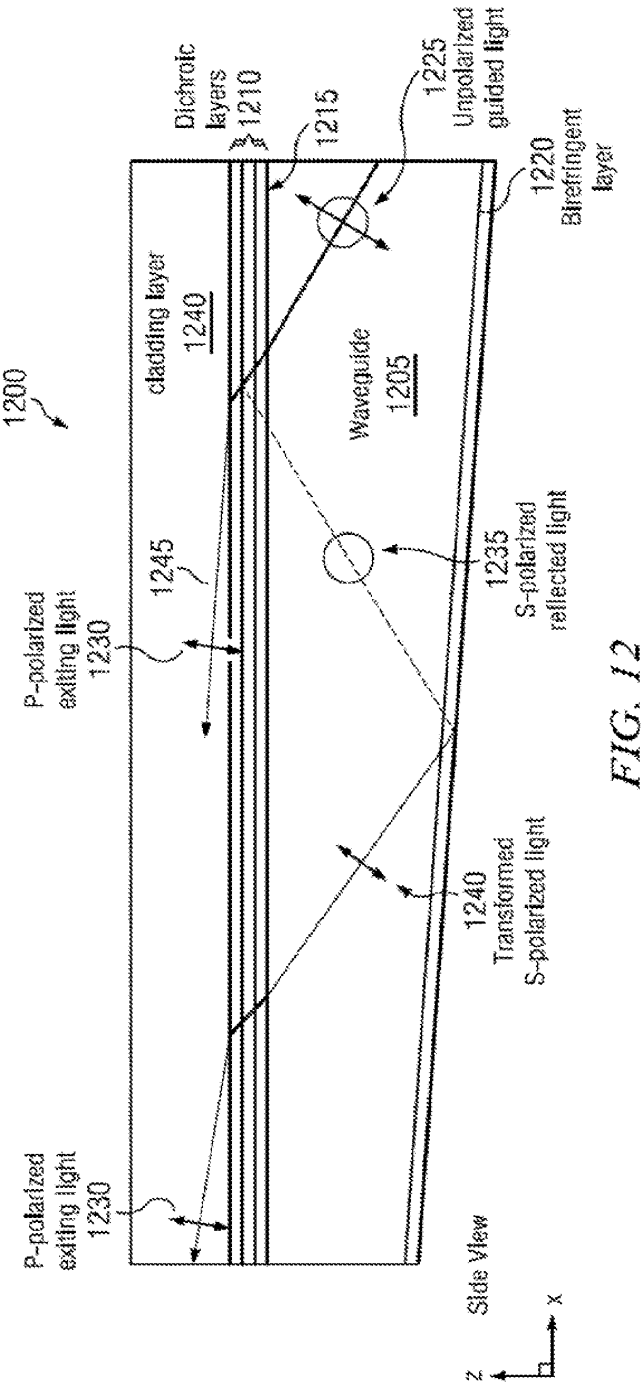

FIG. 12

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Microsoft Corporation v. RealD Spark, LLC
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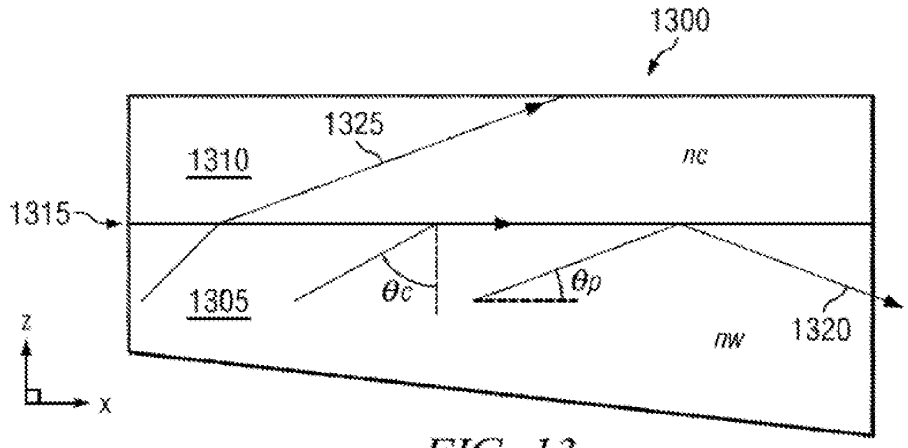

FIG. 13

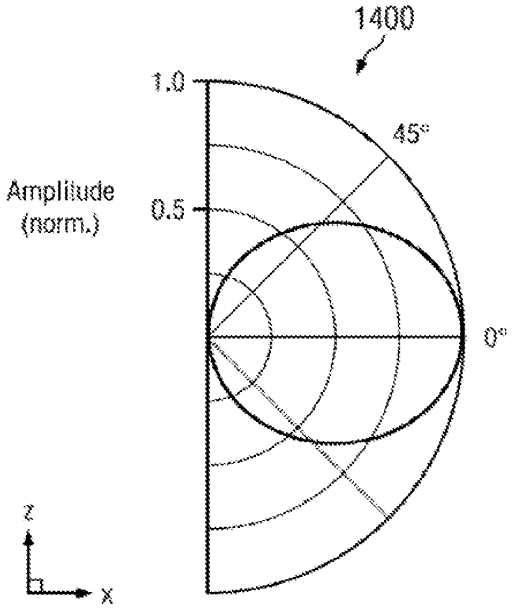

FIG. 14
(PRIOR ART)

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Microsoft Corporation v. RealD Spark, LLC
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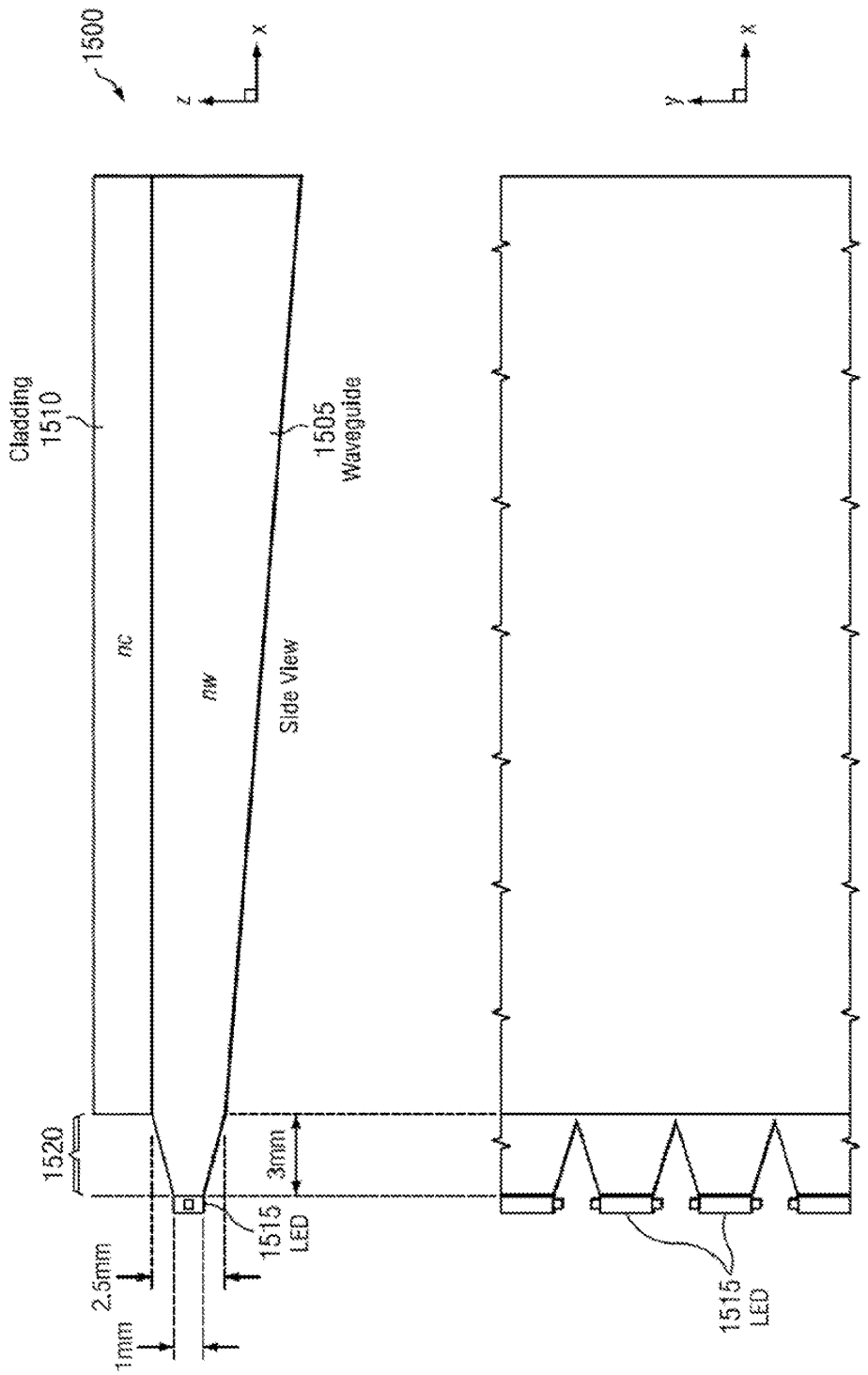

FIG. 15

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

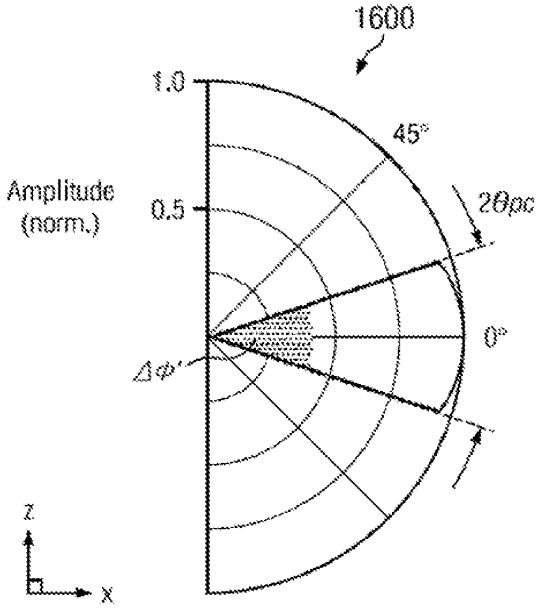

FIG. 16

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

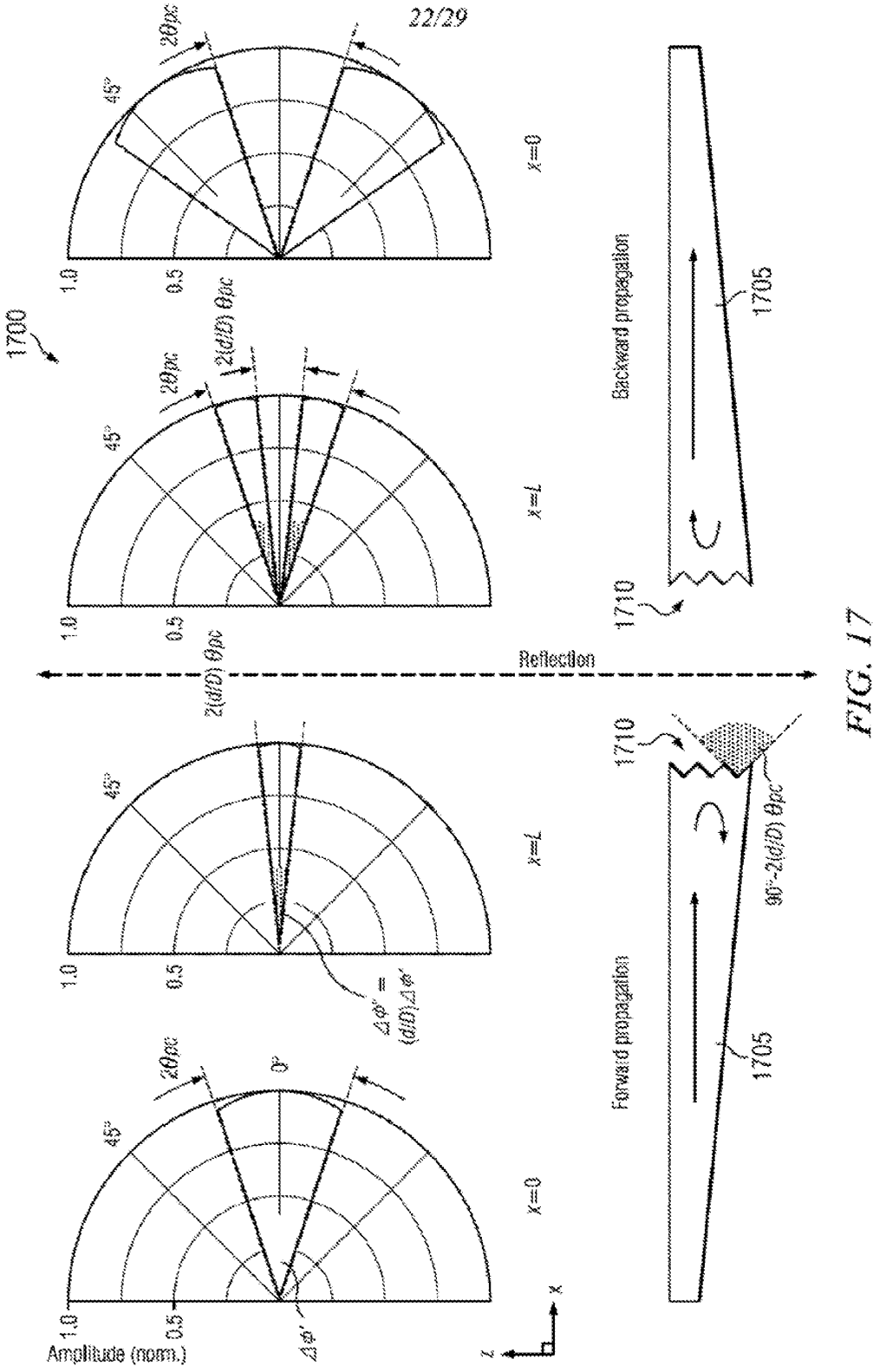

FIG. 17

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

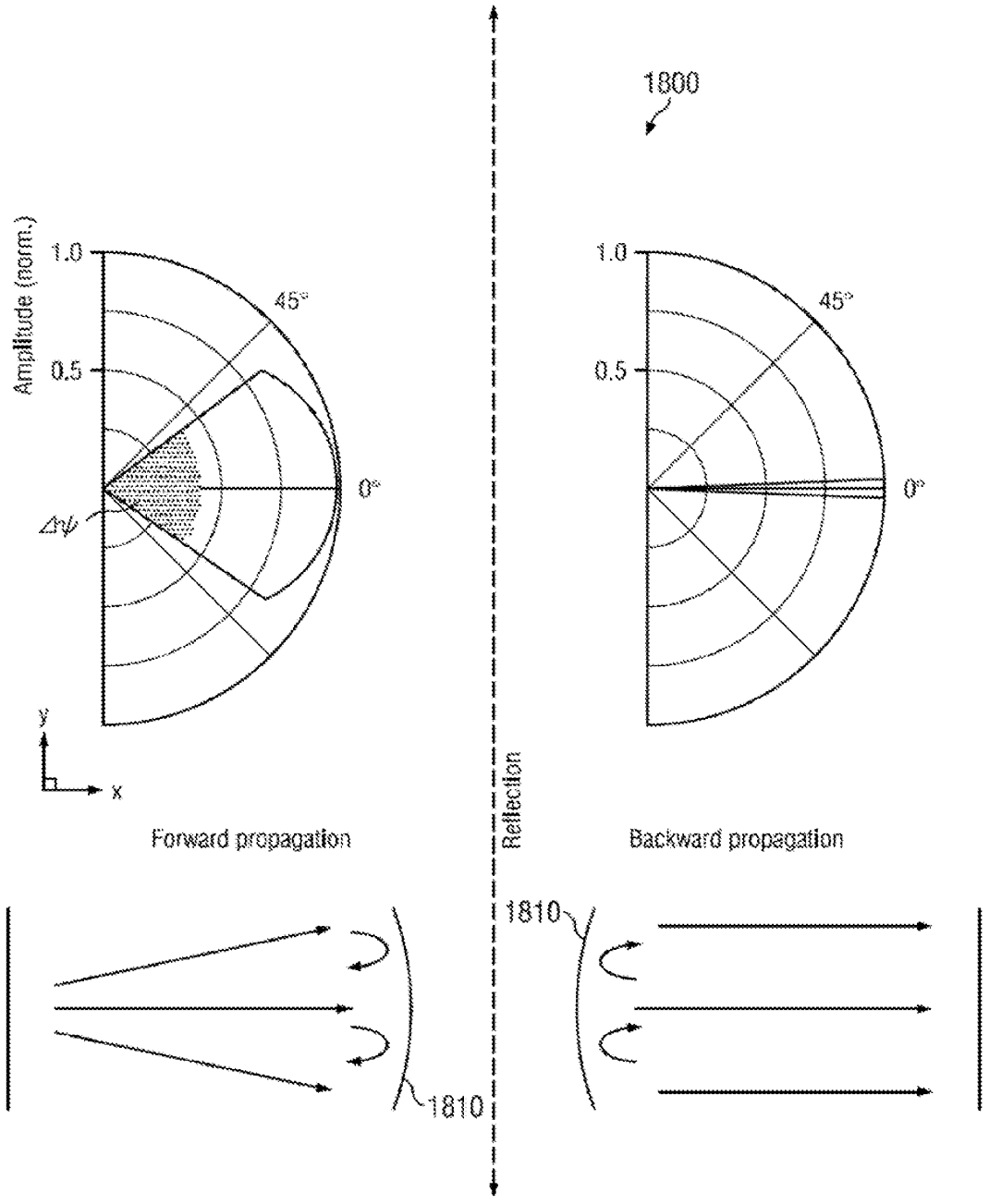

FIG. 18

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Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

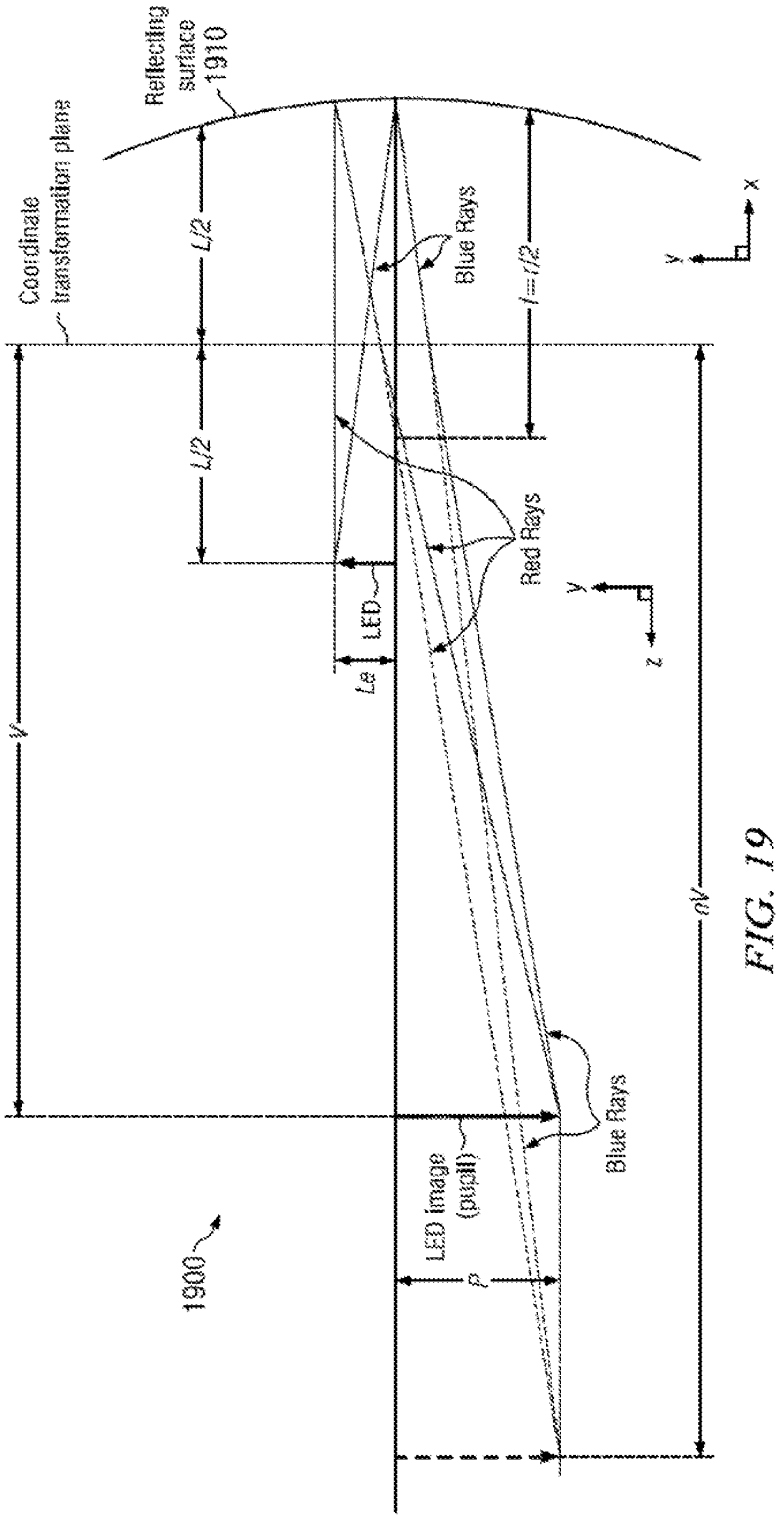

FIG. 19

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Microsoft Corporation v. RealD Spark, LLC
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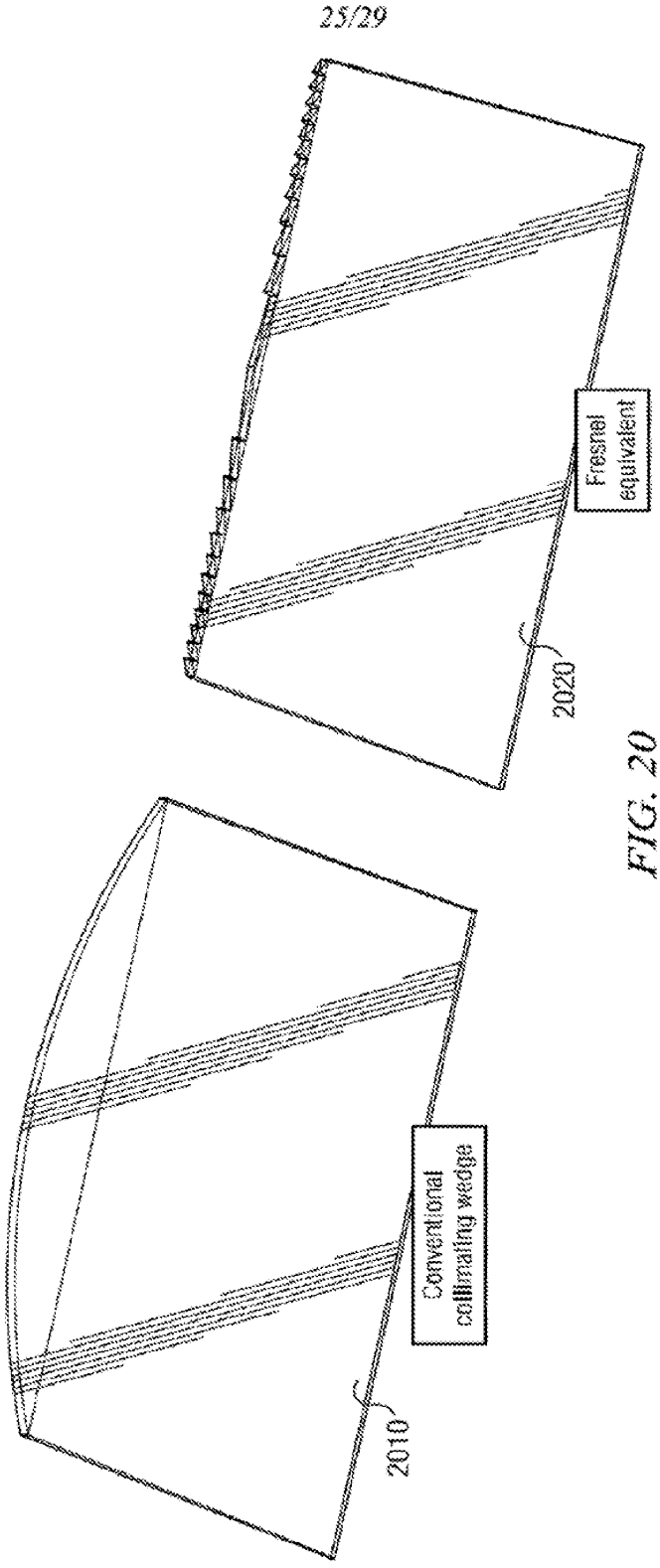

FIG. 20

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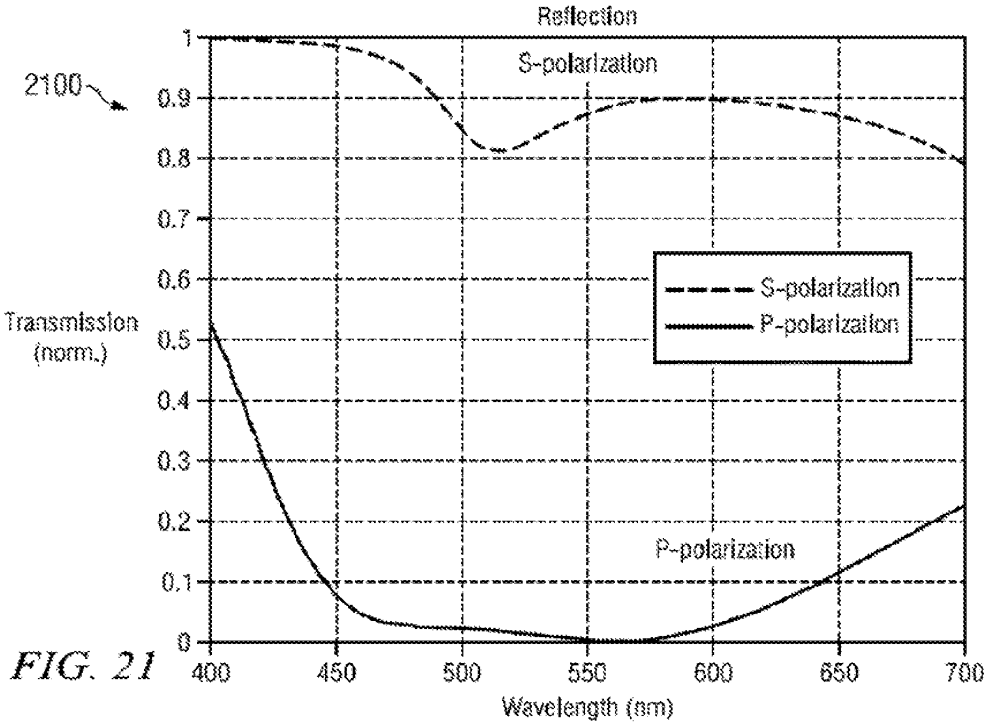

FIG. 21

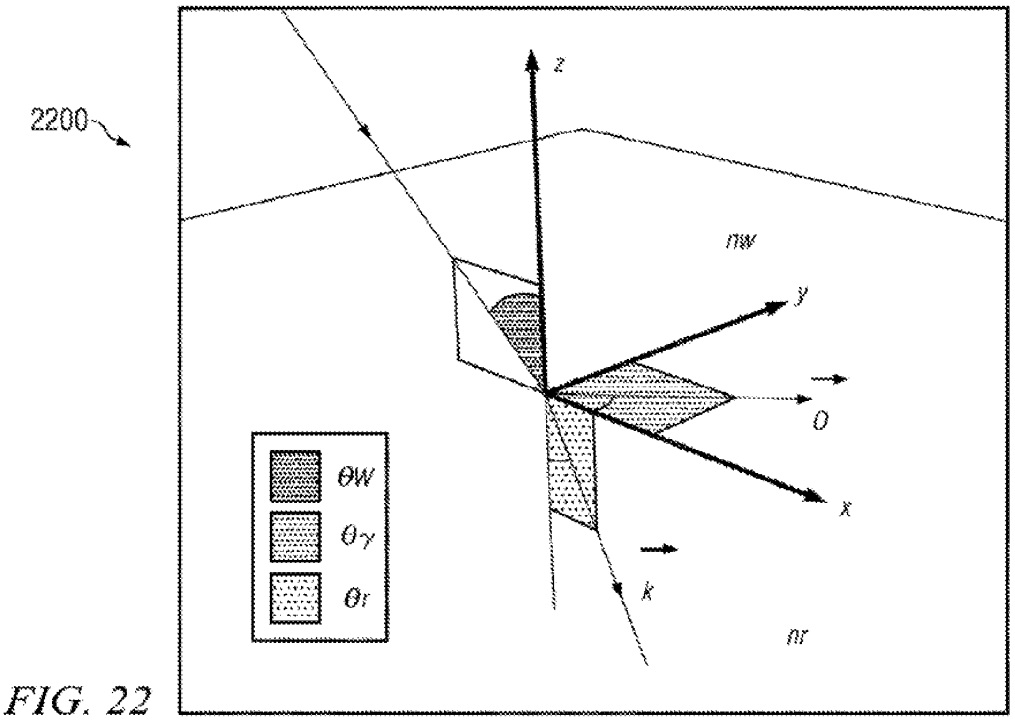

FIG. 22

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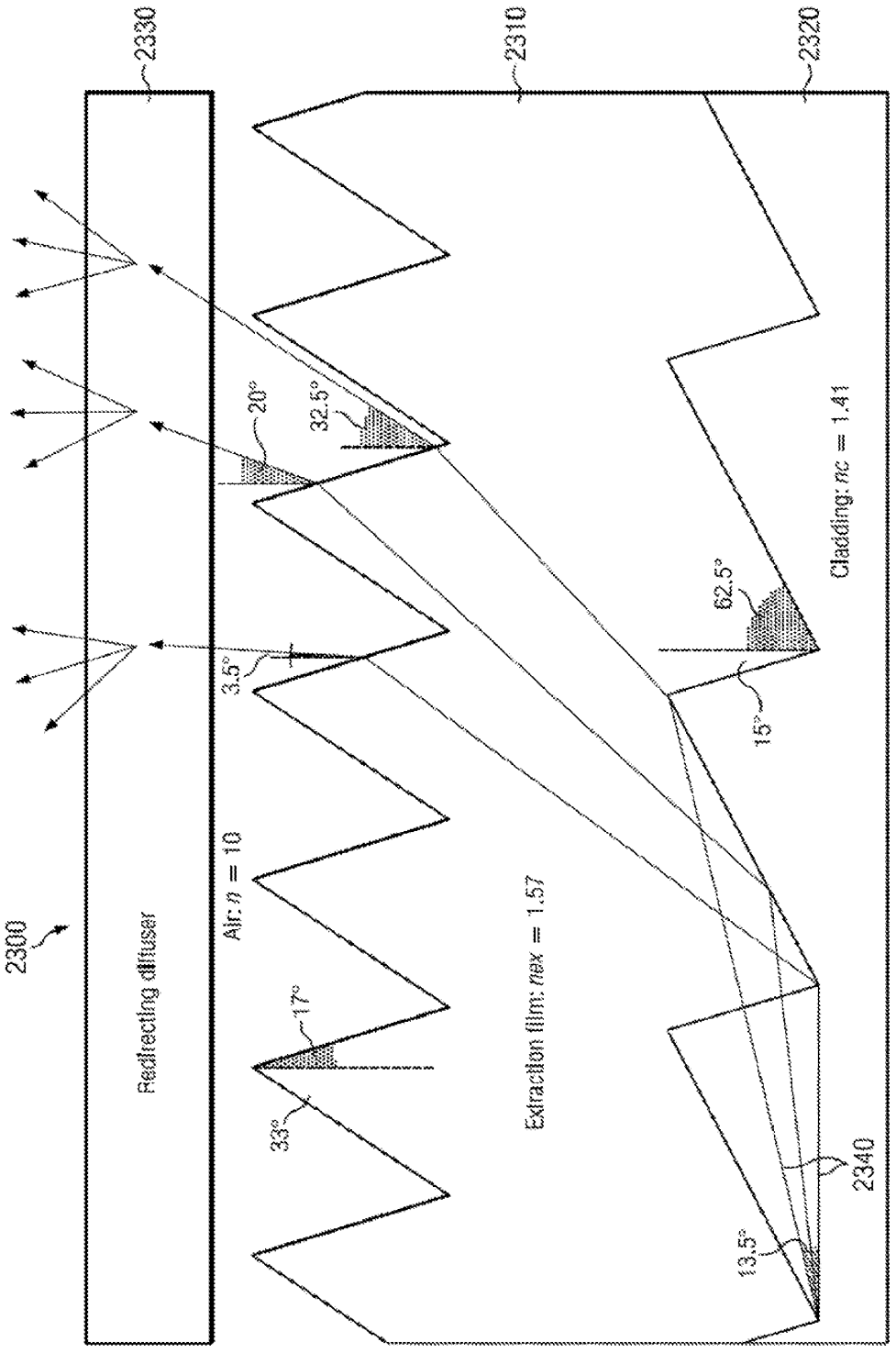

FIG. 23

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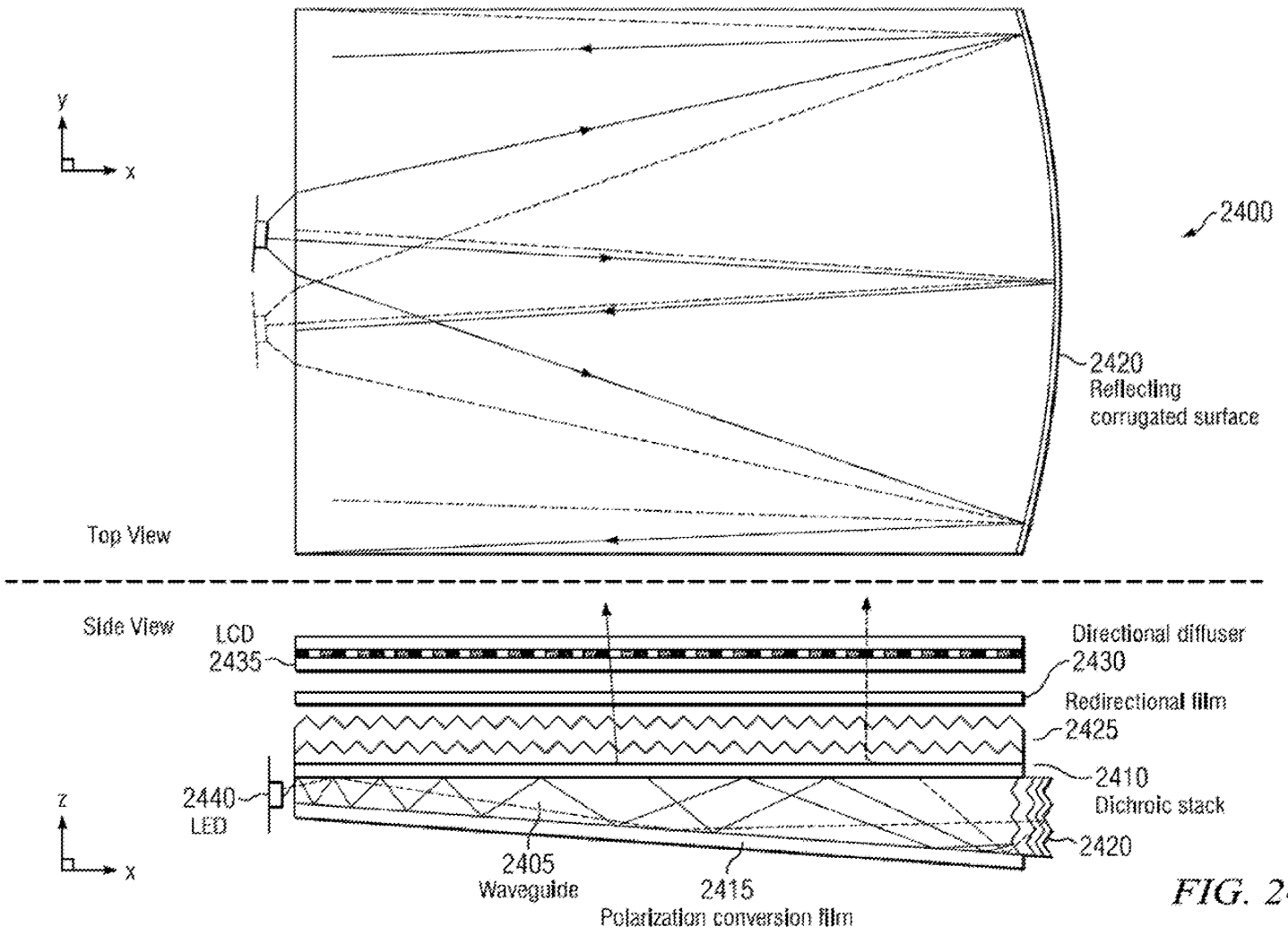
y
x
2400
2420
Reflecting
corrugated surface
Top View
Side View
LCD
2435
Directional diffuser
2430
Redirectional film
2425
2410
Dichroic stack
2420
2440
LED
z
x
2405
Waveguide
2415
Polarization conversion film

FIG. 24

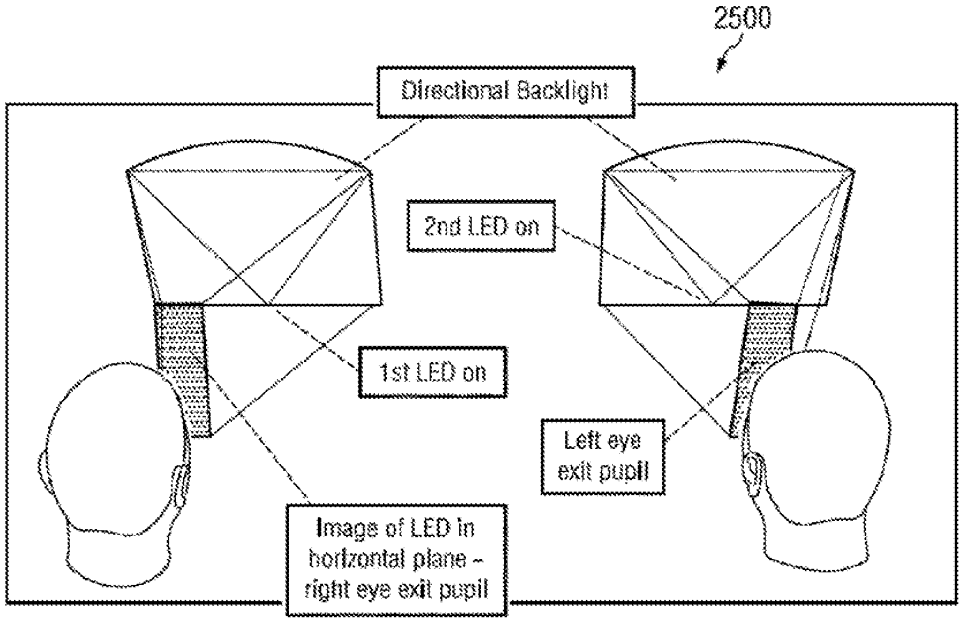

FIG. 25

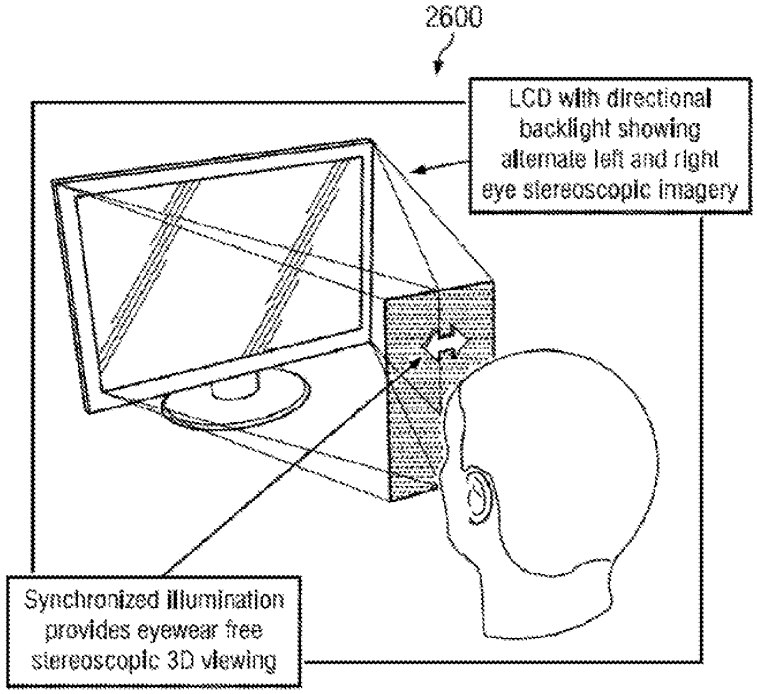

FIG. 26

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/037677

A. CLASSIFICATION OF SUBJECT MATTER

G02B 27/26(2006.01)i, G02F 1/1335(2006.01)i, G02F 1/13357(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B 27/26; H01L 33/60; F21V 7/04; F21V 8/00; G02B 6/00; G02F 1/1335

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: light guide plate, reflective polarizer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-004877 A (NIPPON LEIZ CO., LTD.) 05 January 2006 See Abstract; Figures 1, 8; Claim 1	1-30
Y	EP 2003394 A2 (ROHM AND HAAS DENMARK FINANCE A/S) 17 December 2008 See Abstract; Figure 1A; Paragraphs [0008]-[0009]	1-30
A	US 06108059 A (YANG; YING BAO) 22 August 2000 See Abstract; Figure 1; Claim 1	1-30

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 JUNE 2012 (29.06.2012)	**29 JUNE 2012 (29.06.2012)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. 82-42-472-7140

Authorized officer
KANG Sung Chul
Telephone No. 82-42-481-5666

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2012/037677

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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International Bureau

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WIPO | PCT

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H04N 19/117 (2014.01) *H04N 19/177* (2014.01)

(21) International Application Number:
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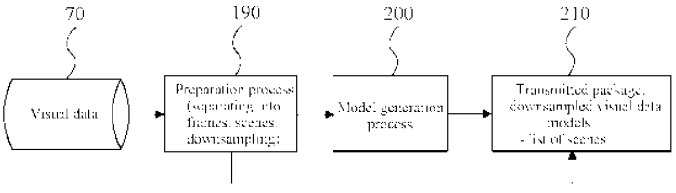
Fig. 5



(57) Abstract: A method for developing an enhancement model for low-quality visual data, the method comprising the steps of receiving one or more sections of higher-quality visual data; and training a hierarchical algorithm. The hierarchical algorithm is operable to increase the quality of one or more sections of lower-quality visual data so as to substantially reproduce the one or more sections of higher-quality visual data. The hierarchical algorithm is then outputted.

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MACHINE LEARNING FOR VISUAL PROCESSING

Field of the Invention

The present invention relates to methods for generating hierarchical algorithms using machine learning techniques to enable high quality reconstruction of lower-quality visual data.

Background

Background - Increase in quality of video and display technology

Developments in display technology have led to significant improvements in the resolution able to be displayed on display hardware, such as on televisions, on computer monitors and using video projectors. For example, television screens that are able to display "High Definition" or "HD" resolution content (typically having a resolution of 1920 x 1080 pixels) have been broadly adopted by consumers. More recently, television screens able to display Ultra High Definition or "Ultra HD" resolution content (typically having a resolution over 3840 x 2160 pixels) are starting to become more widespread.

In contrast, HD resolution video content is only now becoming commonplace and most legacy content is only available at either Digital Versatile Disc Video (or "DVD-Video") resolution (typically having a resolution of 720 x 586 pixels or 720 x 480 pixels) or Standard Definition or "SD" resolution (where the video content only has a resolution of 640 x 480 pixels). Some broadcast channels are limited to SD resolutions. Video-streaming services can be restricted to operating at DVD-Video or SD resolutions, to reduce transmission problems where consumers have limitations on available transmission bandwidth or because of a lack of legacy content at higher resolutions.

As a result, there can be a lack of sufficiently high-resolution video content for display on HD and Ultra HD television screens, for both current video content as well as for legacy video content and video streaming services. Also, over time mobile devices such as mobile 'phones and tablet computers with increasingly larger and higher-resolution screens are being produced and adopted by users. Further, current video content, being output at HD resolutions, is already at a significantly lower resolution than can be displayed by the latest consumer displays operating at, for example, Ultra HD

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resolutions. To provide sufficiently immersive virtual reality (or "VR") experiences, display technology needs to be sufficiently high resolution even for smaller screen sizes.

The user experience of having to display content that has significantly lower resolution than the user's default screen/display resolution is not optimal.

Background - Growth in data transmission and network limitations

The amount of visual data being communicated over data networks such as the Internet has grown dramatically over time and there is increasing consumer demand for high-resolution, high quality, high fidelity visual data content, such as video streaming including, for example, video at HD and Ultra HD resolution. As a result, there are substantial challenges in meeting this growing consumer demand and high performance video compression is required to enable efficient use of existing network infrastructure and capacity.

Video data already makes up a significant fraction of all data traffic communicated over the Internet, and mobile video (i.e. video transmitted to and from mobile devices over wireless data networks such as UTMS/CDMA) is predicted to increase 13-fold between 2014 and 2019, accounting for 72 percent of total mobile data traffic by the end of that forecast period. As a result, there are substantial challenges in meeting this growing consumer demand and more efficient visual data transmission is required to enable efficient use of existing network infrastructure and capacity.

To stream video to consumers using available streaming data bandwidth, media content providers can down-sample or transcode the video content for transmission over a network at one or a variety of bitrates so that the resolution of the video can be appropriate for the bitrate available over each connection or to each device and correspondingly the amount of data transferred over the network can be better matched to the available reliable data rates. For example, a significant proportion of current consumer Internet connections are not able to reliably support continuous streaming of video at an Ultra HD resolution, so video needs to be streamed at a lower quality or lower resolution to avoid buffering delays.

Further, where a consumer wishes to broadcast or transmit video content, the uplink speeds of consumer Internet connections are typically a fraction of the download speeds and thus only lower quality or lower resolution video can typically be transmitted. In addition, the data transfer speeds of typical consumer wireless networks are another potential bottleneck when streaming video data for video at resolutions higher than HD

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resolutions or virtual reality data and content to/from contemporary virtual reality devices. A problem with reducing the resolution of a video when transmitting it over a network is that the reduced resolution video may not be at the desired playback resolution, but in some cases there is either not sufficient bandwidth or the bandwidth available is not reliable during peak times for transmission of a video at a high resolution.

Alternatively, even without reducing the original video resolution, the original video may have a lower resolution than desired for playback and so may appear at a suboptimal quality when displayed on higher-resolution screens.

Background – Video Compression Techniques

Existing commonly used video compression techniques, such as H.264 and VP8, as well as proposed techniques, such as H.265, HEVC and VP9, all generally use similar approaches and families of compression techniques. These compression techniques make a trade-off between the quality and the bit-rate of video data streams when providing inter-frame and intra-frame compression, but the amount of compression possible is largely dependent on the image resolution of each frame and the complexity of the image sequences.

To illustrate the relationship between bitrate and resolution among other factors, it is possible to use an empirically-derived formula to show how the bitrate of a video encoded with, for example the H.264 compression technique, relates to the resolution of that video:

$$\text{bitrate} \propto Q \times w \times h \times f \times m$$

where Q is the quality constant, w is the width of a video, h is the height of a video, f is the frame-rate of a video and m is the motion rank, where $m \in \{1, \ldots, 4\}$ and a higher m is used for fast-changing hard-to-predict content.

The above formula illustrates the direct relationship between the bitrate and the quality constant Q. A typical value, for example, that could be selected for Q would be 0.07 based on published empirical data, but a significant amount of research is directed to optimising a value for Q.

The above formula also illustrates the direct relationship between the bitrate and the complexity of the image sequences, i.e. variable m. The aforementioned existing video codecs focus on spatial and temporal compression techniques. The newer

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proposed video compression techniques, such as H.265, HEVC and VP9, seek to improve upon the motion prediction and intra-frame compression of previous techniques, i.e. optimising a value for m.

The above formula further illustrates a direct relationship between the bitrate and the resolution of the video, i.e. variables w and h. In order to reduce the resolution of video, several techniques exist to downscale the resolution of video data to reduce the bitrate.

As a result of the disadvantages of current compression approaches, existing network infrastructure and video streaming mechanisms are becoming increasingly inadequate to deliver large volumes of high quality video content to meet ever-growing consumer demands for this type of content. This can be of particular relevance in certain circumstances, for example in relation to live broadcasts, where bandwidth is often limited, and extensive processing and video compression cannot take place at the location of the live broadcast without a significant delay due to inadequate computing resources being available at the location.

Background – Video Upscaling Techniques

To reproduce a video at a higher resolution than that at which it has been transmitted (e.g. by a streaming service or broadcaster) or provided (e.g. on DVD or via a video download provider), various "upscaling" techniques exist to increase the resolution of video data/signals, which enhance image quality when starting from a lower resolution image or video and which produce an image or video of a higher resolution.

Referring to Figure 14, a conventional upscaling technique 1400 will now be described.

Received video data 1410 is provided into a decoder system and is, for example, a lower-resolution video encoded in a standard video format, such as an SD resolution video. This video format can be a variety of known video codecs, for example such as H.264 or VP8, but can be any video data that the system is able to decode into component frames of video.

The system then separates a first section of the video data 1410 into single frames at step 1420, i.e. into a sequence of images at the full SD resolution of the video data 1410. For some video codecs, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

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An upscaling technique 1430 is then used on one or more of the frames or sections of frames, to increase the resolution of the areas upon which it is used. The higher resolution frames are then optionally processed at step 1440 into a format suitable for output as a video. The video, being composed of higher resolution frames, will be in the form of a higher resolution video 1450 than the original video file.

For example, a basic upscaling technique that makes little attempt to enhance the quality of the video is known as nearest-neighbour interpolation. This technique simply increases the resolution of received video data by representing an original pixel of the transmitted video as multiple pixels or a "block" of pixels. The resulting effect is that the video appears pixelated and in blocks.

Other less basic upscaling techniques use the existing video data to estimate unknown intermediate pixels between known pixel values in order to increase the resolution with a less noticeable loss in quality, these techniques generally known by the term interpolation, these techniques typically factoring into account a weighted average of known pixels in the vicinity of each unknown intermediate pixel or fit to a curve or line to surrounding values and interpolate to the mid-point along the curve or line (e.g. bicubic or bilinear interpolation). Typically, such upscaling techniques determine values for the additional pixels required to create a higher resolution image by averaging neighbouring pixels, which creates a blurring effect or other visual artefacts such as "ringing" artefacts. Most upscaling techniques use interpolation-based techniques to produce higher-resolution versions of received video data. Various methods of interpolation are possible and well documented in the prior art in relation to video or image enhancement.

Various methods of interpolation are possible and well documented in the prior art in relation to video or image enhancement. There are many problems with conventional upscaling techniques. Upscaling techniques that reduce jagged edges tend to introduce more blur to an up-scaled video, for example, while upscaling techniques that reduce "halos" or "ringing" artefacts tend to make an up-scaled video less sharp. Further, conventional upscaling techniques are not content-aware or adaptive. Fundamentally, conventional upscaling techniques are limited by the Nyquist-Shannon sampling theorem.

As a result of the disadvantages of current upscaling techniques, the quality of video data that has been "up-scaled" to a higher resolution than that at which it is stored or transmitted can be inadequate or non-optimal for its intended function.

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Background – Super Resolution Techniques For Enhancing Images

Super resolution techniques are techniques that can be described as recovering new high-resolution information that is not explicitly present in low-resolution images.

Super resolution techniques have been developed for many different applications, such as for satellite and for aerial imaging and medical image analysis for example. These applications start with low-resolution images where the higher-resolution image is not available or is possibly unknowable, and by using super resolution techniques it is possible to make substantial enhancements to the resolution of such low-resolution images.

Super resolution techniques allow for the creation of one or more high-resolution images, typically from one or more low-resolution images. Typically, super resolution is applied to a set or series of low-resolution images of the same scene and the technique attempts to reconstruct a higher-resolution image of the same scene from these images.

Super resolution techniques fall predominantly into one of two main fields; optical super resolution techniques and geometrical super resolution techniques. Optical super resolution techniques allow an image to exceed the diffraction limit originally placed on it, while geometrical super resolution techniques increase the resolution from digital imaging sensors. In the field of image resolution enhancement, geometrical super resolution seems to be the predominant technique.

Further, super resolution approaches are usually split into learning- or example-based approaches and interpolation-based (multi-frame) approaches. Example based super resolution techniques are generally accepted to be a superior technique to enhance image quality.

One specific super resolution technique is termed multi-exposure image noise reduction. This technique takes the average of many exposures in order to remove unwanted noise from an image and increase the resolution.

Another super resolution technique employed is sub-pixel image localisation, which involves calculating the 'centre of gravity' of the distribution of light over several adjacent pixels and correcting blurring accordingly. However, this technique relies on the assumption that all light in the image came from the same source, which is not always a correct assumption.

Background – Machine Learning Techniques

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Machine learning is the field of study where a computer or computers learn to perform classes of tasks using the feedback generated from the experience or data gathered that the machine learning process acquires during computer performance of those tasks.

Typically, machine learning can be broadly classed as supervised and unsupervised approaches, although there are particular approaches such as reinforcement learning and semi-supervised learning which have special rules, techniques and/or approaches.

Supervised machine learning is concerned with a computer learning one or more rules or functions to map between example inputs and desired outputs as predetermined by an operator or programmer, usually where a data set containing the inputs is labelled.

Unsupervised learning is concerned with determining a structure for input data, for example when performing pattern recognition, and typically uses unlabelled data sets.

Reinforcement learning is concerned with enabling a computer or computers to interact with a dynamic environment, for example when playing a game or driving a vehicle.

Various hybrids of these categories are possible, such as "semi-supervised" machine learning where a training data set has only been partially labelled.

For unsupervised machine learning, there is a range of possible applications such as, for example, the application of computer vision techniques to image processing or video enhancement. Unsupervised machine learning is typically applied to solve problems where an unknown data structure might be present in the data. As the data is unlabelled, the machine learning process is required to operate to identify implicit relationships between the data for example by deriving a clustering metric based on internally derived information. For example, an unsupervised learning technique can be used to reduce the dimensionality of a data set and attempt to identify and model relationships between clusters in the data set, and can for example generate measures of cluster membership or identify hubs or nodes in or between clusters (for example using a technique referred to as weighted correlation network analysis, which can be applied to high-dimensional data sets, or using k-means clustering to cluster data by a measure of the Euclidean distance between each datum).

Semi-supervised learning is typically applied to solve problems where there is a partially labelled data set, for example where only a subset of the data is labelled. Semi-supervised machine learning makes use of externally provided labels and objective

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functions as well as any implicit data relationships.

When initially configuring a machine learning system, particularly when using a supervised machine learning approach, the machine learning algorithm can be provided with some training data or a set of training examples, in which each example is typically a pair of an input signal/vector and a desired output value, label (or classification) or signal. The machine learning algorithm analyses the training data and produces a generalised function that can be used with unseen data sets to produce desired output values or signals for the unseen input vectors/signals. The user needs to decide what type of data is to be used as the training data, and to prepare a representative real-world set of data. The user must however take care to ensure that the training data contains enough information to accurately predict desired output values without providing too many features (which can result in too many dimensions being considered by the machine learning process during training, and could also mean that the machine learning process does not converge to good solutions for all or specific examples). The user must also determine the desired structure of the learned or generalised function, for example whether to use support vector machines or decision trees.

The use of unsupervised or semi-supervised machine learning approaches are sometimes used when labelled data is not readily available, or where the system generates new labelled data from unknown data given some initial seed labels.

Current training approaches for most machine learning algorithms can take significant periods of time, which delays the utility of machine learning approaches and also prevents the use of machine learning techniques in a wider field of potential application.

Background – Machine Learning & Image Super Resolution

To improve the effectiveness of some super resolution techniques, it is possible to incorporate machine learning, otherwise termed a "learned approach", into the image super resolution techniques described above.

For example, one machine learning approach that can be used for image enhancement, using dictionary representations for images, is a technique generally referred to as dictionary learning. This approach has shown effectiveness in low-level vision tasks like image restoration.

When using dictionary learning, the representation of a signal is given as a linear combination of functions drawn from a collection of atoms referred to as a dictionary. For

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example, a given signal y can be represented as:

$$y = \alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_n x_n$$

where $x_1, \ldots, x_n$ are the atoms of a dictionary of size n and $\alpha_1, \ldots \alpha_n$ are coefficients such that $\|\alpha\|_0 < \lambda$, where λ is the sparsity constraint, for example where $\lambda = 3$ no more than three coefficients can be non-zero. The atoms have the same dimensionality as the signal y so, while it is possible to have an atom x_i that is identical to y, a dictionary of simple atoms can usually be used to reconstruct a wide range of different signals.

In theory, at least k orthogonal atoms are required to fully reconstruct signals in k-dimensional space. In practice, however, improved results are achieved through using an over-complete dictionary where there are $n > k$ atoms and these atoms do not have to be orthogonal to one another.

A complete dictionary means that the number of dictionary atoms is the same as the dimensionality of the image patches and that the dictionary atoms are linearly independent (i.e. all orthogonal to each other and can represent the entire, or complete, dimensional space), so where 16 x 16 atoms represent 16 x 16 image patches, the dictionary is complete if it has 16 x 16 = 256 atoms. If more atoms than this are present in the dictionary, then the dictionary becomes over-complete.

An example of an over-complete dictionary is shown in Figure 1, where a 16 x 16 pixel patch is represented by a linear combination of 16 x 16 dictionary atoms 5 that is drawn from the collection of atoms that is the dictionary 1. It is noted that the atoms are not selected locally within the dictionary, but instead are chosen as the linear combination that best approximates the signal patch for a maximum number of atoms allowed and irrespective of their location within the dictionary. Without a constraint that the atoms must be orthogonal to one another, larger dictionaries than the signal space that the dictionary is intended to represent are created.

Over-complete dictionaries are used because they provide better reconstructions, but at the cost of needing to store and transmit all of the new dictionaries and representations created during the dictionary learning process. In comparison with a predetermined library of representations, a significantly increased amount of data is created as a result of dictionary learning because it generates a data set significantly larger than the basis set in a predetermined library of representations and the atoms are not all orthogonal to one another.

In dictionary learning, where sufficient representations are not available in an

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existing library of representations (or there is no library available), machine learning techniques are employed to tailor dictionary atoms such that they can adapt to the image features and obtain more accurate representations. Each new representation is then transferred along with the video data to enable the representation to be used when recreating the video for viewing.

The transform domain can be a dictionary of image atoms, which can be learnt through a training process known as dictionary learning that tries to discover the correspondence between low-resolution and high-resolution sections of images (or "patches"). Dictionary learning uses a set of linear representations to represent an image and, where an over-complete dictionary is used, a plurality of linear representations can be used to represent each image patch to increase the accuracy of the representation.

When using dictionary learning based super resolution techniques, there is a need for two dictionaries: one for the low-resolution image and a separate dictionary for the high-resolution image. To combine super resolution techniques with dictionary learning, reconstruction models are created to enhance the image based on mapping the coefficients of the low-resolution dictionary to coefficients in the high-resolution dictionary. Various papers describe this, including "On Single Image Scale-Up Using Sparse-Representations" by R. Zeyde et al and published in 2010, "Image super-resolution via sparse representation" by J. Yang and published in 2010, and "Coupled Dictionary Training for Image Super-Resolution" by J. Yang et al and published in 2012, which are incorporated by reference.

A disadvantage of using dictionary learning based super resolution techniques on low-resolution images to attempt to recreate the high-resolution image is the need for two dictionaries, one for the low-resolution image and a separate dictionary for the high-resolution image. It is possible to have a single combined dictionary, but in essence there is always in practice an explicit modelling for each resolution to enable representations to be matched between the two resolutions of image.

A further disadvantage of using dictionary learning, however, especially when used with an over-complete dictionary, is the amount of data that needs to be transferred along with the low-resolution image in order to recreate a high-resolution image from the low-resolution image.

Another disadvantage of dictionary learning approaches is that these tend to use a local patch averaging approach in the final step of reconstruction of a higher-resolution image from a lower-resolution image, which can result in unintentional smoothing in the reconstructed image.

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Another further disadvantage of dictionary learning approaches is that it is very slow and can have high memory requirements, depending on the size of the dictionary.

Background – Artefact Removal in Visual Data

Visual data artefacts and/or noise can often be introduced into visual data during processing, particularly during processing to compress visual data or during transmission of the visual data across a network. Such introduced artefacts can include blurring, pixelation, blocking, ringing, aliasing, missing data, and other marks, blemishes, defects, and abnormalities in the visual data. These artefacts in visual data can degrade the user experience when viewing the visual data. Furthermore, these artefacts in visual data can also reduce the effectiveness of visual data processing techniques, such as image super resolution, as well as other visual tasks such as image classification and segmentation, that use processed images as an input.

Lossy compression, in which a visual data is encoded using inexact approximations, is a particularly common source of artefacts. Lossy compression is often required to reduce the size of a digital image or video in order to transmit it across a network without using an excessive amount of bandwidth. High visual data compression ratios can be achieved using lossy compression, but at the cost of a reduction in quality of the original visual data and the introduction of artefacts.

The transmission of visual data across a network can itself introduce artefacts to the visual data through transmission errors between nodes in the network.

Current methods of removing artefacts (herein referred to as visual data fidelity correction) generally only correct a specific types of artefact. Examples of such techniques include deblocking oriented methods, such as Pointwise Shape-Adaptive Discrete Cosine Transform (hereafter referred to as Pointwise SA-DCT), which deal with blocking artefacts. Such techniques do not perform well, and can also introduce further artefacts as a side effect, such as the over smoothing of visual data.

Summary of Invention

Aspects and/or embodiments are set out in the appended claims. These and other aspects and embodiments are also described herein.

Certain aspects and/or embodiments seek to provide techniques for generating hierarchical algorithms that can be used, when converting original high-quality visual

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data into lower-quality visual data, to allow recreation of higher-quality visual data from the lower-quality visual data without significant loss in quality between the original high-quality visual data and the higher quality visual data.

Further aspects and/or embodiments seek to provide techniques for reconstruction and/or enhancement from lower-quality visual data to higher-quality visual data.

Other aspects and/or embodiments seek to provide techniques for machine learning.

General Training Method

According to an aspect, there is provided a method for developing an enhancement model for low-quality visual data, the method comprising the steps of: receiving one or more sections of higher-quality visual data; training a hierarchical algorithm, wherein the hierarchical algorithm is operable to increase the quality of one or more sections of lower-quality visual data to substantially reproduce the one or more sections of higher-quality visual data; and outputting the hierarchical algorithm.

Training hierarchical algorithms can allow enhancement and/or reconstruction models to be developed for enhancing visual data in at least one embodiment. In some embodiments visual data can be image data and/or video data. Furthermore, in some embodiments enhancement models can be developed to increase the accuracy of higher-quality visual data that can be reproduced from lower-quality visual data in comparison to original higher-quality visual data. In at least one embodiment, knowledge of the original visual data can allow the hierarchical algorithm to be trained (and/or developed) based on knowledge of both the original visual data and the low-quality visual data in order to train a hierarchical algorithm to substantially reproduce the original visual data from the low-quality visual data.

Optionally, the hierarchical algorithm is developed from a known initialisation.

In some embodiments, the hierarchical algorithm can be developed from a known initialisation, for example of a hierarchical function or basis. In some of these embodiments, the hierarchical function or basis can be for example haar wavelets or one or more pre-trained hierarchical algorithms or sets of hierarchical algorithms. In at least one embodiment, providing a known initialisation allows the training of hierarchical algorithms to be accelerated, and the known initialisation can be closer to the best solution especially when compared to starting from a random initialisation. In some

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embodiments, a trained hierarchical algorithm can be developed for input visual data, wherein the trained hierarchical algorithm is developed for that input data based on the selected most similar pre-trained algorithm. In at least one embodiment, the selection of the one or more most similar pre-trained algorithm(s) can be made based on one or more metrics associated with the pre-trained models when compared and/or applied to the input data. In some embodiments, metrics can be any predetermined measure of similarity or difference. In some embodiments, the most similar pre-trained algorithm can be used as a starting point for developing a trained or tailored algorithm for the input data as a tailored algorithm does not have to undergo as extensive development as needed when developing an algorithm from first principles.

Optionally, the method is performed at a first network node within a network. Furthermore, optionally the hierarchical algorithm may be transmitted to a second network node in the network.

By lowering the quality of visual data (for example by lowering the resolution of video data) in some embodiments, less data can be sent across a network from a first node to a second node in order for the second node to display the visual data from the first node. In some embodiments, the lower quality visual data together with a model to be used for reconstruction can allow for less data to be transmitted than if the original higher-quality version of the same visual data is transmitted between nodes.

Optionally, the one or more sections of lower-quality visual data are generated from the one or more sections of higher-quality visual data. Furthermore, optionally the one or more sections of lower-quality visual data may be generated from the high-quality visual data using a process comprising down-sampling.

By lowering the quality of a section of visual data in some embodiments, less data can be sent in order to transmit the visual data over a network. Further, in some embodiments, sending both the lower quality version together with a model to be used for reconstruction can still result in less data being transmitted than if the original higher-quality version of the same section of visual data is transmitted alone.

Optionally, the one or more sections of lower-quality visual data are generated from the one or more sections of higher-quality visual data using a process comprising compression and/or quantisation.

Lossy compression, a reduction in frame rate, a reduction in pixel data precision (e.g. from 32-bit to 16-bit) and quantisation of visual data are methods for producing lower-quality visual data from higher-quality visual data and can be used in some embodiments to generate lower-quality visual data from higher-quality visual data.

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Optionally, the one or more sections of higher-quality visual data and/or lower quality visual data comprise any of: a single frame, a sequence of frames and a region within a frame or sequence of frames. Optionally, the one or more sections of higher-quality visual data and/or the one or more sections of lower-quality visual data may comprise an image, a sequence of images, a section of video or an output of a video game.

Depending on the visual data being processed in an embodiment, models can be generated for sections of visual data comprising a single frame, a sequence of frames or a region within a frame or sequence of frames. Each of these options can be used in some or all embodiments in order to provide a method of enhancing or reconstructing visual data to produce higher quality visual data.

General Enhancement / Reconstruction

According to another aspect, there is provided a method for enhancing lower-quality visual data using hierarchical algorithms, the method comprising the steps of: receiving one or more sections of lower-quality visual data; applying a hierarchical algorithm to the one or more sections of lower-quality visual data to enhance the one or more sections of lower-quality visual data to one or more sections of higher-quality visual data, wherein the hierarchical algorithm was developed using a learned approach; and outputting the one or more sections of higher-quality visual data.

In some embodiments, a section of visual data that has been transmitted across a network can be enhanced using hierarchical algorithms. By applying a hierarchical algorithm in some or all of these embodiments, a higher-quality version of the visual data can be output for input lower-quality visual data. Therefore, in some embodiments, only lower-quality visual data need to be transmitted over the network. In other embodiments, lower-quality visual data can be transmitted over the network along with one or more hierarchical algorithms that can be used to enhance lower-quality visual data.

Optionally, the hierarchical algorithm is selected from a library of learned hierarchical algorithms.

In some embodiments, a stored library of learned hierarchical algorithms allows selection of a hierarchical algorithm for comparison without having to develop them or obtain them from an external source. In some embodiments, the comparison can be between a plurality of algorithms in the library. Use of such a library, in at least some embodiments, may result in the faster selection of a suitable hierarchical algorithm for

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enhancing the visual data or, in some embodiments, the most suitable hierarchical algorithm in a library (for example, by basing a measure of suitability on a predetermined metric).

Optionally, the selection of the hierarchical algorithm from the library of learned hierarchical algorithms is determined by metric data associated with the lower-quality visual data.

In some embodiments, it is assumed that the closer the features of the hierarchical algorithm are to those of metric data associated with the lower-quality visual data, the more accurate a reconstruction can be created using that particular hierarchical algorithm. Therefore, by using associated metric data in some embodiments in this way, an appropriate model may be more accurately chosen from the plurality of hierarchical algorithms available.

Optionally, the steps of receiving the one or more sections of lower-quality visual data and applying the hierarchical algorithm to the one or more sections of lower quality visual data occur substantially simultaneously.

In some embodiments, by receiving the one or more sections of lower-quality visual data and substantially simultaneously applying the hierarchical algorithm to one or more sections of lower-quality visual data, the time taken to enhance the visual data can be reduced. This is especially beneficial for live broadcasting embodiments, where it can be advantageous for the time taken for visual data processing before transmission to be minimised.

Optionally, the one or more sections of lower-quality visual data are generated from one or more sections of original higher-quality visual data.

In some embodiments, by generating lower-quality visual data from original higher-quality visual data and transmitting the lower-quality visual data instead of the original higher-quality visual data, less data needs to be processed or sent across a network.

Offline Training

According to another aspect, there is provided a method for developing an enhancement model for visual data, the method comprising the steps of: receiving one or more sections of higher-quality visual data and one or more sections of lower-quality visual data corresponding to the one or more sections of higher-quality data; developing a hierarchical algorithm, wherein the hierarchical algorithm is operable to substantially

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reproduce the one or more sections of higher-quality visual data from the corresponding one or more sections of lower-quality visual data; and storing the developed hierarchical algorithm in a library of developed hierarchical algorithms.

In some embodiments, by developing and storing hierarchical algorithms trained to enhance visual data in a library of enhancement algorithms, trained hierarchical algorithms can be selected from the library for repeated use to reduce the need for individual training from scratch every time enhancement of visual data is required. In some of these embodiments, this approach can save computational expense and speed up the transmission of visual data across a network, for example where it is possible to choose a suitable model for visual enhancement from the library rather than train a new one. It also allows for hierarchical algorithms to be trained in advance of the transmission of visual data, for at least some embodiments, removing time constraints that can be present when training hierarchical algorithms substantially immediately before visual data is transmitted.

Optionally, the developed hierarchical algorithm is stored associated with metric data relating to a content type of the higher-quality visual data and/or lower-quality visual data from which the hierarchical algorithm was developed.

In some embodiments, by storing the trained model in the library with metric data relating to the associated visual data, optionally where the metric data can be used to determine whether the trained model would be suitable for use with visual data having similar metric data, such metric data can be used to compare to metric data associated with further visual data to select a suitable hierarchical algorithm to enhance that further visual data. This means that, in at least some of these embodiments, a specific hierarchical algorithm need not be trained for every set of visual data; existing trained hierarchical algorithms can instead be used to enhance similar sets of visual data to that on which they were trained.

Optionally, the hierarchical algorithm is developed from a known hierarchical algorithm.

In some embodiments, developing a new hierarchical algorithm from a known hierarchical algorithm that was trained on similar visual data to the visual data on which the new algorithm is to be trained can reduce the time and/or computational effort required to train the new hierarchical algorithm.

Optionally, the known hierarchical algorithm is stored in the library of developed hierarchical algorithms.

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For some embodiments, having one or more known algorithms stored in a library of previously developed algorithms can allow for these algorithms to be accessed quickly and easily, increasing the efficiency of the training process.

Optionally, the method is performed at a network node within a network.

By performing the method at a network node in some embodiments, the resulting trained hierarchical algorithms can be transmitted across the network to further network nodes at which they are required. It also allows, in at least some embodiments, for the library of trained models to be stored remotely from the location at which the training takes place.

Optionally, the method additionally comprises a step of encoding the one or more sections of higher quality visual data and/or the one or more sections of lower-quality visual data.

Optionally, the step of encoding the one or more sections of higher quality visual data and/or the one or more sections of lower-quality visual data occurs after the step of developing the hierarchical algorithm.

Visual data is often encoded prior to transmission across a network, or storage in a memory, in embodiments. By encoding the visual data after the hierarchical algorithm has been trained in at least some embodiments, the visual data is then ready for transmission or storage. The trained hierarchical algorithm will then be operable to enhance the quality of decoded visual data in these embodiments.

Optionally, the method additionally comprises a step of refining the hierarchical algorithm after the step of encoding the one or more sections of higher quality visual data and/or the one or more sections of lower-quality visual data.

By refining the hierarchical algorithm after the encoding of the visual data in some embodiments, the hierarchical algorithm can be trained to enhance the quality of the encoded visual data without the visual data having to be decoded first. In some of these embodiments, this can decrease the time required to decode and enhance the lower-quality visual data to substantially reproduce the higher-quality visual data.

According to a further aspect, there is provided a method for reducing the amount of data to be transferred when communicating visual data over a network from a first node to a second node, the method at the first node comprising the steps of: reducing the quality of one or more sections of higher- quality visual data to one or more sections of lower- quality visual data; selecting at least one algorithm operable to increase the quality of at least one section of lower- quality visual data using the higher- quality visual data to optimise the selection of the algorithm, wherein the algorithm corresponds to at

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least the one section of lower quality visual data; transmitting the one or more sections of lower- quality visual data to the second node; and transmitting to the second node one or more references corresponding to the one or more selected algorithms that correspond to the one or more sections of lower- quality visual data transmitted to the second node; wherein the second node is able to identify the selected algorithm using the transmitted one or more references and substantially reproduce the higher- quality visual data from the transmitted lower- quality visual data using the identified selected algorithms that corresponds to each section of lower- quality visual data.

According to another aspect, there is provided a method for increasing the quality of a section of visual data communicated over a network from a first node to a second node, the method at the second node comprising the steps of: receiving a lower-quality visual data via a network; receiving a corresponding reference to an algorithm operable to increase the quality of the lower-quality visual data, the algorithm selected with the knowledge of a higher-quality visual data from which the lower- quality visual data was generated; and using the algorithm to increase the quality of the lower-quality visual data to substantially recreate the higher-quality visual data.

According to a further aspect, there is provided a system for reducing the amount of data transferred when communicating visual data over a network, the system comprising two or more nodes wherein a first node is configured to: reduce the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data; select at least one algorithm operable to increase the quality of at least one section of lower-quality visual data using the higher-quality visual data to optimise the selection of the algorithm, wherein the algorithm corresponds to at least the one section of lower quality visual data; transmit the one or more sections of lower-quality visual data to the second node; and transmit to the second node one or more references to the one or more algorithms that correspond to the one or more sections of lower-quality visual data transmitted to the second node; wherein the second node is configured to: receive a lower-quality visual data via a network; receive a corresponding reference to the algorithm operable to increase the quality of the lower-quality visual data, the algorithm selected with the knowledge of a higher-quality visual data from which the lower-quality visual data was generated; and use the algorithm to increase the quality of the lower-quality visual data to substantially recreate the higher-quality visual data.

By transmitting a lower-quality version of a visual data in some embodiments, such as a section of low-quality visual data or series of visual data sections, together

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with a library reference to an algorithm (i.e. any or all of an algorithm, reconstruction algorithm, model, reconstruction model, parameters or reconstruction parameters) to aid reconstruction of higher quality visual data, such as a high-resolution video frame or series of frames, in at least some embodiments less data can be transferred over a network to enable high-quality visual data to be viewed compared to transmitting the high quality visual data alone.

Optionally, the steps of transmitting the one or more sections of lower-quality visual data to the second node and transmitting to the second node one or more references corresponding to the one or more selected algorithms that correspond to the one or more sections of lower-quality visual data transmitted to the second node occur together, or substantially simultaneously.

By transmitting both visual data and one or more references to algorithms in a library of algorithms, a reduced amount of data can be transmitted as only one or more references to algorithms are transmitted instead of the algorithms themselves.

Optionally, the algorithm is a hierarchical algorithm.

In some embodiments, the algorithms used are hierarchical algorithms. It should be noted that algorithms could also be referred to as models, representations, parameters or functions. In some of these embodiments, hierarchical algorithms can enable substantially accurate reconstruction of visual data, e.g. produce a higher quality high-resolution video from the low-resolution video that is transmitted, for example where quality can be measured by a low error rate in comparison to the original high-resolution video.

Optionally, the algorithm is a non-linear algorithm.

In some embodiments, the use of non-linear algorithms can be more flexible and expressive than dictionary learning based approaches, and use fewer coefficients for the reconstruction of higher-quality visual data. In some of these embodiments, this can allow the reconstruction of the sections of higher-quality to be substantially accurate.

Optionally, the algorithm is selected from a library of algorithms stored at any of: the first node; the second node; a centralised database in the network; or a distributed database in the network.

In some embodiments, a library of algorithms can allow for the selection of an substantially optimal, if not the most optimal, algorithm available in the library to reconstruct the lower-quality visual data into higher quality visual data. In some of these embodiments, the use of a library can also allow the selected algorithm to be referred to by a reference identifier. In certain embodiments, libraries can be provided at both

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nodes, and/or in centralised or distributed databases, and optionally can use common or synchronised reference identifiers for the same algorithms.

Optionally, the received reference corresponds to an algorithm stored in a library at the second node.

By providing common or synchronised libraries of algorithms at both the first and the second nodes in at least some embodiments, and by transmitting a reference or reference identifier when transmitting the corresponding lower-quality visual data to allow selection of matching algorithms from both libraries using the reference identifier to identify the selected algorithm, only the reference identifier and the lower-quality visual data needs to be transmitted between the nodes thus data transmission is reduced as the algorithm itself doesn't need to be transmitted.

Optionally, if the second node cannot identify the selected algorithm, the second node sends a request to any of: the first node; a centralised database; or a distributed database for transmission of the selected algorithm to the second node.

In some embodiments, by configuring the second node to be able to request models from a node (for example a first node or alternatively another node or a node to which multiple libraries are synchronised, depending on embodiment) in situations where the libraries at the second node and other node are not synchronised, the higher-quality visual data can still be reconstructed even if the transmitted reference does not correspond to an algorithm stored at the second node. This can prevent errors in the reconstruction process in some embodiments.

Optionally, the algorithm comprises one or more convolutional neural networks.

In some embodiments, convolutional neural networks can achieve substantially optimal reconstruction of higher-quality visual data from lower-quality visual data (when the reconstructed higher-quality visual data is compared to the original high-quality visual data) while being relatively small in data size, for example when compared to over-complete dictionaries.

Optionally, the high-quality visual data is divided into smaller sections based on similarities between a plurality of sections of the high-quality visual data.

In some embodiments, by dividing the visual data into smaller sections, where the sections can be sequences of frames or portions of one or more frames, and where the division can be based on a particular metric for similarity, more efficient models can be selected. For example, in some embodiments multiple sections can be grouped, all of which comprise part of a landscape shot, and one model can be used to reconstruct the scene, i.e. sequence of frames, as opposed to a using a different model for every

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separate frame in the scene. In some embodiments, if the next scene in the visual data is very different (for example a scene with significant movement after a scene showing a still landscape), then the scene can be detected as being very different and a new model can be selected accordingly for the scene. In some embodiments, specific models can be selected for each scene or section, allowing at least some optimisation or adapting of the reconstruction model(s) in comparison to the use of a generic model for the whole of the visual data.

Optionally the one or more sections comprises any of: a single frame, a sequence of frames and a region within a frame or sequence of frames.

Depending on the visual data being processed, in some embodiments models can be selected for sections of visual data comprising a single frame, a sequence of frames or a region within a frame or sequence of frames. This selection can be necessary in some of these embodiments in order to provide the most efficient method of reconstructing a higher quality version of a part of the original visual data.

Optionally, the visual data is converted into a sequence of sections, optionally before the quality is lowered.

Separating the visual data into a sections, for example into a series of frames or images in some embodiments, allows for the individual sections to be down-sampled, thus reducing the size of visual data, and thereby can allow for lower quality sections to be transmitted as re-encoded visual data in the original code (or optionally re-encoded using a more optimal codec and/or at a lower quality in some embodiments).

Optionally, down-sampling is used to reduce the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data.

By lowering the quality of the section of visual data in some embodiments, less data needs to be sent across a network from a first node to a second node in order for the second node to receive the file. In these embodiments the lower quality version together with a reference to the model to be used for reconstruction can still allow for less data to be transmitted than if the original higher-quality version of the same section of visual data is transmitted.

Optionally, the steps of transmitting the one or more sections of lower-quality visual data to the second node and transmitting to the second node the references to the one or more algorithms that correspond to the one or more sections of lower-quality visual data transmitted to the second node occur substantially simultaneously.

By transmitting the lower quality section of visual data and the model reference simultaneously in some embodiments, the reconstruction process can be initiated

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substantially instantaneously on arrival of the data, as opposed to there being a delay between the arrival of the section of visual data and the model reference or vice versa. In some embodiments, both the model and the section of visual data are necessary for a higher-quality version of the section of visual data to be reconstructed such that the reconstructed visual data is of substantially the same quality as the original higher-quality visual data.

Online Training

According to an aspect, there is provided a method for enhancing visual data when communicating visual data over a network from a first node to a second node, the method at the first node comprising the steps of: reducing the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data; developing at least one hierarchical algorithm operable to increase the quality of the one or more sections of lower quality visual data using the one or more sections of higher-quality visual data to enhance the developed at least one hierarchical algorithm, wherein the developed at least one hierarchical algorithm corresponds to the one or more sections of lower quality visual data; transmitting the one or more sections of lower-quality visual data to the second node; and communicating to the second node at least one of the developed at least one hierarchical algorithms that corresponds to the one or more sections of lower-quality visual data transmitted to the second node; wherein the second node is able to substantially reproduce the one or more sections of higher-quality visual data from the transmitted one or more sections of lower-quality visual data using the developed at least hierarchical algorithm that corresponds to the one or more sections of lower-quality visual data.

According to a further aspect, there is provided a method for enhancing visual data when communicating visual data over a network from a first node to a second node, the method at the second node comprising the steps of: receiving one or more sections of lower-quality visual data via a network; receiving a corresponding at least one hierarchical algorithm operable to increase the quality of the one or more sections of lower-quality visual data, the at least one hierarchical algorithm developed with the knowledge of one or more sections of higher-quality visual data corresponding to the one or more sections of lower-quality visual data; and using the at least one hierarchical algorithm to increase the quality of the one or more sections of lower-quality visual data to substantially recreate the one or more sections of higher-quality visual data.

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According to another aspect, there is provided a system for reducing the amount of data transferred when communicating visual data over a network, the system comprising two or more nodes wherein a first node is configured to: reduce the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data; develop at least one hierarchical algorithm operable to increase the quality of the one or more sections of lower quality visual data using the one or more sections of higher-quality visual data to enhance the developed at least one hierarchical algorithm, wherein the developed at least one hierarchical algorithm corresponds to the one or more sections of lower quality visual data; transmitting the one or more sections of lower-quality visual data to the second node; and communicate to the second node at least one of the developed at least one hierarchical algorithms that corresponds to the one or more sections of lower-quality visual data transmitted to the second node; wherein the second node is configured to: receive one or more sections of lower-quality visual data via a network; receive a corresponding at least one hierarchical algorithm operable to increase the quality of the one or more sections of lower-quality visual data, the at least one hierarchical algorithm developed with the knowledge of one or more sections of higher-quality visual data corresponding to the one or more sections of lower-quality visual data; and use the at least one hierarchical algorithm to increase the quality of the one or more sections of lower-quality visual data to substantially recreate the one or more sections of higher-quality visual data.

In some embodiments, by developing a hierarchical algorithm for enhancing the quality of a specific set of lower-quality visual data, a more accurate enhancement of that visual data can be achieved at a receiving node in a network. In some of these embodiments, having knowledge of the higher-quality visual data to which the lower-quality visual data corresponds can lead to the training and/or development of more accurate hierarchical algorithms. In further of these embodiments, having knowledge of the compression settings of the lower-quality visual data can also help in training and/or development of more accurate hierarchical algorithms and, in such embodiments, training hierarchical algorithms on visual data having the same compression settings can provide substantially accurate hierarchical algorithms for those compression settings. Furthermore, in some embodiments, communicating the lower-quality algorithm across the network along with the associated lower-quality visual data can reduce the amount of data required to be transmitted across the network when compared with the transmission of the higher-quality data alone. For some embodiments, this is especially

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true in the case where the higher-quality visual data is at a significantly higher quality than the lower-quality visual data.

Optionally, the developed at least one hierarchical algorithm is selected from a plurality of hierarchical algorithms developed in parallel at the first node.

Optionally, the at least one hierarchical algorithm is developed in parallel to the encoding of the lower-quality visual data.

In some embodiments, developing multiple hierarchical algorithms in parallel while encoding the visual data can speed up the process of preparing the visual data and hierarchical algorithm for communication across a network. In some of these embodiments, by developing multiple hierarchical algorithms in parallel, a greater number of possible algorithm structures can be explored and the most suitable chosen.

Optionally, the steps of transmitting the one or more sections of lower-quality visual data to the second node and communicating to the second node the developed at least one hierarchical algorithm that corresponds to the one or more sections of lower-quality visual data transmitted to the second node occur substantially simultaneously.

By transmitting the visual data and communicating the associated hierarchical algorithm substantially simultaneously in some embodiments, the reconstruction process at the second node can begin as soon as the hierarchical algorithm is received. This can reduce the delay, in some of these embodiments, between receiving lower-quality visual data and outputting higher-quality visual data.

Optionally, the communicating to the second node of the at least one of the developed at least one hierarchical comprises transmitting the developed at least one hierarchical algorithm to the second node.

In some embodiments, transmitting the whole of the developed hierarchical algorithm to the second node ensures that the developed hierarchical algorithm is available for use at the second node.

According to a further aspect, there is provided a method for reducing the amount of data to be transferred when communicating visual data over a network from a first node to a second node, the method at the first node comprising the steps of: reducing the quality of a section of higher-quality visual data to a section of lower-quality visual data; analysing a first example based model for the use of reconstruction of the lower-quality section of visual data; analysing a further one or more example based models for the use of reconstruction of the lower-quality section of visual data; selecting one or more example based models from a plurality of example based models to use based on a specified metric; transmitting the section of lower-quality visual data to the second

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node; and transmitting to the second node the one or more selected example based models that correspond to the lower-quality section of visual data transmitted to the second node; wherein the second node is able to substantially reproduce the higher-quality section of visual data from the transmitted lower-quality section of visual data using the one or more example based models that corresponds to the lower-quality section of visual data.

According to another aspect, there is provided a method for increasing the quality of a lower-quality section of visual data communicated over a network from a first node to a second node, the method at the second node comprising the steps of: receiving a lower-quality section of visual data via a network; receiving a corresponding example based model operable to increase the quality of the lower-quality section of visual data; and using the example based model to increase the quality of the lower-quality section of visual data to substantially recreate the higher-quality section of visual data.

According to a further aspect, there is provided a system for reducing the amount of data to be transferred when communicating visual data over a network, the system comprising two or more nodes wherein a first node is configured to: reduce the quality of a higher-quality section of visual data to a lower-quality section of visual data; analyse a first example based model for the use of reconstruction of the lower-quality section of visual data; analyse one or more example based models for the use of reconstruction of the lower-quality section of visual data; select one or more example based models from a plurality of example based models to use based on a specified metric; transmit the section of lower-quality visual data to the second node; and transmit to the second node the one or more example based models that correspond to the section of lower-quality visual data transmitted to the second node; wherein the second node is configured to: receive a lower-quality section of visual data via network; receive one or more corresponding example based models operable to increase the quality of the lower-quality section of visual data; and use the one or more example based models to increase the quality of the lower-quality section of visual data to substantially recreate the higher-quality section of visual data.

According to an aspect, there is provided a method for increasing the quality of a lower-quality section of visual data, the method at the first node comprising the steps of: analysing a first example based model for the use of increasing the quality of the lower-quality section of visual data; analysing a further one or more example based models for the use of increasing the quality of the lower-quality section of visual data; and selecting one or more example based models from a plurality of example based models to use

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based on a specified metric; wherein the quality of the lower-quality section of visual data is able to be substantially increased using the one or more example based models that corresponds to the lower-quality visual data.

In some embodiments, by transmitting a section of lower-quality visual data over a network together with an example based model to aid reconstruction of high-quality visual data, less data can be transferred over the network to enable a higher-quality visual data to be displayed when compared to transmitting higher-quality visual data alone. In some of these embodiments, by selecting one or more example based models from a plurality of example based models, higher-quality visual data is operable to be reconstructed from the lower-quality visual data and the one or more example based models together. As any example based models used in such embodiments are already in existence and just need to be selected and not created, the delay between the recording of the higher-quality visual data and emission of the reconstructed higher-quality visual data can be minimised. Some of these embodiments can therefore be used for the live broadcast of visual data pertaining to an event. As there exists a plurality of example based models, in some embodiments optional analysis of a plurality of models allows for the selection of an example based model which, when used in the reconstruction of a lower-quality section of visual data, will generate the highest quality output data on reconstruction compared to other selectable models. The visual data to be transmitted can be recorded in the form of higher-quality visual data in some embodiments, the quality of which is then reduced before transmission as outlined above. The visual data can, in alternative embodiments, be recorded in the form of lower-quality visual data, which requires no further decrease in quality before transmission. In some embodiments, visual data can be video and or image data. In some embodiments, quality can relate to the resolution of visual data and/or other attributes such as a higher or lower frame rate.

In some embodiments, a combination of two or more example based models may provide an optimum resource for reconstruction of the lower-quality section of visual data. In some of these embodiments, the two or more example based models can be combined in such a way so as to form a new example based model that is transmitted alongside the lower-quality section of visual data. The lower-quality section of visual data can further be transmitted alongside more than one example based model in some embodiments, if that provides a required level of reconstruction into a higher-quality visual data.

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In some embodiments, the live section of visual data transmitted will be at a lower quality. Aspects disclosed herewith can still be used in order to increase the quality of the section of visual data in some embodiments, even without an original high-quality version.

Optionally, one or more sample sections of visual data are transmitted from the first node to the second node in advance of a live transmission; and a subset of example based models is selected from the plurality of example based models based on a specified metric from the one or more sample sections of visual data; wherein the one or more example based models used to substantially increase the quality of the live transmission is selected from the subset of example based models.

Optionally, one or more sample sections of visual data are transmitted from the first node to the second node in advance of a live transmission; wherein one or more example based models can be generated in advance of the live transmission based on a specified metric from the one or more sample sections of visual data.

Optionally, one or more sample sections of visual data are transmitted from the first node to the second node in advance of a live transmission; wherein one or more example based models from the plurality of example based models can be modified in advance of the live transmission based on a specified metric from the one or more sample sections of visual data.

The process of selecting the example based model to be used in some embodiments can be made more efficient by providing a smaller pool of example based models from which the selection can be made. Computational effort can thereby not be wasted in at least some of these embodiments, as a reconstruction using an example based model that is very unlikely to be used as the selected model for the relevant visual data, e.g. frame or video, will not be performed.

In some embodiments, by transmitting a section of visual data in advance of the live broadcast, example based models that are likely to be used can be grouped into a subset of the total plurality of example based models available.

During the live broadcast, in some embodiments, one or more example based models can be selected from the subset, rather than from the entire available library of models. If deemed necessary, in at least some embodiments, or if sufficient time is available before the live broadcast in other embodiments, the section of visual data can be transmitted in advance of the live broadcast and this can allow for the modification of an existing example based model or generation of a new example based model so as to

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provide a model or models for the more accurate reconstruction from a lower-quality section of visual data.

Optionally, the example based model comprises any of: a generative model; a non-linear hierarchical algorithm; or a convolutional neural network; or a recurrent neural network; or a deep belief network; or a dictionary learning algorithm; or a parameter; or a mapping function.

Optionally the example based model comprises a specific parameter or mapping function for the reconstruction of data.

In embodiments, the example based model can be one of a number of different model types. This increases the flexibility of the method and allows accurate reconstruction of the higher quality visual data in such embodiments.

Optionally the higher-quality visual data is divided into smaller sections based on similarities between a plurality of sections of the higher-quality visual data.

In some embodiments, by dividing the visual data into smaller sections or 'scenes', based on a particular metric for similarity, more efficient models can be generated. For example, in some embodiments multiple sections can be selected, all of which comprise part of a landscape shot, and only one model will be required to reconstruct the scene as opposed to a marginally different model for every separate section. If the next scene in the visual data is very different, for example a scene with significant movement, then in some embodiments this will be detected as such and a new model generated accordingly for the scene. Specific models can be trained for each scene or section in some embodiments, enabling the reconstruction approach to be adaptive and to allow at least some optimisation of reconstruction.

Optionally a section of visual data can comprise any of: a single frame; or a sequence of frames; or a region within a frame or sequence of frames.

Depending on the visual data being processed, in some embodiments models can be generated for sections of visual data comprising a single frame, a sequence of frames or a region within a frame or sequence of frames. Each option could be necessary in some embodiments in order to provide the most efficient method of reconstructing a higher-quality version of a part of the original visual data.

Optionally the visual data is converted to a sequence of sections before the quality is reduced.

By separating the visual data into sections, for example by separating video data into a series of frames in some embodiments, the amount of data is temporarily increased, as the reductions in data from any compression methods previously used on

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the video file will be undone. However in some of these embodiments, this allows for the individual sections to be down-sampled thus reducing the size of the visual data, thereby allowing for lower-quality sections to be transmitted as re-encoded visual data in the original or optionally a more optimal codec but at a lower quality.

Optionally analysis of any two or more example based models occurs in parallel.

By analysing multiple example based models in parallel in some embodiments, the time taken to select a suitable example based model from a library of models can be reduced. This is especially beneficial for live broadcasting embodiments, where it can be advantageous for the time taken for processing visual data before transmission to be minimised.

In some embodiments, a pipeline of analysis can be performed for multiple subsequent sections of visual data in parallel. In some of these embodiments, analysis can be performed for subsequent sections of visual data in respect of compression settings and/or to classify the section or sections into categories in order to perform further content-specific analysis, where this further analysis can be performed once the visual data has been decoded, and in some embodiments this analysis can allow a reduction of the number of models considered for use with the visual data for enhancement or as starting points for training a model.

Optionally, a plurality of example based models are stored in a library.

In some embodiments, a stored library of example based models at the first node allows the analysis process to quickly select example based models for comparison without having to obtain them from the network. This, in turn, may result in a faster selection of the most suitable model for transmission across the network in some of these embodiments.

Optionally the sections of visual data are transmitted in the chronological order according to the section of higher-quality visual data.

By transmitting the sections of visual data in chronological order in some embodiments, the time difference between a section of visual data being recorded and a reconstructed higher-quality visual data being received by the second node can be minimised. For live broadcasting embodiments, this means that the lag between an event happening in front of a camera and a viewer watching a reconstructed version of the event can be reduced.

Optionally the sections of visual data are transmitted in the order in which they were transmitted by the first node.

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Optionally the quality of the lower-quality sections of visual data is increased according to the order in which the sections of visual data were transmitted by the first node.

Some sections of visual data might be easier to process than others, for example a section of video comprising a single black frame would require less computational effort to process than a fast-moving scene. Therefore in some embodiments the sections of visual data that are easier to process could arrive at the second node before the more difficult to process sections. If the visual data is to be reconstructed and viewed in the order in which it was originally recorded in such embodiments, any sections of visual data which arrive out of sequence at the second node can be buffered in some of these embodiments and the sections placed in a chosen order, before increasing the quality and outputting the reconstructed visual data.

Optionally the analysis of an example based model for the use of reconstruction of the lower-quality section of visual data comprises the further steps of: extracting features of a section of the higher-quality visual data; and using the extracted features to select a predetermined example based model from the plurality of predetermined example based models to provide initial parameters for the developed example based model.

The closer the features of the example based model match those extracted from the corresponding section of visual data, the more accurate a reconstruction can be created using that particular example based model, in at least some embodiments. Therefore by extracting features from a section of the higher-quality visual data in some embodiments an appropriate model may be more accurately chosen from the plurality of example based models available.

Optionally the specified metric used to select and/or modify and/or generate an example based model is based on generating the highest quality output data following reconstruction, preferably wherein quality can be defined using any of: an error rate; a peak signal-to-noise ratio; or a structural similarity index.

A reconstructed section of visual data of the highest quality according to any of the above metrics can be desirable to a viewer, as it is liable to show the truest representation of the original higher-quality visual data, at least for some embodiments. In such embodiments, the broadcaster of the original higher-quality visual data is also likely to prefer that the viewer sees the visual data as it has been prepared, without distortion from the down sampling and transmission process.

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Optionally the higher-quality section of visual data is divided into smaller sections based on similarities between a plurality of sections of the higher-quality visual data.

In some embodiments, by dividing the visual data file into smaller sections or 'scenes', based on a particular metric for similarity, less data needs to be transmitted over the network. For example, in some embodiments multiple sections can be selected, all of which comprise part of a landscape shot, and only one model will be required to reconstruct the scene to an acceptable level as opposed to a marginally different model for every separate section. If the next scene in the visual data is very different in such embodiments, for example a scene with significant movement, then it will be detected as such using the extracted features as described above and a new model can be selected accordingly.

Optionally a section comprises any of: a single frame, a sequence of frames and a region within a frame or a sequence of frames.

Depending on the visual data being processed, in some embodiments models can be selected for sections of visual data comprising a single frame, a sequence of frames and a region within a frame or a sequence of frames. In these embodiments, each or all approaches could be necessary in order to provide the most efficient method of reconstructing a higher-quality version of a part of the original visual data.

Optionally the steps of transmitting the section of lower-quality visual data to the second node and transmitting to the second node the example based model that corresponds to the section of lower-quality visual data transmitted to the second node occur substantially simultaneously.

By transmitting the lower-quality section of visual data and the example based model simultaneously in some embodiments, the reconstruction process can be initiated substantially simultaneously on arrival of the data, as opposed to a delay between the arrival of the section of visual data and the example based model or vice versa. Both the example based model and the section of visual data are necessary for a higher-quality version of the section of visual data to be reconstructed, in some embodiments, and so any delay between their arrivals will result in a delay between the original visual data being transmitted from a first node and the reconstructed visual data being viewed at a second node.

Optionally the step of lowering the quality of a section of visual data is performed using down-sampling.

By lowering the quality of the section of visual data in some embodiments, less data needs to be sent across a network from a first node to a second node in order for a

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second node to receive the section of visual data. In these embodiments the lower-quality version, together with an example based model to be used for reconstruction, can still allow for less data to be transmitted than if original higher-quality section of visual data is transmitted.

Optionally a library is stored at both the first and second nodes, and a reference to one or more example based models from the library at the first node is transmitted to the second node.

It can advantageous in some embodiments to minimise the amount of data sent over a network. Higher-resolution videos can comprise significant amounts of data, which can be slow to transmit over existing network infrastructures such as the Internet. Some embodiments can provide a solution to the problem of video transmission over a network by transmitting instead a lower-quality section of video and an example based model, as described above. In some embodiments, in order to further reduce the amount of data transmitted over a network, a lower- quality section of visual data can be transmitted along with a reference to an example based model, in lieu of the example based model itself. In some of these embodiments the reference comprises less data than the example based model to which it refers. In such embodiments a library of similarly referenced example based models can be accessed from both the first and second nodes, so that once a model is selected at the first node and the reference transmitted, the correct model to be used at the second node can be identified.

Optionally, an off-site computing system performs a method comprising the steps of: receiving a lower- quality section of visual data; analysing a first example based model for the use of reconstruction of the lower- quality section of visual data; analysing a further one or more example based models for the use of reconstruction of the lower-quality section of visual data; selecting one or more example based models from a plurality of example based models to use based on a specified metric; generating a higher- quality section of visual data from the lower- quality section of visual data using the one or more example based models that correspond to the lower- quality visual data.

Optionally, there is provided a method further comprising the step of: receiving a higher- quality section of visual data from a third node, before transmitting the higher-quality section of visual data to the first node.

Optionally, one or more of the nodes is based in an off-site computing system.

In some embodiments off-site, or 'cloud computing', systems allow for the performance of computerised tasks on a server not necessarily local to the site of the recording or reconstruction of a section of visual data. This allows for more powerful

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servers to be used according to the budget available for such services, and hence increased parallel processing of different example based models in some of these embodiments. The off-site system used in such embodiments could also provide a backup of any sections of visual data passing through the servers, thereby offering a solution in the case of loss of data at a site local to the recording or reconstruction of a section of visual data. If the computing system is scalable, as is preferable, then a growing amount of visual data processing work can be accommodated should the need arise in these embodiments.

Sub-Pixel Convolutions

According to an aspect, there is provided a method for enhancing one or more sections of lower-quality visual data using a hierarchical algorithm, the method comprising the steps of: receiving one or more sections of lower-quality visual data; enhancing the one or more sections of lower-quality visual data to one or more sections of higher-quality visual data using the hierarchical algorithm, wherein at least the first step of the hierarchical algorithm is performed in a lower-quality domain; and wherein the hierarchical algorithm operates in both a higher-quality domain and the lower-quality domain.

In embodiments, an algorithm performing at least the first processing steps of as enhancement in a lower quality domain ensures the visual data is at least partially if not substantially processed whilst still in lower-quality, reducing the computational complexity of the enhancement. Subsequent processing steps may move to the higher-quality domain to undertake further processing and output higher-quality visual data in such embodiments. Optionally, in some of these embodiments, only the last processing step or steps are performed in the higher-quality domain.

In some embodiments, resampling into the higher dimension space of visual data from a low-quality to high-quality domain happens before being processed through a super resolution network for enhancement, for example in some of these embodiments being enhanced using bicubic interpolation, but this enhancing does not add information useful for super resolution and forces the network to perform subsequent computation in a higher-quality domain when for example extracting feature maps and performing non-linear mapping. This "initial upscaling" makes the computation of the network/algorithm computationally expensive and increases memory requirements. In some embodiments,

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the low quality domain is a low resolution domain while the high quality domain is a high resolution domain.

Optionally, this method can be used as a filtering approach in place of other resampling or upsampling filters for use with encoding and decoding of visual data.

In some embodiments, using the method as a filter for visual data codecs can provide very high computational efficiency, and therefore can also provide minimal energy costs in performing such filtering. In these or other embodiments, the method can provide a filter that is fast and/or flexible in expression and that can perform substantially accurate filtering in at least some embodiments.

Optionally, an activation function can follow the use of the method as a filtering approach.

Optionally, the first step of the hierarchical algorithm comprises extracting one or more features from the one or more sections of lower-quality visual data.

In embodiments, extracted features may be used to produce a value or series of values based on a metric from the input data. In some embodiments, the metric can then be used to select a hierarchical algorithm from the library which is most appropriate for the input data, as each hierarchical algorithm has associated metric values based on the input data from which the models were respectively trained, the selection based on the similarity between the metrics associated with the input data and each of the pre-trained models.

Optionally, the last step of the hierarchical algorithm comprises producing higher-quality visual data corresponding to the lower-quality visual data, and at least the last step of the hierarchical algorithm may be performed in the higher-quality domain.

In some embodiments, by using the last step of the hierarchical algorithm to perform enhancement from the lower-quality domain after feature maps have been extracted and non-linear mapping has been performed in the lower-quality domain, the layers other than the final layer are less computationally expensive and require less memory than if they were operating in high resolution space and the final layer can perform more complex upscaling.

In some embodiments, the final layer can be a sub-pixel convolutional layer that is capable of upscaling low resolution feature maps into high resolution output, thus avoiding using a non-adaptive generic or handcrafted bicubic filter, and allowing for a plurality of more complex upscaling filters for each feature map. Further, in some of these embodiments, having the final layer perform super resolution from the lower resolution space can reduce the complexity of the super resolution operation.

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Optionally, the higher-quality visual data is at a higher resolution than the lower-quality visual data, wherein the lower-quality visual data may contain a higher amount of artefacts than the higher-quality visual data.

In some embodiments, separating the visual data into a series of sections allows for the individual sections to be down-sampled thus reducing the visual data size, thereby allowing for lower quality sections to be transmitted as re-encoded visual data in the original or optionally a more optimal codec but at a lower resolution.

Optionally, the hierarchical algorithm comprises a plurality of connected layers, and the connected layers may be sequential.

Optionally, the at least one section lower-quality visual data comprises any of: a single frame of lower-quality visual data, a sequence of frames of lower-quality visual data, and a region within a frame or sequence of frames of lower-quality visual data. Furthermore, the lower-quality visual data may comprise a plurality of frames of video.

Depending on the visual data being processed, in some embodiment models can be generated for sections of visual data comprising a single frame, a sequence of frames or a region within a frame or sequence of frames. In these embodiments, some or each of these options could be used in order to provide the most efficient method of reconstructing a higher quality version of a part of the original visual data.

Optionally, the hierarchical algorithm differs for each section of visual data.

In some embodiments, each section of visual to be transferred is likely to be at least slightly different from the preceding section. These embodiments it can therefore allow for more accurate reconstruction if the hierarchical algorithm to be transmitted alongside each section of visual data is also different in order to account for these differences in the sections of visual data. For such embodiments, a new model can therefore be generated for each section of visual data accordingly.

Optionally, the hierarchical algorithm is selected from a library of algorithms.

In some embodiments, providing libraries of algorithms allows selection of an algorithm from the libraries and allows for modifications to be made to the stored hierarchical algorithms to enhance the visual data, reducing the computational complexity.

Optionally, the standardised features of the at least one section of received lower-quality visual data are extracted and used to select the hierarchical algorithm from the library of algorithms.

In some embodiments, extracted standardised features are used to produce a value or series of values based on a metric from the input data. In these embodiments,

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the metric can then be used to select the pre-trained model from the library which is most appropriate for the input data, as each model in the library has associated metric values based on the input data from which the models were respectively trained, the selection based on the similarity between the metrics associated with the input data and each of the pre-trained models.

Optionally, the hierarchical algorithm to be selected from the library of algorithms is based on generating the highest quality version of the lower-quality visual data, preferably wherein quality can be defined by any of: an error rate; a bit error rate; a peak signal-to-noise ratio; or a structural similarity index.

The predetermined metrics used in some embodiments to determine the hierarchical algorithm to be selected can be based on a predicted quality of the output data for each pre-trained model. In some of these embodiments, quality can be defined by any or all of: an error rate; a peak signal-to-noise ratio; or a structural similarity index.

Spatio-temporal approach

According to an aspect there is provided a method for enhancing at least a section of lower-quality visual data using a hierarchical algorithm, the method comprising the steps of: receiving at least a plurality of neighbouring sections of lower-quality visual data; selecting a plurality of input sections from the received plurality of neighbouring sections of lower quality visual data; extracting features from the plurality of input sections of lower-quality visual data; and enhancing a target section based on the extracted features from the plurality of input sections of lower-quality visual data.

In some embodiments, performing the enhancement on the extracted features reduces the computational expense of the enhancement by using hierarchical algorithms trained on the lower-quality visual data.

Optionally, the target section corresponds to one of the received plurality of neighbouring sections of lower-quality visual data. Alternatively, the target section may not correspond to one of the received plurality of neighbouring sections of lower-quality visual data.

In some embodiments, having the target section correspond to one of the received sections allows the enhancement to work in the spatial domain. Conversely, in some embodiments, when the target section does not correspond to one of the received sections, then enhancement can be used to predict sections occurring between received sections, or alternatively to predict future sections.

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Optionally, the at least one section of lower-quality visual data comprises any of: a single frame of lower-quality visual data, a sequence of frames of lower-quality visual data, and a region within a frame or sequence of frames of lower-quality visual data. The lower-quality visual data may further comprise a plurality of frames of video.

Depending on the visual data file being processed, in some embodiments models can be selected for sections of visual data comprising a single frame, a sequence of frames or a region within a frame or sequence of frames. In these embodiments each could be necessary in order to provide the most efficient method of reconstructing a higher quality version of a part of the original visual data.

Optionally, at least one of the plurality of selected input sections and the target sections are frames of lower-quality visual data, and the at least one of the plurality of selected input sections occurs sequentially before the target section. Furthermore, at least one of the plurality of selected input sections and the target sections may be frames of lower-quality visual data, and the at least one of the plurality of selected input sections may occur sequentially after the target section.

In some embodiments, having one of the selected input sections occur sequentially in time before or after the target section of the lower-quality visual data enables the enhancement to predict a possible future section, or section still to be received, but that is not included in the any possible target section. As such, in some of these embodiments, having a section before or after the target section may also enable the enhancement to predict a section occurring between two sections.

Optionally, the hierarchical algorithm comprises a plurality of layers, furthermore the layers may be any of sequential, recurrent, recursive, branching or merging.

Having a number of layers in some embodiments, which may or may not be sequential, recurrent, recursive, branching or merging allows different levels of processing to occur at different times and the layers can work in parallel, ensuring optimal efficiency when enhancing the lower-quality visual data.

Optionally, the extracting the subset of features is based upon a predetermined extraction metric.

In some embodiments, enabling a variety of features to be extracted as set by the predetermined extraction metric ensures the enhancement can be tailored to a particular system. As such, in some of these embodiments the computational expense can increased or decreased appropriately based on system resources.

Optionally, the received plurality of neighbouring sections of lower-quality visual data are consecutive sections of lower-quality visual data.

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In some embodiments the use of consecutive sections of lower-quality visual data enables more accurate enhancement of the lower-quality visual data. Receiving a plurality of sections or consecutive sections providing more information used to be able to be used when enhancing sections around the received sections of lower-quality visual data.

Optionally, a predetermined algorithm metric used to determine the hierarchical algorithm to be selected.

In some embodiments, having a plurality of predetermined algorithms which may be selected based on a predetermined algorithm metric ensure optimal efficiency when enhancing the visual data by having a library of hierarchical algorithms which have already been determined to enhance the quality of visual data. In these embodiments, these predetermined algorithms may then be used as a basis for further enhancements.

Optionally, predetermined algorithm metric is based on generating the highest quality version of the lower-quality visual data, preferably wherein quality can be defined by any of: an error rate; a bit error rate; a peak signal-to-noise ratio; or a structural similarity index. Furthermore, standardised features of the received plurality of neighbouring sections of lower quality visual data may be extracted and used to select the hierarchical algorithm from the library of algorithms.

In some embodiments, a reconstructed section of visual data of the highest quality according to any of the above metrics can be desirable to a viewer, as it is liable to show the truest representation of the original higher- quality visual data. In these embodiments, the broadcaster of the original higher- quality visual data is also likely to prefer that the viewer sees the visual data as it has been prepared, without distortion from the down sampling and transmission process.

Optionally, other data can be provided to the algorithm. Optionally, the other data can be optical flow between frames. Optionally, the optical flow between frames can be calculated outside of the algorithm or can be part of the training of the algorithm.

In some embodiments, other data can be fed into the network, such as optical flow between the frames or a measure thereof. In these embodiments, the optical flow can be calculated separately outside the neural network or can be incorporated into the training of the neural network. In these embodiments, this data can simply be concatenated onto the end of each frame data. In some embodiments it is not sent during transmission. In other embodiments, a variant of optical flow can be extracted from the encoded video (as it forms a basis of the inter-frame compression).

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Enhancing Visual Data

According to a aspect there is provided a method for enhancing at least a section of lower-quality visual data, the method comprising steps of: receiving at least a section of the lower-quality visual data; selecting a hierarchical algorithm from a plurality of hierarchical algorithms, wherein the step of selection is based on a predetermined metric and wherein the hierarchical algorithms were developed using a learned approach and at least one of the hierarchical algorithms is operable to increase the quality of the lower-quality visual data; and using the selected hierarchical algorithm to increase the quality of the lower-quality visual data to create a higher-quality visual data.

Some embodiments provide a method for enhancing at least a section of visual data that has been transmitted across a network. In these embodiments, by selecting a hierarchical algorithm based on a predetermined metric, a suitable hierarchical algorithm can be chosen from a library of algorithms that will be able to more accurately recreate the original visual data than a generic hierarchical algorithm.

Optionally, the lower-quality visual data is divided into smaller sections based on similarities between a plurality of sections of the original visual data.

In some embodiments, by dividing the visual data into smaller sections or 'scenes', based on a particular metric for similarity, more efficient models can be generated. For example, in some embodiments multiple sections can be selected, all of which comprise part of a landscape shot, and only one hierarchical algorithm will be required to remove artefacts from the scene as opposed to a marginally different model for every separate section. In some of these embodiments, if the next scene in the visual data is very different, for example a scene with significant movement, then it will be detected as such and a new hierarchical algorithm can be generated accordingly. In some embodiments, specific hierarchical algorithms can be trained for each scene or section, enabling the artefact removal approach to be adaptive and to allow at least some optimisation of the artefact removal.

Optionally, the predetermined metric is based on a content-type and a measure of artefact severity of the lower-quality visual data. Furthermore, the artefact severity may be based on at least one artefact which may be any one of, or combination of: blocking, blurring, pixelation, ringing, aliasing, missing data, and other marks, blemishes, defects, and abnormalities in visual data.

In some embodiments, by basing the predetermined metric on the artefact severity of the lower-quality visual data, the artefact correction model resulting from the

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training and optimisation process can be referenced by the artefact severity of the scene it relates to. In these embodiments, this allows for a more accurate selection of a suitable artefact removal model when selecting a model from the library to clean new visual data.

Optionally, the plurality of hierarchical algorithms is any of: pre-trained hierarchical algorithms on example data; or manually created hierarchical algorithms.

In some embodiments, a pre-trained hierarchical or manually created hierarchical algorithm will be able to more accurately recreate the original visual data than a generic artefact removal hierarchical algorithm

Optionally, if a suitable hierarchical algorithm is not present in the plurality of hierarchical algorithms, a generic hierarchical algorithm is selected instead.

In some embodiments, a generic hierarchical algorithm may be used instead of a specific, trained model in situations where the library of algorithms does not include an visual data artefact removal model that has been trained on a similar enough content type and artefact graded to the received visual data. In these embodiments, the generic hierarchical algorithm may then be more accurate in removing the artefacts than the specifically trained hierarchical algorithms available.

Accelerating Machine Optimisation Processes

According to an aspect, there is provided a method for training learned hierarchical algorithms, the method comprising the steps of: receiving input data; generating metrics from the input data; selecting at least one hierarchical algorithm from a plurality of predetermined hierarchical algorithms based on comparing the generated metrics from the input data and like metrics for each of the plurality of predetermined hierarchical algorithms; developing the selected hierarchical algorithm based on the input data; and outputting a developed hierarchical algorithm.

Providing a plurality of pre-trained sets of parameters or models in some embodiments allows the training of a machine learning process to be accelerated. In these embodiments, input data to be processed by a trained machine learning process can have a tailored model, or set of parameters, developed for that input data based on the selected most similar pre-trained model. In such embodiments, the selection of the one or more most similar pre-trained model(s) can be done based on one or more metrics associated with the pre-trained models compared to the input data. In at least some of these embodiments the most similar pre-trained model can be used as a

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starting point for developing the tailored model for the data as a tailored model does not have to undergo as extensive development as needed when developing a model from first principles. In some embodiments, using a similar or the most similar pre-trained model can also help with avoiding or escaping local minima (for incorrect solutions) during training.

Optionally, the method further comprises the step of storing the developed hierarchical algorithm with plurality of predetermined hierarchical algorithms along with the generated metrics from the input data.

In some embodiments, each new tailored model is then stored in a library of pre-trained models. In these embodiments, repeating or identical input data can re-use a tailored model that already exists without any further modification. In such embodiments, the closer a model is to an optimised version the less computation is required to generate a more optimal model. In these embodiments, as more signals and data are processed, an increasingly more extensive collection of models can be established in the library, requiring reduced development for tailored models for new data thereby saving computational effort.

Optionally, the plurality of predetermined hierarchical algorithms may be any of: pre-trained hierarchical algorithms on example data; or manually created hierarchical algorithms.

In some embodiments, the predetermined hierarchical algorithms can be based on example data or manually created to allow a user to create specific behaviours in any eventual trained model or set of parameters.

Optionally, the step of developing the selected hierarchical algorithm may be based on the input data comprises developing a more optimised hierarchical algorithm.

In some embodiments, developing the predetermined hierarchical algorithms can improve the example-based set of parameters to create a more optimised set of parameters.

Optionally, the hierarchical algorithm comprises at least one of any of: a specific parameter for the reconstruction of data; or a mapping function for the reconstruction of data.

In some embodiments, each hierarchical algorithm can be used to provide for the reconstruction of data. In some of these embodiments, the reconstruction process can vary, and therefore the model can comprise different features, coefficients and/or parameters that would allow for reconstruction and each layer of the hierarchical algorithm can comprise features, coefficients and/or parameters. Further, in some

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embodiments, the parameters for the reconstruction of visual data can comprise one or more hierarchical algorithms.

Optionally, the plurality of hierarchical algorithms may be stored in a repository.

For ease of access to the plurality of predetermined example-based models, in some embodiment the models can be stored in a repository. In these embodiments, the repository can take the form of a library. In some embodiments, the repository can be located on a remote device and/or distributed computing system (such as a cloud computing and/or storage service and/or distributed networked system or peer-to-peer system).

Optionally, the method may comprise the further steps of: extracting features of the input data; and using the extracted features to select a predetermined hierarchical algorithm from the plurality of predetermined hierarchical algorithms to provide initial parameters for the developed hierarchical algorithm.

In some embodiments, extracted standardised features are used to produce a value or series of values based on a metric from the input data. In these embodiments, the metric can then be used to select the pre-trained model from the library which is most appropriate for the input data, as each model in the library has associated metric values based on the input data from which the models were respectively trained, the selection based on the similarity between the metrics associated with the input data and each of the pre-trained models.

Optionally, the metrics may be based on generating the highest quality output data, preferably wherein quality can be defined using any of: an error rate; a peak signal-to-noise ratio; a distance metric; a similarity measure; or a structural similarity index.

In some embodiments, the predetermined metrics used to determine the hierarchical algorithm to be selected is based on a predicted quality of the output data for each pre-trained model. In some of these embodiments, quality can be defined by any or all of: an error rate; a peak signal-to-noise ratio; or a structural similarity index.

Optionally, the hierarchical algorithm is selected based on providing optimal initialisation data when in use

By providing initialisation data which is optimal in at least some embodiments, thereby being as close as possible to the section of visual data being analysed, fewer iterations are required to adapt the model into a form to allow for the highest quality reconstruction according to any of the metrics above. In these embodiments,

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computational effort and time is therefore reduced when processing the section of visual data.

Enhancing Model Libraries

According to an aspect, there is provided a method for enhancing visual data when communicating visual data over a network from a first node to a second node, the method at the first node comprising the steps of: developing at least one modified hierarchical algorithm from a known hierarchical algorithm operable to substantially recreate at least one section of higher-quality visual data; transmitting to the second node references to one or more known hierarchical algorithms from which the modified hierarchical algorithms were developed; and transmitting to the second node one or more modifications to the one or more known hierarchical algorithms operable to reproduce the one or more modified hierarchical algorithms from the known hierarchical algorithms; wherein the second node is able to recreate substantially the higher-quality visual data using the modified hierarchical algorithm.

According to another aspect, there is provided a method for enhancing visual data when communicating visual data over a network from a first node to a second node, the method at the second node comprising the steps of: receiving a reference to a known algorithm corresponding to a section of higher-quality visual data; receiving corresponding modifications to the known hierarchical algorithm operable to produce a modified hierarchical algorithm, the modified hierarchical algorithm developed with the knowledge of the section of higher-quality visual data; and using the modified algorithm to substantially recreate the section of higher-quality visual data.

In some embodiments, knowledge of the section of higher-quality visual data can comprise knowing the encoder settings and/or the content category for at least one of the low-quality visual data, original visual data and the higher-quality visual data. In some of these embodiments, the content category can be based on a predetermined set of categories or a determines set of categories.

According to a further aspect, there is provided a system for enhancing visual data when communicating visual data over a network, the system comprising two or more nodes, wherein a first node is configured to: develop at least one modified hierarchical algorithm from a known hierarchical algorithm operable to substantially recreate at least one section of higher-quality visual data; transmit to the second node references to one or more known hierarchical algorithms from which the modified

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hierarchical algorithms were developed; and transmit to the second node one or more modifications to the one or more known hierarchical algorithms operable to reproduce the one or more modified hierarchical algorithms from the known hierarchical algorithms; wherein a second node is configured to: receive a reference to a known algorithm corresponding to a section of higher-quality visual data; receive corresponding modifications to the known hierarchical algorithm operable to produce a modified hierarchical algorithm, the modified hierarchical algorithm developed with the knowledge of the section of higher-quality visual data; and use the modified algorithm to substantially recreate the section of higher-quality visual data.

In some embodiments, by transmitting a reference to a known algorithm and modifications to that algorithm that allow a modified algorithm to be produced to enable reconstruction of a high- quality section or series of sections of visual data, less data can be transferred over a network to enable a high- quality visual data to be viewed compared to transmitting the high quality visual data. In some of these embodiments the algorithms, also known as models, representations or functions, can also be more accurate and therefore enable a more accurate reconstruction, i.e. produce a higher quality high- quality visual data, for example where quality can be measured by a low error rate in comparison to the original high- quality visual data.

Optionally, known hierarchical algorithm is selected from a library of hierarchical algorithms stored at the first node.

Optionally, the reference received by the second node corresponds to a known hierarchical algorithm stored in a substantially matching library at the second node.

Optionally, if the second node cannot identify the known hierarchical algorithm, the second node sends a request to the first node for transmission of the known hierarchical algorithm from the first node to the second node.

In some embodiments, by providing common or synchronised libraries of algorithms at both the first and the second nodes, and by transmitting a reference or reference identifier when transmitting the corresponding lower- quality visual data to allow selection of matching algorithms from both libraries using the reference identifier to identify the selected algorithm, only the reference identifier, the lower- quality visual data and the modifications to the stored hierarchical algorithms need to be transmitted between the nodes thus data transmission is reduced as the full algorithm doesn't need to be transmitted.

Optionally, the modified hierarchical algorithm is stored in a library at the first node after being developed.

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In some embodiments, by storing the newly developed algorithm at the first node, the algorithm may be used as a starting point to develop further modified algorithms for similar high quality visual data, increasing the efficiency of the method in future situations.

Optionally, the modified hierarchical algorithm is stored in a library at the second node after transmission of the one or modifications to the known hierarchical algorithm from the first node to the second node.

In some embodiments, storing the modified algorithm at the second node after it has been recreated from the known algorithm and the transmitted modifications allows it to be referenced in the future when the modified algorithm is used as a starting point to develop a new algorithm at the first node. In such embodiments, this can prevent duplication.

In some embodiments, the first node may transmit known algorithms to the second node prior to sending the modifications required to make the modified algorithm to ensure that the required known algorithm is present at the second node. In such embodiments, this can reduce errors.

Optionally, one or more representations of the one or more sections of higher-quality visual data are transmitted to the second node and to which the one or more modified hierarchical algorithms are applied to substantially reproduce the one or more sections of higher-quality visual data.

In some embodiments, by transmitting representations of the higher quality visual data to the second node the reconstruction of the higher quality visual data can be aided by applying the modified reconstruction model to the representation, but still with less data being transferred across the network than if the higher quality visual data had been transmitted.

Optionally, one or more sections of lower-quality visual data corresponding to the one or more sections of higher-quality visual data are transmitted to the second node and to which the one or more modified hierarchical algorithms are applied to substantially reproduce the one or more sections of higher-quality visual data.

Optionally, down-sampling is used to reduce the quality of one or more sections of higher-quality visual data to one or more sections of lower quality visual data.

Optionally, the one or more sections of lower-quality visual data are generated from the one or more sections of higher-quality visual data using a process of compression and/or quantisation.

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In some embodiments, by lowering the quality of the section of visual data, less data needs to be sent across a network from a first node to a second node in order for the second node to receive the file. In these embodiments, the lower quality version together with a model to be used for reconstruction can still allow for less data to be transmitted than if the original higher-quality version of the same section of visual data is transmitted (where the quality can be determined by the resolution and/or the level of compression).

Strided Convolutions

According to an aspect, there is provided a method for enhancing at least a section of lower-quality visual data using a hierarchical algorithm, the method comprising steps of: receiving at least one section of lower-quality visual data; extracting a subset of features, from the at least one section of lower-quality visual data; forming a plurality of layers of reduced-dimension visual data from the extracted features; and enhancing the plurality of layers of reduced dimension visual data to form at least one section of higher-quality visual data wherein the at least one section of higher-quality visual data corresponds to the at least one section of lower-quality visual data received.

In some embodiments, extracting a subset of features from a section of lower quality visual data enables performance to be increased by only performing the enhancement on the subset of features as opposed to the entirety of the lower quality visual data, thereby reducing the amount of computation, whilst still achieving acceptable enhancements.

Optionally, the extracted subset of features is dependent upon one or more predetermined factors.

In some embodiments, the use of a predetermined factor to extract the subset of features enables the method to be tailored to a plurality of systems of different capabilities, and allows customisation of the amount of data to extract, allowing for a more accurate selection of a reconstruction model to enhance the lower quality visual data in an appropriate amount of time.

Optionally, the number of layers is dependent upon the one or more predetermined factors.

In some embodiments, the number of layers being based upon the one or more predetermined factors ensures the reconstructed higher-quality visual data corresponds to the lower-quality visual data received.

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Optionally, the lower-quality visual data comprises a plurality of sections of video data.

In some embodiments, video may be used in the method, enabling the techniques to be applied to lower-resolution video data and upscaling it to corresponding higher resolution video data.

Optionally, the at least one section of lower-quality visual data comprises any of: a single frame of lower-quality video data, a sequence of frames of lower-quality video data, and a region within a frame or sequence of frames of lower-quality video data.

In some embodiments, depending on the visual data being processed, models can be used for sections of video data comprising a single frame, a sequence of frames or a region within a frame or sequence of frames. In some of these embodiments, each option could be necessary in order to provide the most efficient method of reconstructing a higher resolution version of a part of the received video file. In some embodiments, regions can include areas within a section, or segmentation between the background and foreground within a section, or some other content-based segmentation such as saliency based segmentation (i.e. where on each section of visual data a viewer is most likely to look).

Optionally, the hierarchical algorithm differs for each section of visual data.

In some embodiments, the use of different hierarchical algorithms for each section of visual data enables the most efficient hierarchical algorithm to be used for a particular section as opposed to using a single hierarchical algorithm for the entire visual data.

Optionally, the hierarchical algorithm is selected from a library of algorithms.

In some embodiments, a library of a plurality of algorithms allows for efficient selection of an hierarchical algorithm from the plurality of algorithms without delays due to communication links.

Optionally, standardised features of the at least one section of received lower-quality visual data are extracted and used to select the hierarchical algorithm from the library of algorithms.

Optionally, the hierarchical algorithm to be selected from the library of algorithms is based on generating the highest quality version of the lower-quality visual data, preferably wherein quality can be defined by any of: an error rate; a bit error rate; a peak signal-to-noise ratio; or a structural similarity index.

In embodiments, a variety of options are available in order to select which algorithm in the library of algorithms will output the best enhanced and enhanced visual

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data from the received visual data, for example an error rate such as the bit error rate can be used

General Aspects

It should be noted that in some aspects and/or embodiments, the terms model and/or algorithm and/or representation and/or parameters and/or functions can be used interchangeably.

It should also be noted that visual data, in some embodiments, may comprise image and/or video data.

Optionally, the modified hierarchical algorithm is trained using a learned approach.

In some embodiments, hierarchical or non-hierarchical algorithms can be substantially accurate and therefore enable a more accurate reconstruction, i.e. produce higher quality high- quality visual data from the low- quality visual data that is transmitted, for example where quality can be measured by resolution or by a low reproduction error rate in comparison to the original high- quality visual data. In some embodiments, using a learned approach can substantially tailor the hierarchical model or models for each portion of low-quality visual data.

Optionally, the learned approach comprises machine-learning techniques. The modified hierarchical algorithm may also be a non-linear hierarchical algorithm, which may comprise one or more convolutional neural networks.

In some embodiments, non-linear models can be substantially accurate in reconstructing higher- quality sections of visual data than dictionary-based approaches. In these embodiments, through using a learning-based approach, i.e. an approach that does not rely on pre-defined visual data features and operators, the model(s) can be optimised for each section or sequence of sections.

In some embodiments, the training of convolutional neural networks can be more computationally complex than dictionary learning for a similar accuracy, but the resulting model or algorithm can also be more flexible in representing visual data while using fewer coefficients for the reconstruction. In these embodiments, the resultant convolutional neural network model to be transmitted alongside the lower- quality visual data can be both smaller and can be more accurate in the reconstruction of a higher-quality visual data.

Some aspects can provide an improved technique for generating reconstruction

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parameters that can be used, when converting an original high- quality video into a down-sampled low- quality video, to allow recreation of a higher- quality version of the video from down-sampled low- quality video without significant loss in quality, for example having a low reconstruction error in comparison with the original high- quality video, and with a reduction in visual data transferred over a network. In such aspects, the application of such a technique can reduce the data transmitted when transmitting visual data in comparison with existing techniques while enabling reproduction of the visual data at its original quality without significant loss in quality in comparison to the original visual data (where quality can be defined by objective metrics such as error rate, PSNR and SSIM as well as subjective measures). In such aspects, such a proposed technique can allow minimal changes to be made to the overall infrastructure of video service providers, as it can augment most existing video compression techniques, and can provide advantages in video encoding and video streaming applications.

Optionally, the higher-quality visual data is at a higher- quality than the lower-quality visual data.

Optionally, the lower-quality visual data contains a higher amount of artefacts than the higher-quality visual data.

Optionally, the hierarchical algorithm performs visual data enhancement, preferably using super- quality techniques.

Optionally, the hierarchical algorithm uses a spatio-temporal approach.

In some embodiments, optionally for use for a section of visual data, the example based model may be a neural network and can use spatio-temporal convolution. In some embodiments, separating visual data into a series of sections allows for the individual sections to be down-sampled thus reducing the visual data size, thereby allowing for lower quality sections to be transmitted as re-encoded visual data in the original or optionally a more optimal codec but at a lower quality . In some embodiments, a spatio-temporal network can allow an improvement in performance by exploiting the temporal information in the visual data and, for example, within a similar scene in sequential sections of visual data, there may be stationary sections of background in the sequential sections providing information relevant for the higher- quality version of that scene such that temporally consecutive sections can be used to super resolve one section.

Aspects and/or embodiments include a computer program product comprising software code to effect the method and/or apparatus of other aspects and/or embodiments herein described.

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References to visual data can be references to video data and/or image data in some aspects and/or embodiments and vice versa. References to low-quality and/or lower-quality can be references to low-resolution and/or lower-resolution in some aspects and/or embodiments and vice versa. References to high-quality and/or higher-quality and/or highest quality and/or original quality can be references to high-resolution and/or higher-resolution and/or highest-resolution and/or original resolution in some aspects and/or embodiments and vice versa. References to sections can be references to frames and/or portions of frames in some aspects and/or embodiments and vice versa. References to enhance or enhancement can be references to upscale and/or upscaling in some aspects and/or embodiments and vice versa.

Brief Description of Drawings

Embodiments of the present invention will now be described, by way of example only and with reference to the accompanying drawings having like-reference numerals, in which:

Figure 1 illustrates an over-complete dictionary of 16 x 16 atoms;

Figure 2a illustrates the layers in a convolutional neural network with no sparsity constraints;

Figure 2b illustrates the layers in a convolutional neural network with sparsity constraints;

Figure 3 illustrates the encoding process to generate for transmission, from high-resolution visual data, a combination of low-resolution visual data and convolution neural network able to use super resolution to increase the resolution of the low-resolution data;

Figure 4 illustrates the decoding process using the low-resolution visual data and convolution neural network to recreate a version of the high-resolution visual data;

Figure 5 is a flowchart illustrating the method steps for encoding a visual data for transmission using the process of Figure 3;

Figure 6 is a flowchart illustrating the method steps for decoding the visual data and convolution neural network data generated using the method shown in Figure 5;

Figure 7 is a diagram of an efficient sub-pixel convolutional network according to an embodiment, featuring two feature map extraction layers built with convolutional neural networks, and a sub-pixel convolutional layer that aggregates the feature maps from low-resolution space and builds the super resolution image in a single step;

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Figure 8 is a diagram of the network architecture according to an embodiment for super resolution using three input frames where only the input layer is modified to jointly handle three input frames for the super resolution prediction of only the middle frame while the hidden layers are identical to those in Figure 7;

Figure 9 is a flow chart illustrating the method steps for a machine learning process;

Figure 10 illustrates the encoding process to generate for transmission, from high resolution visual data and known convolutional neural networks, low resolution visual data and modifications to the known convolutional neural network;

Figure 11 illustrates the decoding process using the low resolution visual data and a reference to a known convolutional neural network, along with modifications to that network, to recreate a version of a high resolution visual data;

Figure 12 illustrates a further encoding process to generate for transmission, from high resolution visual data and known convolutional neural networks a modified convolution neural network; and

Figure 13 illustrates a further decoding process using a reference to a known convolutional neural network, along with modifications to that network, to recreate a version of a high resolution visual data;

Figure 14 is a flowchart illustrating the method steps for a conventional image enhancement process from a lower resolution original visual data to a higher resolution visual data;

Figure 15 is a flowchart illustrating the method steps for an image enhancement process according to an embodiment, where visual data is up-scaled from a lower-resolution original visual data to a higher-resolution visual data, using a combination of the received visual data and a convolutional neural network selected from a library, the convolutional neural network able to use super resolution techniques to increase the resolution of the received visual data;

Figure 16 is a flowchart illustrating the method steps for an image enhancement process to: generate a down-sampled visual data for transmission from a higher-resolution original visual data, the transmission of the down-sampled visual; and an image enhancement process to upscale from the down-sampled visual data to a higher-resolution visual data, using a combination of the received down-sampled visual data and a convolutional neural network selected from a library, the convolutional neural network able to use super resolution techniques to increase the resolution of the received down-sampled visual data;

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Figure 17 is a flowchart illustrating the method steps for an image enhancement process according to the embodiment in Figure 16, with additional steps for encoding visual data at another node prior to transmitting the encoded visual data to the node performing the method of Figure 16;

Figure 18 is a flowchart illustrating the method of Figure 15, with the additional steps of extracting a reduced dimension representation and concatenating the visual data to create a reduced dimension representation of the separated frame;

Figure 19 is a flowchart illustrating the method of Figure 16, with the additional steps of extracting a reduced dimension representation and concatenating the visual data to create a reduced dimension representation of the separated scene;

Figure 20 is a flowchart illustrating the method steps for an image enhancement process according to the embodiment in Figure 19, with additional steps for encoding visual data at another node prior to transmitting the encoded visual data to the node performing the method of Figure 19;

Figure 21 illustrates the selection of pixels from visual data based upon a predetermined value to produce reduced resolution visual data for processing by the method illustrated in Figures 18 through 20;

Figure 22 illustrates an overview of a method of generating models for use in image artefact removal;

Figure 23 illustrates a method of using the image artefact removal models;

Figure 24 illustrates an alternative method of using the image artefact removal models;

Figure 25 illustrates the encoding process to generate, for transmission, from high resolution video data, a combination of low resolution visual data and a reference to an algorithm able to use super resolution to increase the resolution of the low resolution visual data;

Figure 26 illustrates the decoding process using the low resolution visual data and the algorithm corresponding to the received reference to recreate a version of the high resolution visual data; and

Figure 27 illustrates the method steps of the encoding process to generate for transmission, from original visual data being recorded through to the transmitted package of a lower-resolution scene along with a hierarchical algorithm.

Specific Description

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Various embodiments will now be described in detail with reference to the Figures referenced above.

Reduction of Complexity In Neural Networks

With reference to Figures 2a and 2b, various possible configurations of neural network for use in at least some embodiments shall now be described in detail.

An example layered neural network is shown in Figure 2a having three layers 10, 20, 30, each layer 10, 20, 30 formed of a plurality of neurons 25, but where no sparsity constraints have been applied so all neurons 25 in each layer 10, 20, 30 are networked to all neurons 25 in any neighbouring layers 10, 20, 30. The example simple neural network shown in Figure 2a is not computationally complex due to the small number of neurons 25 and layers. Due to the density of connections, however, the arrangement of the neural network shown in Figure 2a won't scale up to larger sizes of network, i.e. the connections between neurons/layers, easily as the computational complexity soon becomes too great as the size of the network scales and scales in a non-linear fashion.

Where neural networks need to be scaled up to work on inputs with a high number of dimensions, it can therefore become too computationally complex for all neurons 25 in each layer 10, 20, 30 to be networked to all neurons 25 in the one or more neighbouring layers 10, 20, 30. A predetermined initial sparsity condition is used to lower the computational complexity of the neural network, for example when the neural network is functioning as an optimisation process, by limiting the number of connection between neurons and/or layers thus enabling a neural network approach to work with high dimensional data such as images.

An example of a neural network is shown in Figure 2b with sparsity constraints, according to at least one embodiment. The neural network shown in Figure 2b is arranged so that each neuron 25 is connected only to a small number of neurons 25 in the neighbouring layers 40, 50, 60 thus creating a neural network that is not fully connected and which can scale to function with, higher dimensional data – for example as an optimisation process for video. The smaller number of connections in comparison with a fully networked neural network allows for the number of connections between neurons to scale in a substantially linear fashion.

Alternatively, in some embodiments neural networks can be use that are fully connected or not fully connected but in different specific configurations to that described in relation to Figure 2b.

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Further, in some embodiments, convolutional neural networks are used, which are neural networks that are not fully connected and therefore have less complexity than fully connected neural networks. Convolutional neural networks can also make use of pooling or max-pooling to reduce the dimensionality (and hence complexity) of the data that flows through the neural network and thus this can reduce the level of computation required. In some embodiments, various approaches to reduce the computational complexity of convolutional neural networks can be used such as the winograd algorithm or low-rank matrix approximations.

End-to-end Super Resolution Enhancement Model Generation & Reconstruction

Although initially designed to enhance single image frames, super resolution techniques can also be used on multiple frames in some embodiments. To apply these techniques in such embodiments, multiple low-resolution frames can be gathered together and the sub-pixel shifts between the individual frames can be used to create a higher resolution image than the original. In such embodiments, a series of frames can be combined to form a higher resolution video than was originally provided.

To improve on the above described dictionary-based approach for encoding and decoding video using super resolution techniques, in at least some embodiments it is proposed to use deep learning techniques and convolutional neural network models instead of dictionary learning techniques and dictionary-based models.

Dictionary learning is closely related to sparse coding techniques, while deep learning is only more loosely connected with sparse coding. Sparse coding is an effective mechanism that assumes any natural image can be sparsely represented in a transform domain. Sparse coding is a technique used to automatically find a small number of representative patterns which, when combined in the right proportions, reproduce the original input patterns. The sparse coding for an input then consists of those representative patterns. From a signal processing perspective, it follows that complicated signals can be broken down into a small, i.e. sparse, number of simple signals.

The transform domain can be a dictionary of image atoms, which can be learnt through a training process known as dictionary learning that tries to discover the correspondence between low-resolution and high-resolution sections of images (or "patches"). Dictionary learning uses a set of linear representations to represent an image

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and where an over-complete dictionary is used, a plurality of linear representations can be used to represent each image patch to increase the accuracy of the representation.

In at least some embodiments, instead it is proposed to use machine learning with deep learning techniques that can instead create non-linear representations of an image or sequence of images.

When using machine learning and sparse coding principles, a training process is used to find optimal representations that can best represent a given signal, subject to predetermined initial conditions such as a level of sparsity.

When using convolutional neural networks in at least some embodiments, the efficiency in terms of computational and memory cost can be important.

In some embodiments, convolutional neural network models (or hierarchical algorithms) can be transmitted along with the low-resolution frames of video data because the convolutional neural network models reduce the data transmitted in comparison with learned dictionaries being transmitting along with the low-resolution images, especially in comparison to transmitting learned over-complete dictionaries with the low-resolution images, in the case where the models and dictionaries have the same level of reconstruction accuracy.

The convolutional neural network models of some embodiments allow the reconstruction process and image representation to be non-linear. This is in contrast to the dictionary-based approach, which represents images in a linear fashion, as described above. The convolutional neural network models of some embodiments offer reconstruction with a feed-forward mechanism based on image convolution that is able to be computed in parallel and for which methods with high computational speed are available, such as the AMD® Tiled Convolution approach which can be used for fast image filtering.

The series of convolutions in a convolutional neural network model of some embodiments allow the neural network to be used to search for pixel correlations in a region far larger than the initial patch decomposition, but applying a weighting to weaken the importance of correlations for locations further away from the pixel of interest. In contrast, linear sparse coding approaches like dictionary learning are restricted to looking for correlations in an initial patch size, to avoid the computational complexity of searching the entire image. As a result, the method of these embodiments can more fully exploit the natural or non-local redundancies of the video frames and between a sequence of video frames.

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In some embodiments, optionally the convolutional neural network models only assume local spatial or spatio-temporal correlations in an image or video. This assumption is in contrast to the assumption that small data patches must be well represented by a restricted number of atoms from a dictionary, which is a sparsity constraint applied to dictionary learning and over-complete dictionary approaches.

In some embodiments, recurrent neural network models can be used. Recurrent neural network models have single layers that are used iteratively. The layers of a recurrent neural network model can be unrolled into a number of layers in order to be treated in a similar fashion to convolutional neural networks, in some embodiments.

Referring now to Figures 3 and 5, a technique that can be used in method, apparatus and/or system embodiments to encode video data will now be described in detail.

Original video data 70 is a high-resolution video, for example having a resolution of 1920 pixels by 1080 pixels (also known as "1080p" video) or 3840 pixels by 2160 pixels (also known as "4K" video). This video data can be encoded in a variety of known video codecs, such as H.264 or VP8, but can be any video data that can be decoded into the component frames of the video. The original video data 70 is provided as input visual data for encoding using the technique.

The original video data 70 is then split into single full-resolution frames at step 80 (or step 190), i.e. into a sequence of images at the full resolution and/or quality of the original video data 70. For some video codecs, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

Optionally, at step 90 (or step 190), in some embodiments the full-resolution frames can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection". The video data is split or clustered into scenes to enable more specific training and optimisation. By scene, it is meant a consecutive group or sequence of frames, which at the coarsest level can be the entire video, a single frame or at the most granular level can be or a section/segment of a frame.

The exact approach employed for splitting frames into scenes can be performed in many ways, depending on embodiment, with the four main approaches being described below:

A first approach is the use of the frame-type groupings of the underlying video codec. In this approach, a scene is defined in the encoded video by each group of pictures (sometimes referred to by the abbreviation "GoP"), for example between two I-

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frames. This is probably the simplest approach for scene selection and does not require much additional computation to perform scene analysis of the video, but the approach does not allow any flexibility in the level of granularity in the definition of each scene.

The second approach is the use of a scene or shot transition detector, for example as described in the paper "A Unified Model for Techniques on Video-Shot Transition Detection" by Jesús Bescós, Guillermo Cisneros, José M. Martínez, José M. Menéndez, and Julián Cabrera as published in IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 7, NO. 2, APRIL 2005 on pages 293-307 which is incorporated herein by reference. This approach proposes a unified detection model to detect camera-shot transitions in video, detecting both abrupt and gradual camera-shot transitions.

The third approach is the use of a clustering approach after applying an unsupervised learning or dimensionality reduction approach such as K-means clustering or manifold learning or Principle Component Analysis (PCA) etc. A suitable K-means clustering approach is detailed in the paper "Constrained K-means Clustering with Background Knowledge" by Kiri Wagstaff, Claire Cardie, Seth Rogers and Stefan Schroedl as published in the Proceedings of the Eighteenth International Conference on Machine Learning, 2001, p. 577-584. A suitable manifold learning approach is proposed in the paper "Algorithms for manifold learning" by Lawrence Cayton published on June 15, 2005. Both of these papers are herein incorporated by reference.

The fourth approach is to use a range of predefined scene classes and then automatically classifying scenes using the predefined classes. Examples of this approach can be found in the paper "Nonparametric Scene Parsing: Label Transfer via Dense Scene Alignment" by Ce Liu, Jenny Yuen and Antonio Torralba having IEEE reference 978-1-4244-3991-1/09 and the paper "80 million tiny images: a large dataset for non-parametric object and scene recognition" by Antonio Torralba, Rob Fergus and William T. Freeman. Both of these papers are herein incorporated by reference.

The exact approach for how a scene is defined is independent from the rest of the approach, and will vary by embodiment, although it will have an impact on the training time and the reconstruction performance so there is a level of optimisation required for each possible embodiment to find a balance between the speed and the accuracy of the scene detection step.

Alternatively, no scene matching needs to be performed at step 90 (or step 190) in some embodiments. A further alternative for some embodiments is to perform only very basic time-stamping of the video, to determine how to reassemble the video frames

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for later stages in the technique, for example during transmission or during playback of the video.

Regardless whether the video has been broken into frames or scenes (i.e. groups of multiple frames) in step 90 (or step 190) or remains as a sequence of frames from step 80 (or step 190), each frame is down-sampled into lower resolution frames at a suitably lower resolution. Optionally, in some embodiments this step can occur before the frames are grouped into scenes in step 80 (or step 190), so step 90 (or step 190) can be exchanged with step 90 (or step 190) in these alternative embodiments. The lower-resolution frame can, for example, be 33% to 50% of the data size relative to the data size of the original-resolution frame, but in should be appreciated that in embodiments the lower resolution can be any resolution that is lower than the original resolution of the video.

In step 110 (or step 200), in at least one embodiment super resolution techniques are employed to create a specific model using machine learning for each frame, so that the model can be used to substantially recreate the original resolution version of a lower-resolution frame and trained using machine learning based on knowledge of the original-resolution frame. This step is termed the training and optimisation process. In some embodiments, generic models can be developed for types of scene or frame. Alternatively, in other embodiments, models can be developed for each scene.

By employing a deep learning approach to generating the model in embodiments, a non-linear hierarchical model can be created in some of these embodiments to reconstruct a higher-resolution frame from the lower-resolution frame.

An example of a deep learning approach, but in respect of only still images and without use of the original image to optimise the reconstruction model, is described in the paper "Learning a Deep Convolutional Network for Image Super-Resolution" by Chao Dong, Chen Change Loy, Kaiming He, and Xiaoou Tang published in D. Fleet et al. (Eds.): ECCV 2014, Part IV, LNCS 8692, pp. 184–199, 2014 and this paper is incorporated herein by reference. This paper relates to using super resolution techniques when trying to obtain an unknown high resolution version of a given low resolution image and proposes the use of a convolutional neural network to learn mappings between low resolution and high resolution images.

While the creation of non-linear hierarchical models is more computationally complex than creating linear models using dictionary learning approaches, in at least some embodiments it can be more flexible. Further, the non-linear models created in

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some of these embodiments can use only a few coefficients to enable reconstruction in comparison to the dictionary-based approach, thus such models can require less data to be transmitted. Still further, the non-linear models used in some embodiments can be more accurate in reconstructing higher-resolution frames than dictionary-based approaches. The non-linear models created in some embodiments are small convolutional neural networks rather than over-complete dictionaries. In contrast to the local patch averaging approach that tends to be used in reconstruction by dictionary learning approaches, the use of a convolutional neural network model in embodiments also allows a more appropriate filter to be learned for final reconstruction where neighbouring patches are considered, which can avoid unintended smoothing of the reconstructed higher-resolution image.

The training and optimisation process in embodiments can be configured according to a desired trade-off between computational time spent and desired quality of results. In general, the number of iterations used during the training process yields approximately logarithmic gains in reconstruction accuracy, so in some embodiments it is preferred to use an automatic threshold to stop further optimisation. When favouring quality of results in embodiments, the automatic threshold can be set to a predetermined value of reconstruction error, for example by calculating the mean squared error, but other methods can be used. Alternatively, in some embodiments the automatic threshold can be set to limit the training and optimisation process to a predetermined number of iterations. As a further alternative, in some embodiments a combination of these two factors can be used.

In some embodiments, step 120 (or step 210), the portion of the low-resolution video and the reconstruction model for that portion of video are output for transmission. Optionally, in some embodiments the video and model can be stored together within a suitable data container format such as a Matroska Multimedia Container (otherwise known as a MKV container). Alternatively, in some embodiments the video and model can be combined with other sections or the entire video and placed into a suitable data container format. In some embodiments, at step 120 (or step 210), the low-resolution video frames can be re-encoded using either the original video codec applied to the original video data 70 or, alternatively, a more optimal video codec can be applied to the video data to produce output video data 130. Optionally, if scene detection or time stamping was performed, in some embodiments the data output for transmission can include either a list of scenes or time stamp data respectively, or this data could be stored within the data container.

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In embodiments there can be a number of variations to the encoding framework described above. For the above described technique, it can be assumed in many embodiments that there would be a one-to-one mapping between scene and model, however this does not need to hold true as a local cluster of scenes could be used to train each model in some embodiments. Conversely, it could also be possible in some embodiments to use several similar models to initialise (by way of a weighted average) initial parameters for training new unseen scenes. It may also be sufficient to simply weight the models without requiring any further optimisation in some embodiments - similar to label fusion methods used in medical imaging for example.

Referring now to Figures 4 and 6, embodiments for reconstructing the video encoded using the technique will now be described in detail.

First, the data 130 is received from the network. In embodiments, the data received 130 depends on how the data was prepared for transmission in step 120 (or 210) as detailed above in the various possible embodiments and the prepared data can include the video data and one or more reconstruction models for that video data. In some embodiments, it is possible that the video data and one or more reconstruction models are not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required to decode or reconstruct the higher-resolution video from the data transmitted over the network.

At steps 140 and 150 (and step 220), the received data is prepared for reconstruction depending on the embodiment. In most embodiments, this step involves separating the low-resolution video from the reconstruction models (step 220). Optionally, in some embodiments the low-resolution video is decompressed using the video codec used for transmission into full-resolution image frames (step 230) and each of the frames is matched up with the corresponding reconstruction model, which are also unpacked into frame-by-frame order (step 240).

At step 160 (step 250), the reconstruction model is applied to each of the frames to output higher-resolution frames depending on the embodiment. The reconstruction, or decoding, process in most embodiments involves applying the optimised super resolution convolutional neural network model, or reconstruction model, for each scene in order to restore the lower-resolution video to its original resolution having substantially the same quality as the original high-resolution video. Given the corresponding models for each lower-resolution frame, the original higher-resolution frames can be reconstructed with high accuracy for at least some of these embodiments.

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The complexity of the reconstruction process can be far simpler, i.e. require less computation, when compared to that of training the model in most embodiments. In most embodiments, the reconstruction process is very similar to a single iteration of the training process, however there is no optimisation required and the process simply applies the learnt convolutional neural network model to reconstruct the image on a patch-by-patch basis. In some embodiments, a singular model is applied to each scene and can be sent as accompanying data in the video container ahead of the scene in which it is used. In some embodiments, the model associated with each scene can either be indexed in a data stream, synchronised with the video and audio stream, or indexed in a frame-to-model look-up table which can be sent ahead of the video stream depending on the embodiment.

The image reconstruction in most embodiments has a linear computational complexity, dependent on the total number of pixels of each frame, as the reconstruction process requires a series of convolution functions (typically less than 3) to be applied for each relevant image patch centred around each pixel. A basic reconstruction step for each image is as described in the paper "Learning a Deep Convolutional Network for Image Super-Resolution" by Chao Dong, Chen Change Loy, Kaiming He, and Xiaoou Tang published in D. Fleet et al. (Eds.): ECCV 2014, Part IV, LNCS 8692, pp. 184–199, 2014, and this step can be used with or without modification in some embodiments however, in some of these embodiments these functions can be applied in parallel across multiple images and in some embodiments it can be feasible to perform real-time reconstruction for video playback.

Super resolution operates on a patch-by-patch basis in most embodiments, but it may not be necessary to perform super resolution for every single patch of an image in some embodiments. In some embodiments, where the patch is flat and smooth, using a bi-cubic upscaling can be sufficient. It may be faster in some embodiments, for both training and reconstruction, if these patches could be bypassed. To identify these patches, one approach as set out in the paper "Coupled Dictionary Training for Image Super-Resolution" by Jianchao Yang, Zhaowen Wang, Zhe Lin, Scott Cohen and Thomas Huang (as published in IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 21, NO. 8, AUGUST 2012), incorporated by reference, can be used in some embodiments to filter out patches which have low variances and ignoring these areas of the image. Alternatively, in other embodiments edge detectors could be used instead to identify areas of interest.

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Further still, in some embodiments some level of inter-frame comparison can be used to identify regions of the image which do not change from frame to frame, thereby eliminating areas of the image from duplicating the efforts of super resolution reconstruction which occur in a previous frame. In these embodiments the underlying video code for the low-resolution video can be used to identify the regions of change as part of its inter-frame compression mechanism and this information could be taken advantage for more efficient real-time super resolution reconstruction and video playback. In addition, in some embodiments an auxiliary data-structure, such as a random fern, can be used to keep track of the uniqueness of patches that have been reconstructed. Given that an image may contain many repeating patches, use of this approach in some embodiments could prevent unnecessary reconstruction of patches whereby the result is already known (in another patch). Similar approaches have been used in key frame detection for real-time camera localisation for augmented reality applications.

The proposed method and system of encoding and decoding video of at least some of the embodiments can augment existing video compression and decompression codecs. By using the same codec as used to create the video data, the low resolution video that is transmitted can be encoded with the same video codec but at a lower resolution that that of the original in some embodiments. Thus, in some embodiments the proposed method and system can be independent of the original codec used to create and compress the video. Alternatively, in some embodiments it is possible to select an alternative codec for transmission and to re-encode the video back into the original codec when the video data has been transmitted, uncompressed and restored to a high resolution version of the original video data.

By incorporating, for example in some embodiments, image enhancement techniques into a video compression process, a reduction in resolution of the video during transmission can be achieved and thus lower amounts of data are transmitted because the image can be enhanced at the node receiving the reduced-resolution video to recreate the video at the original resolution. By using super resolution as the image enhancement technique in such embodiments, and with the knowledge of the original high-resolution image before applying image enhancement techniques, it is possible to down-sample the original high-resolution image to a lower-resolution image and choose one or more representations from a library of representations that can be used to create a high-resolution image from the down-sampled image based on the knowledge of the original image. In such embodiments, this results in only a down-sampled image and the

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super resolution reconstruction model or parameter being transmitted over a network instead of the original high resolution video, thus decreasing the amount of data transferred while maintaining a similar level of image quality relative to the original once the high-resolution image has been recreated.

At step 170, in some embodiments each of the segments of video are output from the reconstruction process as higher-resolution frames at the same resolution as the original video 70. In these embodiments, the quality of the output video 180 is substantially similar to that of the original video 70, within the error bounds optionally applied by the machine learning process that develops the reconstruction model at step 110 (or step 200) of the encoding process.

At step 180, in some embodiments the segments of video are combined such that the video can be displayed. Optionally at step 170 or 180, in other embodiments the video can be re-encoded with the original codec used on the original video 70 or a more predetermined optimal codec, to enable playback on a decoder or display device.

In most embodiments, the proposed technique does not perform conventional compression by rearranging the original data and discarding redundant data or data deemed to be of least importance such that the majority of the data is intact. Instead, in these embodiments the technique determines a series of simple light-weight functions through machine learning that can be used to reconstruct the original data while minimising the reconstruction error given some pre-defined cost function (a number of optimisation or search frameworks common to machine learning can be used, such as gradient descent or stochastic gradient descent). Thus, it follows that the technique of these embodiments can be described as an optimisation process of the reconstruction functions rather than the data redundancy/reduction process of conventional compression techniques.

Sub-Pixel Convolution

Referring now to Figures 3 and 5, embodiments using another technique to encode visual data will now be described in detail. These embodiments can be used in combination with other embodiments and alternative and optional embodiments described elsewhere in this specification.

Again, in these embodiments, original video data 70 is provided into the method or system and is a high-resolution video, for example having a resolution of 1920 pixels by 1080 pixels (also known as "1080p" video) or 3840 pixels by 2160 pixels (also known

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as "4K" video). This video data can be encoded in a variety of known video codecs, such as H.264 or VP8 but can be any visual data for which the system or method is able to decode into the component sections.

The original video data 70 is then split into single full-resolution frames at step 80 (or step 190), i.e. into a sequence of images at the full resolution of the original video data 70. For some video codecs, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

Optionally, at step 90 (or step 190), the full-resolution frames can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection". The video data is split or clustered into scenes to enable more specific training and optimisation. By scene, it is meant a consecutive group or sequence of frames, which at the coarsest level can be the entire video or at the most granular level can be a single frame.

To super resolve a low-resolution image to high-resolution space, it is necessary to increase the dimensionality of the low-resolution image to match that of the high-resolution image at some point during the operation of the example based model or convolutional neural network. By upscaling the low-resolution image to a high-resolution as an input to an example-based model, the example-based model does not need to learn the super resolution filters to perform upscaling from the low-resolution space to a high-resolution space but this approach can sacrifice reconstruction accuracy and introduces computational complexity as all subsequent processing must occur at the high resolution dimensionality.

Referring to Figure 7, there is shown an efficient sub-pixel convolutional neural network (ESPCN) 700 having a low-resolution input image 710 with two feature map extraction layers 720, 730 built with convolutional neural networks and a sub-pixel convolution layer 740 that aggregates the feature maps from low-resolution space and builds the super resolution image 750 in a single step.

In an embodiment, as shown in Figure 7, the high-resolution data is super resolved from the low-resolution feature maps only at the very end of the network, in the final or last layer of the network, therefore avoiding the need to perform most of the computation in the larger high-resolution dimensionality. As processing speed depends substantially directly on the input image dimensionality, operation in the low-resolution space will allow for faster processing. Further, by performing feature map extraction before upscaling, more complex and more accurate upscaling (i.e. additional

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reconstruction accuracy) is possible by the final or last layer of the network as an upscaling or resampling function can be learned and is content and data adaptive as compared to the applying an explicit generic or handcrafted interpolation filter to perform upscaling (for example, a bicubic interpolation filter) that is heuristically chosen beforehand.

The task of the example based model, in some embodiments a single image super resolution network, is to estimate a high resolution image given a low resolution image that is downscaled or downsampled from a corresponding high resolution image. In some cases, for example video compression,the down sampling operation can be deterministic and known: to produce the low resolution image from the high resolution image, the high resolution image can be convolved using a Gaussian filter (but other filters can be used), thus simulating a point spread function in a camera, then downsampled by a upscaling ratio r. However general super resolution and upscaling are typically not deterministic and in some embodiments, in order to mitigate for non-deterministic operations, training can be performed for a range of different down sampling operations. In other embodiments, estimation can be performed, for example by training a classifier or some visual comparison, and optionally this could be parametised for the super resolution process in some embodiments. In general, both the low and high resolution image have C colour channels, thus can be represented as real-valued tensors of size $H \times W \times C$ and $rH \times rW \times C$ respectively. In some embodiments, rather than recovering an high resolution image from an upscaled and interpolated version of the low resolution image, instead the low resolution image is used by a three layer convolutional network to avoid upscaling before the low-resolution image is fed into the network. In the network, a sub-pixel convolution layer is applied to upscale the low resolution feature maps to produce a high resolution image using super resolution.

For a network composed of L layers, the first $L-1$layers can be described as follows:

$$f^1(\boldsymbol{I}^{LR}; W_1, b_1) = \emptyset\,(W_1 * \boldsymbol{I}^{LR} + b_1),$$
$$f^l(\boldsymbol{I}^{LR}; W_{1:l}, b_{1:l}) = \emptyset\,(W_1 * f^{l-1}(\boldsymbol{I}^{LR}) + b_l),$$

where $W_l, b_l, l \in (1, L-1)$ are learnable network weights and biases respectively. W_l is a 2D convolution tensor of size $n_{l-1} \times n_l \times k_L \times k_L$, where n_l is the number of features at level l, $n_0 = C$, and k_l is the filter size and level l. The biases b_l are vectors

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of length n_1. The non-linearity function $\emptyset$ applies element-wise and is fixed. The last layer f^1 has to convert the low resolution feature maps to a high resolution image I^{SR}.

In an embodiment, the high-resolution data is super resolved from the low-resolution feature maps by a sub-pixel convolution layer, to learn the upscaling operation for image and video super resolution. If the last or final layer performs upscaling, feature extraction occurs through non-linear convolutions in the low-resolution dimensions, so a smaller filter size can be used to integrate the same information relative to doing so in the high-resolution dimensions thus reducing computational complexity.

In an embodiment, the convolutional neural network consists of a plurality of non-linear mapping layers followed by a sub-pixel convolution layer. The benefit is the reduced computational complexity compared to a three-layer convolutional network used to represent the patch extraction and representation, non-linear mapping and reconstruction stages in the conventional sparse-coding-based image reconstruction methods and using an upscaled and interpolated version of the low-resolution input. The convolutional neural network of the embodiment uses learned filters on the feature maps to super resolved the low-resolution data into high-resolution data (instead of using hand crafted interpolation or a single filter on the input images/frames).

Instead of using a deconvolution layer to recover resolution from max-pooling and other image down-sampling layers, according to some embodiments upscaling of a low-resolution image is performed by convolution.

In an embodiment, convolution is performed with a fractional stride of $\frac{1}{r}$ in the low-resolution space, which can be implemented by interpolation, perforate or un-pooling from low-resolution space to high-resolution space followed by a convolution with a stride of 1 in high-resolution space.

In another embodiment, convolution with a stride of $\frac{1}{r}$ in the low-resolution space is performed with a filter W_d of size k_s with a weight spacing $\frac{1}{r}$ to activate different parts of W_d for the convolution. The weights that fall between the pixels are not activated and therefore not calculated. The number of activation patterns is r2 and each activation pattern, according to its location, has at most $\left(\frac{k_s}{2}\right)^2$ weights activated. These patterns are periodically activated during the convolution of the filter across the image depending on different sub-pixel: mod (x, r), mod (y, r) where x, y are the output pixel co-ordinates in high-resolution space. In the situation where mod (k_s, rks) = 0, for a neural network with l layers, the low-resolution feature maps $f^{l-1}(I^{LR})$ from the last non-linear mapping layer

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are aggregated to produce the final estimate of the high-resolution image $f^L(I^{LR})$ using the following formula:

$$I^{SR} = f^L(I^{LR}) = PS\,(W_L * f^{L-1}(I^{LR}) + b_L$$

where W_L and b_L represent learnable filters and biaises respectively. The final convolution filter W_L is of size $n_{L-1} \times r^2C \times k_L \times k_L$, where C is the number of colour channels in the original image and r the resampling ratio. PS is a periodic shuffling operator. Thus, after the convolution, but before applying PS, we have a tensor that has dimension $rH \times rW \times C \cdot r^2$, where h and v are horizontal and vertical dimensions of the high-resolution image. The result of applying PS is a $rH \times rW \times C$ array, i.e. the same dimensions as the high-resolution image. This is achieved by periodic shuffling PS described in the following way:

$$PS(T)_{x,y,c} = T_{\lfloor x \rfloor, \lfloor y \rfloor, c \cdot r \cdot mod(y,r) + c \cdot mod(x,r)}$$

It is easy to see that when $k_L = \frac{k_S}{r}$ and $mod\,(k_S, r) = 0$it is equivalent to sub-pixel convolution in the low-resolution space with the filter W_d. This last layer, or sub-pixel convolution layer, produces a high resolution image from the low resolution feature maps directly, with a more distinguishable filter for each feature map and can operate with increased efficiency as the operation of the periodic shuffling described can be processed in parallel in a single cycle.

Given a training set consisting of high resolution image examples $I_n^{H\,R}, n = 1 \ldots N$, the corresponding low resolution images $I_n^{L\,R}, n = 1 \ldots N$ are generated, and the pixel-wise mean squared error (MSE) of the reconstruction is calculated as an objective function to train the network:

$$l(W_{1:L}, b_{1:L}) = \frac{1}{r^2 HW} \sum_{x=1}^{rH} \sum_{x=1}^{rW} (I_{x,y}^{H\,R} - f_{x,y}^{L}(I^{LR}))^2$$

Referring to Figure 8, there is shown a network architecture 800 for super resolution using three input frames 810a, 810b and 810c (and then 810b, 810c and 810d). Only the input layer of the neural network is modified to jointly handle three input frames for the super resolution prediction of only the middle frame 830b (or 830c). The hidden layers 820a, 820b) are identical to those shown in Figure 7.

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As shown in Figure 8, in an embodiment, spatio-temporal convolutions are performed in the initial layer of the neural network. Using a spatio-temporal input layer as an extension of the network to handle video data allows reconstruction performance to be improved for video data by exploiting the temporal redundancy between consecutive frames in a video.

In some embodiments, the settings $I = 3$, $(f_1, n_1) = (5, 64)$, $(f_2, n_2) = (3, 32)$, and $f_3 = 3$ can be used. In the training phase of these embodiments, $17r \times 17r$ pixel sub-images were randomly selected from the training ground truth images I^{HR}, where r is the upscaling factor. In other embodiments, other parameters can be chosen based on the available computing hardware and/or training time. To synthesise the low resolution samples I^{LR}, I^{HR} were blurred using a Gaussian filter in these embodiments and were sub-sampled by the upscaling factor. In these embodiments, the sub-images were extracted from original images with a stride of $(17 - \sum \bmod (f, 2)) \times r$ from I^{HR} and a stride of $(17 - \sum \bmod (f, 2))$ from I^{LR}. In other embodiments, arbitrary sized sub-images can be selected: smaller sub-images can enable faster updates in training (as updates can be made faster since fewer convolutions are required per sub-image) and can also allow more individual training examples to be used and can further allow an increase in representations; while larger sub-images can be more process-efficient for batch systems, particularly where there is sufficient training data available. It can be noted that in most embodiments the lower limit on sub-image size is dependent on the filter sizes used in a neural network while the upper limit is memory- and dataset- related. This ensures that all pixels in the original image appear once and only once as the ground truth of the training data. $\tanh$ may be used as the activation function in these embodiments. In some embodiments, the training may stop after no improvement of the cost function is observed after 100 epochs. In some of these embodiments, the initial learning rate may be set to 0.01 and final learning rate may be set to 0.0001 and updated gradually when the improvement of the cost function is smaller than a threshold μ.

In some embodiments, the network is adapted for video super-resolution with a modification to the input layer. Instead of handling single frames independently, consecutive frames are jointly processed by feeding the consecutive multi-frame data such that the input can be expressed or converted into a three-dimensional vector of corresponding patches from multiple frames such that the temporal changes between consecutive frames are captured to the network. In an alternative embodiment, fixed temporal sampling can be used where videos have varying or different framerates,

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optionally selecting the lowest frame rate when the network is trained. After patch extraction, the data is processed by hidden layers through the network and results in an output layer producing a single frame of high-resolution image corresponding to the network prediction of the middle frame in the input consecutive frames. In some alternative embodiments, there are both multiple input frame and multiple output frames.

In use for video processing, blocks of 3, 5 and 7 (or more) consecutive video frames may be used to super resolve the middle frame or frames. It should be noted that an increased number of frames could become impractical as each additional frame provides decreasingly less of a gain in accuracy. In order to handle the first and last frames of videos that do not have enough neighbouring frames to form a block of consecutive frames, the first and last frame may be repeated 1, 2 and 3 times respectively. The peak signal to noise ratio (PSNR) may be used as the performance metric to evaluate the models used.

Referring now to Figures 4 and 6, an embodiment for reconstructing the video encoded using the technique will now be described in detail.

First, the data 130 is received from the network. The data received 130 depends on how the data was prepared for transmission in step 120 (or 210) as detailed above and will include the video data and one or more reconstruction models for that video data. It is possible that the video data and one or more reconstruction models are not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required to decode or reconstruct the higher-resolution video from the data transmitted over the network.

At steps 140 and 150 (and step 220), the received data is prepared for reconstruction. This step generally involves separating the low-resolution video from the reconstruction models (step 220). Optionally, the low-resolution video is decompressed using the video codec used for transmission into full-resolution image frames (step 230) and each of the frames is matched up with the corresponding reconstruction model, which are also unpacked into frame-by-frame order (step 240).

At step 160 (step 250), the reconstruction model is applied to each of the frames to output higher-resolution frames. The reconstruction, or decoding, process involves applying the optimised super resolution convolutional neural network model, or reconstruction model, for each scene in order to restore the lower-resolution video to its original resolution having substantially the same quality as the original high-resolution video. Given the corresponding models for each lower-resolution frame, the original higher-resolution frames can be reconstructed with high accuracy.

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In a further embodiment, at least a portion of the process described within Figure 3 can take place within a 'cloud computing' system. In this embodiment, original video data 70 is transmitted to an off-site computing system wherein one or more of the processes outlined in this specification take place. A different section of video data may be processed in parallel on the off-site computing system. The limit of the number of sections of video processed in parallel is dependent on the computational complexity of the sections of video and the processing power of the cloud servers. Once the cloud-based processing is complete, data can be transmitted back to a local computing system. The cloud service can be used as a real-time relay server, receiving lower-resolution videos, the resolutions of which are then to be increased before being re-transmitted. This arrangement can relay data from bandwidth-restrained locations to locations where there is not such a constraint on bandwidth.

In a further embodiment, the training process for the example based models takes place exclusively for the reconstruction of the high-frequency components of the higher-resolution section of video. The results may then be added as a residue to a section of video reconstructed using bi-cubic interpolation.

In a further embodiment, the architecture of any convolutional neural networks used in the reconstruction process is amended such that the upscaling, in terms of physically changing the number of pixels, occurs in the middle or the last layer of the network by way of a deconvolution function. The first layer of the network is described as obtaining low resolution features whilst the high resolution features are only learnt in the last layer. It is not necessary to learn the low resolution features in a high resolution space. By keeping the resolution low for the first couple of layers of convolutions, the number of operations required can be reduced. The computational performance then depends more on the resolution of the input rather than resolution of the output. Alternatively, the network layers can be reorganised such that the output of the sub-pixel convolution layer of the convolutional neural network (which can be the last layer or a preceding layer, depending on the embodiment) predicts the square of the upscaling factor number of pixels (e.g. r^2) instead of the number of upscaling factor pixels (e.g. r). The other pixels represent the neighbouring pixel to the original input pixel in low resolution. Every 4 pixels must then be reshaped and reordered to form the high resolution image. A higher video processing speed can be obtained using this approach whilst maintaining a high level of quality for the output. The number of convolutions required is therefore reduced. This embodiment may be used in conjunction with any other embodiment.

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In some and other embodiments, a neural network can have multi-stage upscaling (or other function) where an earlier layer upscales and then a later layer upscales, for example a middle layer upscales by 2x and then the last layer upscales by 2x. This type of "chained" approach can allow for neural networks to be trained in a long network (or "chain") of functional layers, for example having a range of upscaling factors (e.g. 2x, 3x and 4x) with multiple upscaling layers and output layers. One of more of these layers can be sub-pixel convolution layers of the described embodiments.

The complexity of the reconstruction process is far simpler compared to that of training the model. The process is very similar to a single iteration of the training process however there is no optimisation required and it is simply applying the learnt convolutional neural network model to reconstruct the image on a patch-by-patch basis. The size of a single patch may vary, according to the resolution requirements of the output section of video. The patch size will be determined offline via hyper-parameter optimisations when training models. Generally, a larger patch size will reduce the computational requirements for processing a section of video, and also reduce the bandwidth required to transmit the section of video. When bandwidth is particularly limited, the processing power of an end user terminal is low, or a user is willing to endure a lower quality section of video, the patch size may be increased to allow for video transmission under one or more of those circumstances. The quality of the reconstruction will be compromised but the processing power required at the end-user terminal will be significantly reduced.

A singular model is applied to each scene and can be sent as accompanying data in the video container ahead of the scene in which it is used. The model associated with each scene can either be indexed in a data stream, synchronised with the video and audio stream, or indexed in a frame-to-model look-up table which can be sent ahead of the video stream.

At step 170, each of the segments of video are output from the reconstruction process as higher-resolution frames at the same resolution as the original video 70. The quality of the output video 180 is substantially similar to that of the original video 70, within the error bounds optionally applied by the machine learning process that develops the reconstruction model at step 110 (or step 200) of the encoding process.

At step 180, the segments of video are combined such that the video can be displayed. Optionally at step 170 or 180, the video can be re-encoded with the original codec used on the original video 70 or a more predetermined optimal codec, to enable playback on a decoder or display device.

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The use of the final layer to perform super resolution can be used to perform upscaling for low-resolution images and/or video without knowledge of any original high-resolution content or where there is no higher-resolution content for the low-resolution images and/or video. Additionally, the use of the spatio-temporal approach can be used to perform upscaling for low-resolution images and/or video without knowledge of any original high-resolution content or where there is no higher-resolution content for the low-resolution images and/or video. Further, both the use of the final layer to perform super resolution and the use of the spatio-temporal approach can be used in combination to perform upscaling for low-resolution images and/or video without knowledge of any original high-resolution content or where there is no higher-resolution content for the low-resolution images and/or video. Specifically, some embodiments can use one or more generic example based models, for example selecting these from a library of generic example based models and for example applying some criteria in selecting such example based models, that use either or both of example based models having a final layer that performs super resolution and/or use a spatio-temporal approach in the input layer of the example based model.

Real Time Model Development/Selection

Referring now to Figure 27, an embodiment using the technique to encode visual data will now be described in detail. These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

Original video data 2740 can be provided into the method or system of the embodiment using a camera 2735 and usually comprises a high-resolution video, for example having a resolution of 1920 pixels by 1080 pixels (also known as "1080p" video) or 3840 pixels by 2160 pixels (also known as "4K" video). This video data can be encoded in a variety of known video codecs, such as H.264 or VP8, but can be any video data for which the system or method is able to decode into the component frames of the video depending on the embodiment.

In some embodiments, the original video data 2740 is then split into single full-resolution frames within step 150 i.e. into a sequence of images at the full resolution of the original video data 140. In some of these embodiments, for some video codecs, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential

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frames.

In some embodiments, model selection or at least initial model selection can be performed based on the uncompressed video data.

Optionally, within step 2750, in some embodiments the full-resolution frames can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection". The video data is split or clustered into scenes to enable more specific optimisation. By scene, it is meant a consecutive group or sequence of frames comprising a section of video, which at the coarsest level can be the entire video or at the most granular level can be a single frame. In some embodiments, the scenes can be arranged according to the order in which they were filmed or into a sequence for appropriate decoding of any group of pictures (as scenes will typically comprise related visual content and appropriate ordering can allow compression to work efficiently, for example).

In some embodiments, regardless whether the video has been broken into frames or scenes (i.e. groups of multiple frames) in step 150 or remains as a sequence of frames from step 140, each frame can down-sampled into lower-resolution frames at a suitably low resolution. Optionally, in some embodiments this step can occur before the frames are grouped into scenes in step 150. In some embodiments, the lower-resolution frame is optionally 33% to 50% of the data size relative to the data size of the original-resolution frame, but can be any resolution that is lower than the original resolution of the video. In other embodiments, the quality can be reduced by quantisation and/or compression instead of reducing the resolution of the visual data or in addition to reducing the resolution of the visual data.

At step 2755, a scene is selected in some embodiments. In this embodiment used for real-time encoding, this scene can initially be the first frame chronologically that was recorded by the camera 2735, or the first frame appearing in the original video file 2740. Following this frame, a second frame to be recorded or a second frame appearing in the original video file 2740 can next be selected. After that would appear a third frame, and so on, until the broadcast was complete.

A first example based model is taken from a library of example based models and analysed for use in the reconstruction of data in step 2760. A second example based model can be taken and analysed in parallel in step 2770, as can a third example based model as shown in step 180. There is no fixed upper limit to the variable n, variable n being the number of example based models which can be analysed in parallel, where n is at least two.

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In step 2795, the most accurate example based model is chosen to be used for the reconstruction of data. The most accurate example based model can be defined as an example based model which would result in the highest quality of reconstruction, wherein quality can be defined using any of: an error rate; a peak signal-to-noise ratio; or a structural similarity index when compared to the original video file 2740.

In step 210, the lower-resolution scene and the example based model for the reconstruction of that scene are output for transmission over a network. Optionally, a reference to the model can be transmitted in lieu of the actual model. This requires a synchronised or matched library at both the transmitting and receiving nodes of the process, such that the reference can be used by the library at the transmitting node, and the model identified from the reference to the same model in the library at the receiving node as in the library at the transmitting node.

Optionally, the video and model (or model reference) can be stored together within a suitable data container format such as a Matroska Multimedia Container (otherwise known as a MKV container). Alternatively, the video and model can be combined with other sections, or the entire video and placed into a suitable data container format. At step 210 the low-resolution video frames can be re-encoded using either the original video codec applied to the original video data 2740 or, alternatively, a more optimal video codec can be applied to the video data to produce a smaller output file. Optionally, if scene detection or time stamping was performed, the data output for transmission can include either a list of scenes or time stamp data respectively, or this data could be stored within the data container.

There can be a number of variations to the encoding framework described above. For the above described technique, it can be assumed that there would be a one-to-one mapping between scene and example based model, however this does not need to hold true as each scene could be accompanied by more than one example based model.

Referring now to Figure 5, an embodiment for reconstructing the video encoded using the technique will now be described in detail.

First, the transmitted data 210 is received from the network. The data received 210 depends on how the data was prepared for transmission in step 2750 as detailed above and will include the video data and one or more reconstruction models for that video data. It is possible that the video data and one or more reconstruction models are not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required to decode or reconstruct the higher-resolution video from the data transmitted over the network.

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At step 220, the transmitted data is prepared for reconstruction. This step comprises separating the low-resolution video from the one or more example based models. Optionally, the low-resolution video is decompressed using the video codec used for transmission into full-resolution image frames and each of the frames is matched up with the corresponding reconstruction model, which are also unpacked into frame-by-frame order.

At step 250, the reconstruction model is applied to each of the scenes to output higher-resolution scenes. The reconstruction, or decoding, process involves applying the optimised super resolution convolutional neural network model, or reconstruction model, for each scene in order to restore the lower-resolution video to its original resolution having substantially the same quality as the original high-resolution video. Given the corresponding models for each lower-resolution scene, the original higher-resolution scenes can be reconstructed with high accuracy, where accuracy is defined as above.

This embodiment of the invention requires no optimisation, and comprises applying a previously learnt example based model to reconstruct a scene, and does not necessarily include any adaptation or modification of the existing example based models in the library. The one or more example based models associated with each scene can be indexed in a data stream, synchronised with the video and audio stream, or indexed in a frame-to-model look-up table that can be sent ahead of the video stream.

The image reconstruction has a linear computational complexity dependent on the total number of pixels of each frame, as it requires a series of convolution functions (typically less than 3) to be applied for each relevant image patch centred around each pixel. The basic reconstruction step for each image can be used with or without modification in some embodiments from the approach described in the paper "Learning a Deep Convolutional Network for Image Super-Resolution" by Chao Dong, Chen Change Loy, Kaiming He, and Xiaoou Tang published in D. Fleet et al. (Eds.): ECCV 2014, Part IV, LNCS 8692, pp. 184–199, 2014, however these functions can be applied in parallel across multiple images and it is feasible to perform real-time reconstruction for video playback.

Within step 250, each of the segments of video is output from the reconstruction process as higher-resolution frames and at substantially the same resolution as the original video 2440.

Further within step 250, the segments of video are combined such that the video can be displayed. Optionally the video can be re-encoded with the original codec used on the original video 2740 or a predetermined more optimal codec, to enable playback

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on a decoder or display device.

In a further embodiment, at least a portion of the process described within Figure 27 can take place within a 'cloud computing' system. In this embodiment, the original video file 2740 is transmitted to an off-site computing system, preferably a scalable computing system, where the first scene is prepared 2750. As before, a plurality of example based models 2760, 2770, 2780, 2790 can then be analysed for their use in reconstruction of the data, before a most accurate model 2795 is chosen and a transmitted package 210 prepared. The transmitted package 210 is then sent from the cloud server to a local server, where the reconstruction process 220, 230, 240, 250 can take place. While the first scene is being processed in this way, a second section of video can be processed in parallel on the off-site computing system. The limit of the number of sections of video processed in parallel is dependent on the computational complexity of the sections of video and the processing power of the cloud servers. The cloud service can be used as a real-time relay server, receiving lower-resolution videos, the resolutions of which are then to be increased before being re-transmitted. This arrangement can relay data from bandwidth-restrained locations to locations where there is not such a constraint on bandwidth.

In a further embodiment, one or more sections of video are transmitted via the process outlined above, in advance of a live recording. Example based models that are likely to be useful can therefore be identified before they are required, and the library of models from which they are selected reduced to those more likely to be used. The selection procedure 2795 can therefore be made faster or with reduced computation, as there are fewer models to choose between, hence the lag between the recording of an event and the higher-resolution reconstruction being displayed can be reduced compared to comparing the performance of all of the models in the library of models.

Model Libraries

Referring now to Figure 25, an embodiment using another technique to encode visual data will now be described in detail. These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

Original video data 2510 is provided into the method or system using the technique and is a high-resolution video, for example having a resolution of 1920 pixels by 1080 pixels (also known as "1080p" video) or 3840 pixels by 2160 pixels (also known

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as "4K" video). This video data can be encoded in a variety of known video codecs, such as H.264, VP8 or VP9 but can be any video data for which the system or method is able to decode into the component frames of the video.

The original video data 2510 is then split into single full-resolution frames at step 2520, i.e. into a sequence of images at the full resolution of the original video data 2510. For some video codecs, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

Optionally, at step 2520, the full-resolution frames can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection". The video data is split or clustered into scenes to enable more specific training and optimisation. By scene, it is meant a consecutive group or sequence of frames, which at the coarsest level can be the entire video or at the most granular level can be a single frame.

Regardless of whether the video has been broken into frames or scenes (i.e. groups of multiple frames) or remains as a sequence of frames, each frame is down-sampled into lower resolution frames at a suitably lower resolution for transmission over a network, for example the Internet. Optionally, this step can occur before the frames are grouped into scenes in step 2520. The lower-resolution frame is optionally 25% to 50% or 10% to 50% of the data size relative to the data size of the original-resolution frame, but the lower resolution can be any resolution that is lower than the original resolution of the video. This will result in the full lower resolution video being smaller in size than the original-resolution video.

An analysis step 2530 is performed on the frames of the down-sampled video in order to find a reconstruction model from a library that can be used to increase the resolution of the scene and enhance the quality of the video. A model is selected based on one or more metrics of the selected scene that can be compared to metrics associated with the reconstruction models stored in the library, and an image enhancement procedure is performed on the down-sampled scene. The quality of the enhanced scene is compared with the original using objective metrics such as error rate, PSNR and SSIM and/or subjective measures. An appropriate model is then selected at step 240 based on these quality comparisons. The library from which the models are selected comprises a set of pre-trained models which have been generated from example, or training, videos and which are associated with metrics to enable comparison of the video from which the models were generated with the selected scene being

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enhanced. The library from which the model is selected may be stored at one or more specific nodes in the network, or may be distributed over two or more nodes.

By employing a deep learning approach when creating the models, a non-linear hierarchical model can be selected to reconstruct a higher-resolution frame from the lower-resolution frame.

The non-linear models are more accurate in reconstructing higher-resolution frames than dictionary-based approaches. The non-linear models selected are small convolutional neural networks rather than over-complete dictionaries. In contrast to the local patch averaging approach that tends to be used in reconstruction by dictionary learning approaches, the use of a convolutional neural network model also allows a more appropriate filter to be selected for final reconstruction where neighbouring patches are considered, which can avoid unintended smoothing of the reconstructed higher-resolution image.

In step 2550, the portion of the low-resolution video and a library reference for reconstruction model for that portion of video are output for transmission. Optionally, the video and library reference can be stored together within a suitable data container format such as a Matroska Multimedia Container (otherwise known as a MKV container). Alternatively, the video and library reference can be combined with other sections or the entire video and placed into a suitable data container format. At step 2550, the low-resolution video frames can be re-encoded using either the original video codec applied to the original video data 2510 or, alternatively, a more optimal video codec can be applied to the video data to produce output video data. Optionally, if scene detection or time stamping was performed, the data output for transmission can include either a list of scenes or time stamp data respectively, or this data could be stored within the data container. Optionally, a list (or data stream) of model references that is synchronised with the output low resolution video frames can also be included. Alternatively, the transmission package can include a list of references to library content/models/parameters for each frame, which can be ordered by either frame playback or decode order, and this can be synchronised to the video frames. A further alternative is that the transmission package can include a list of scene transitions (at defined frame intervals) and then a list of references to library content/models/parameters for a matching number of scenes or transitions.

Referring now to Figure 26, an embodiment for reconstructing the video encoded using the technique will now be described in detail.

First, the data 2610 is received from the network. The data received 2610

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depends on how the data was prepared for transmission in step 2550 as detailed above and will include the video data and one or more library references to reconstruction models for that video data. It is possible that the video data and one or more library references are not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required to decode or reconstruct the higher-resolution video from the data transmitted over the network.

At steps 2620 and 2630, the received data is prepared for reconstruction. These steps generally involve separating the low-resolution video from the library references to reconstruction models. Optionally, the low-resolution video is decompressed using the video codec used for transmission into full-resolution image frames and each of the frames is matched up with the corresponding library reference to a reconstruction model, which are also unpacked into frame-by-frame order.

At step 2630, the reconstruction model corresponding to the library reference is obtained from a stored library of reconstruction models and at step 2640 is applied to each of the frames to output higher-resolution frames. The reconstruction, or decoding, process involves applying the reconstruction model for each scene in order to restore the lower-resolution video to its original resolution having substantially the same quality as the original high-resolution video. Given the corresponding models for each lower-resolution frame, the original higher-resolution frames can be reconstructed with high accuracy.

The complexity of the reconstruction process is far simpler compared to that of training the model. The process, known as the feed-forward process or pass for neural networks, is very similar to a single iteration of the training process however there is no optimisation required and it is simply applying the selected convolutional neural network model to reconstruct the image on a patch-by-patch basis. In comparison, training neural networks can also incorporate a back-propagation process or pass, depending on embodiment. A singular model is applied to each scene and the library reference to it can be sent as accompanying data in the video container ahead of the scene in which it is used. The library reference associated with each scene can either be indexed in a data stream, synchronised with the video and audio stream, or indexed in a frame-to-model look-up table which can be sent ahead of the video stream.

At step 2650, each of the segments of video are output from the reconstruction process as higher-resolution frames at the same resolution as the original video 210. The quality of the output video is substantially similar to that of the original video 210, within the error bounds optionally applied by the machine learning process that selects

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the reconstruction model at step 2650 of the encoding process.

At step 2650, the segments of video are combined such that the video can be displayed. Optionally at step 2650, the video can be re-encoded with the original codec used on the original video 2510 or a more predetermined optimal codec, to enable playback on a decoder or display device.

Upscaling & Visual Data Enhancement

Super resolution approaches are usually split into learning- or example-based approaches and interpolation-based (multi-frame) approaches. Some embodiments are concerned only with learning- or example-based approaches to super resolution. Specifically, these embodiments can work with most or all learning- or example-based techniques where there can be a set of different upscaling results depending on the selected parameters for the techniques.

In some embodiments, super resolution techniques can output representations that can be used to enhance the higher-resolution images created from lower-resolution images. To improve the effectiveness of these representations in some embodiments, learning- or example-based approaches incorporate machine learning. When using dictionary representations for images, this combination is generally referred to as dictionary learning. In dictionary learning, where sufficient representations are not available in an existing library of representations (or there is no library available), machine learning techniques are employed to tailor dictionary atoms such that they can adapt to the image features and obtain more accurate representations.

It is noted that atoms are not selected locally within the dictionary, but instead are chosen as the linear combination that best approximates the signal patch for a maximum number of atoms allowed and irrespective of their location within the dictionary. Without a constraint that the atoms must be orthogonal to one another, larger dictionaries than the signal space that the dictionary is intended to represent can be created.

Embodiments can use dictionary learning reconstruction models or convolutional neural network reconstruction models for up-scaling, or a mixture of these two techniques. In some embodiments, a library of reconstruction models is stored that can be generated from example, or training, video data where both the original and reduced-resolution video can be compared. Along with the reconstruction models, in some embodiments data needs to be stored relating to the example or training video for each reconstruction model in the library to enable each model to be matched to a scene that

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is being up-scaled. In these embodiments the data stored relating to the example or training video can be metadata or metrics related to the video data, or it can be samples or features of the example or training video.

Referring now to Figure 15, embodiments using a technique 1500 to increase the resolution of visual data will now be described in detail. These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

In these embodiments, received video data 1540 is provided into a decoder system and is a lower-resolution video encoded in a standard video format. This video format can be a variety of known video codecs, depending on the embodiment, and in embodiments can be codecs such as H.264 or VP8 or can be any visual data which the system is able to decode into component sections.

In embodiments, the system then separates video data 1510 into single frames at step 1520, i.e. into a sequence of images at the full resolution of the received video data 310. For some video codecs, depending on the embodiment, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

Optionally, as shown in Figure 16, in some embodiments the frames extracted in step 1520 from the video 1510 can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection" in step 1610. In these embodiments step 1610 involves identifying sequential scenes once these are detected. In some of these embodiments, the detected scenes can enable a more accurate reconstruction model or models to be selected from the library of reconstruction models as appropriate from the scene or frames within the scene in step 1620, which is a modified version of step 1530 in process 1500 where the most appropriate model is selected on a frame-by-frame basis. By scene, it is meant a consecutive group or sequence of frames, depending on embodiment, which at the coarsest level can be the entire video or at the most granular level can be a single section of a frame.

Alternatively, and in order for any delay to be reduced between the arrival of the lower resolution video 1510 and the generation of a higher resolution output video 370, in some embodiments basic scene selection in step 1610 can be accomplished by grouping frames into scenes chronologically, for example by applying time stamps and collecting together a predetermined range of timestamps. Initially, in these embodiments the first frame or section of frame can be analysed and a metric created to enable

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reference to the library of reconstruction models in step 1620. In such embodiments, if a subsequent frame or section of a subsequent frame is sufficiently similar according to a comparison metric, then the subsequent frame or frames can be included as part of a group of frames with the first frame. In these embodiments, this process can continue until a subsequent frame is not sufficiently similar to the previous frame or frames, at which point the frame or group of frames are collated into a scene in step 410. in these embodiment the process then starts to find the next scene, starting from the insufficiently similar scene. In such embodiments, each scene is processed in the order in which it was decoded from the received video 1510.

Returning to the method 1500 shown in Figure 15, in some embodiments an analysis step 1530 is performed on the frames of the received video in order to find a reconstruction model from a library in step 1540 which can be used to increase the resolution of the scene and enhance the quality of the video in step 1550, based on a metric of the selected scene that can be compared to metrics associated with the reconstruction models stored in the library. A model in step 1540 is selected, and an image enhancement procedure is performed in step 1550 using both the model selected in step 1540 on the selected frame generated in step 1520 from the received video 1510. The library from which the model is selected in step 1540 comprises a set of pre-trained models which have been generated from example, or training, videos and which are associated with metrics to enable comparison of the video from which the models were generated with a selected frame being enhanced in step 1550.

There are a number of methods for feature extraction approaches that can be used to create metrics for each frame and therefore which can be stored in the library in association with the pre-trained reconstruction models. In many computer vision applications, a common approach is to use a visual bag-of-words approach. Other popular methods include histogram extraction and scale invariant feature transform (SIFT) or GIST features. After feature extraction in step 1530, each scene from a target video can be matched to the "most similar" scene from a library in a number of ways in step 1540. The simplest approach is to use a pre-defined similarity or distance metric such as, Manhattan distance, Euclidean distance or structural similarity (SSIM) or additionally, a learned distance metric. A k-nearest neighbour (kNN) data-structure such as a ball-tree or a locality-sensitive hash table can be used to facilitate a direct nearest-neighbour search. Alternatively, each unique scene can be thought of as being "labelled", then a variety of machine learning scene recognition and matching approaches can be used to classify new scenes into the "labelled" scenes of the library

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such as adversarial training techniques, where such techniques involve training another neural network to indicate whether the scene is labelled correctly.

In step 1560, the reconstructed scene for that section of video is optionally prepared for output 1510. Optionally at step 1560, the output video 1570 can be re-encoded with the original codec used on the original video 1510 or a more predetermined optimal codec, to enable playback on a decoder or display device.

It should be appreciated that the term 'frame', particularly in reference to grouping multiple frames into scenes, can refer to both an entire frame of a video and an area comprising a smaller section of a frame.

The video 1510 in process 1500 or 1600 can originate from physical media such as a DVD or other physical data storage medium, but can also originate from a local or remote streaming network service.

Referring now to Figure 17, a modified process 1700 (based on process 1600 but which could equally be a modified version of process 1500) is shown.

Here, process 1600 in some embodiments is modified with further steps. Specifically, step 1710 begins with a high resolution video file, for example at HD resolution. Then, at step 1720, the video is down-sampled to, for example, SD resolution to enable transmission over a bandwidth-restricted network. Optionally, in other embodiments, quantisation can be used to lower the bitrate of visual data such as video. At step 1730, the lower-resolution or quantised video (depending on embodiment) is transmitted over a network becoming the input video data 1510 of either process 1500 or 1600 described above in relation to Figures 15 or 16 respectively.

Further, output video 1570 in process 1500 or 1600 can be output directly to a display or may be stored for viewing on a display on a local or remote storage device, or forwarded to a remote node for storage or viewing as required.

In alternative embodiments, the input video concerned may be media for playback, such as recorded video or live streamed video, or it can be videoconference video or any other video source such as video recorded or being recorded on a portable device such as a mobile phone or a video recording device such as a video camera or surveillance camera.

It should also be appreciated that particular combinations of the various features described and defined in any aspects of the invention can be implemented and/or supplied and/or used independently.

Specific Description – Machine Learning Optimisation

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Embodiments relating to a dictionary learning approach with dictionary-based models and embodiments relating to a deep learning approach using convolutional neural network models will now be described. Other suitable machine learning techniques will also be able to benefit from using a library of pre-trained model. These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

Referring now to Figure 9, an embodiment of a machine learning process will now be described in detail.

Data 910 is provided to the method or system 900, and may for example be in the form of a video data file or image data. Other data formats may also be used. Specific metrics are extracted from, or generated based on, the data in step 920. The metrics can based on measuring which of the pre-trained models generates the highest quality output data. Quality can be defined using any or a combination of: an error rate; a peak signal-to-noise ratio; or a structural similarity index. These metrics are then used to select a pre-trained model from a library 942 in step 930. The selected pre-trained model is then developed in step 940 so as to be more accurately able to perform the desired output function on the input data 910. The output model 950 can then be used on the input data 910 either immediately or at in future.

To generate the initial pre-trained models, the same process 900 can be used but instead of inputting live data 910, training or example data is used.

The developed model is then saved in the library 942 in step 941, to be used if required in the future. A model does therefore not have to be redeveloped if similar data is input in the future. The library 942 therefore grows as the system is used.

If employing a deep learning approach to generating the model in step 940, a non-linear hierarchical model 950 can be created.

The training and optimisation process 900 can be configured according to a desired trade-off between computational time spent and desired quality of results. In general, the number of iterations used during the training process 940 yields approximately logarithmic gains in reconstruction accuracy, so it is preferred to use an automatic threshold to stop further optimisation. When favouring quality of results, the automatic threshold can be set to a predetermined value of reconstruction error, for example by calculating the mean squared error, but other methods can also be used. Alternatively, the automatic threshold can be set to limit the training and optimisation process to a predetermined number of iterations. As a further alternative, a combination

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of these two factors can be used.

This process 900 can be of use in the fields of image and video enhancement. If the input data 910 is in the form of a section (frame or frames) of video, the selection of an initial model from the library 930 can be based on metrics associated with the style of video being processed, for example a fast-moving action scene, or a stationary background scene. The model 950 can then be developed in step 940 to more closely represent the section of video for which it is to be used.

The training and optimisation process 900 can also be considered in the case of image registration and alignment. An initialisation can be provided which is closer to the most optimal image alignment with regards to a metric, for example a distance metric cost function.

Specific Description – Enhanced Libraries

Referring now to Figure 10, an embodiment using the technique to encode visual data will now be described in detail. These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

Original video data 1010 is provided into the method or system using the technique and is a high-resolution video, for example having a resolution of 1920 pixels by 1080 pixels (also known as "1080p" video) or 3840 pixels by 2160 pixels (also known as "4K" video). This video data can be encoded in a variety of known video codecs, such as H 264 or VP9 but can be any video data for which the system or method is able to decode into the component frames of the video.

The original video data 1010 is then split into single full-resolution frames at step 1020 , i.e. into a sequence of images at the full resolution of the original video data 210. For some video codecs, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

Optionally, at step 1020, the full-resolution frames can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection". The video data is split or clustered into scenes to enable more specific training and optimisation. By scene, it is meant a consecutive group or sequence of frames, which at the coarsest level can be the entire video or at the most granular level can be a single frame.

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Regardless whether the video has been broken into frames or scenes (i.e. groups of multiple frames) in step 1020 or remains as a sequence of frames, each frame is either down-sampled into lower resolution frames at a suitably lower resolution, or reproduced as a set of representations of the frame such as a matrix of vectors with generalised information for portions of the frame or groups of one or more pixels. Optionally, this step can occur before the frames are grouped into scenes. The lower-resolution frame is preferably 33% to 50% of the data size relative to the data size of the original-resolution frame, while the representations of the frame can be anything from 1% to 50% of the data size of the original-resolution frame. The lower resolution frame can have any resolution that is lower than the original resolution of the video.

In step 1030, an analysis is performed on frames of the downsampled video, or on the representations, or on the models alone in order to find a reconstruction model from a library of models which can be used to either recreate a close approximation of the high-resolution video purely from a model, or recreate a close approximation of the high-resolution video from a set of representations of the high-resolution video, or increase the resolution of the downsampled video and enhance the quality of the video. An initial model is selected based on a metric of the selected scene that can be compared to metrics associated with the reconstruction models stored in the library. The selection of the initial model may be based on only these metrics, or alternatively multiple initial models may be applied independently to the downsampled video to produce an enhanced lower-resolution frame or recreate a frame, the quality of the enhanced or recreated frame being compared with the original scene to select the most appropriate initial model from the group. The quality of the recreated or enhanced scene is compared with the original using objective metrics such as error rate, PSNR and SSIM and/or subjective measures. An appropriate model is then selected at step 1040 based on these quality comparisons as well as whether to use solely a model, or a set of representations of the frame, or the lower-resolution frame. The library from which the models are selected comprises a set of pre-trained models which have been generated from example, or training, videos and which are associated with metrics to enable comparison of the video from which the models were generated with the selected scene being enhanced.

In step 1060, super resolution techniques are employed to create a specific model using the model selected at step 1040 as the initial model and using machine learning for each frame, so that the model can be used to substantially recreate the original resolution version of a lower-resolution frame, or a set of representations, or

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without use of either the original or lower-resolution frame or representations, and trained using machine learning based on knowledge of the original-resolution frame. This step is termed the training and optimisation process.

At step 1070, the optimised reconstruction model is saved to the library for future use as an initial model in step 1030.

Alternatively, the modified model can be developed from scratch, without using a known model as a starting point. A known model can then be compared with the generated model to produce a list of modifications required to produce the modified model from the known one.

In step 1050, the portion of the low-resolution video, or the representations and/or the reconstruction model for that frame or portion of video are output for transmission. Rather than transmit the full reconstruction model, a library reference to the initial model selected at step 1040 can be output, together with the modifications required to produce the reconstruction model from it. Alternatively, instead of the lower-resolution video, transmitting a representation of the image can further reduce the data transmitted. As a further alternative, only transmitting a model still further reduces the data transmitted. Optionally, the video or representations and model can be stored together within a suitable data container format such as a Matroska Multimedia Container (otherwise known as a MKV container). Alternatively, the video or representations and model can be combined with other sections or the entire video and placed into a suitable data container format. At step 250, the low-resolution video frames can be re-encoded using either the original video codec applied to the original video data 1010 or, alternatively, a more optimal video codec can be applied to the video data to produce output video data 1050. Optionally, if scene detection or time stamping was performed, the data output for transmission can include either a list of scenes or time stamp data respectively, or this data could be stored within the data container. Alternatively, a list of frame by frame references (which are ordered by either frame playback or decode order) can be used which is synced to the video frames. Another alternative is to include a list of scene transitions (as defined by frame numbers) along with an ordered list of references matching the number of scenes. The skilled person will appreciate that other examples are possible.

Referring now to Figure 11, an embodiment for reconstructing the video encoded using the technique will now be described in detail.

First, the data 1100 is received from the network. The data received 1100 depends on how the data was prepared for transmission in step 1050 as detailed above

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and will include the video data or representations of the video data and/or references to one or more initial reconstruction models for to recreate high-resolution video data, along with any modifications to the referenced models required to reproduce the final reconstruction models. It is possible that the video data or representations, references to the one or more initial reconstruction models and the modifications to those models are not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required to decode or reconstruct the higher-resolution video from the data transmitted over the network.

At steps 1120 and 1130, the received data is prepared for reconstruction. This step generally involves separating the low-resolution video or representations if transmitted from the references to known reconstruction models and the modifications to those models required to reproduce the optimised reconstruction model. Optionally, the low-resolution video is decompressed at step 1120 using the video codec used for transmission into full-resolution image frames and each of the frames is matched up with the corresponding reconstruction model, which are also unpacked into frame-by-frame order.

The reconstruction models developed at step 1170 are recreated from the reference to a known reconstruction model and the modifications received at step 1110. At step 1130 the received reference is used to locate the known reconstruction model from which the optimised reconstruction model was developed in a library of models stored at the second node. The received modifications are then applied to this known reconstruction model at step 1160, recreating the optimised reconstruction model. After this reconstruction has taken place, the optimised reconstruction model is saved in the library at the second node for future reference at step 1170 using the same reference as was used when saving the model to the first node's library at step 1170. An incremental (or decremental) counter can be used to create new references for the modified algorithm that would then be the same for both nodes (in a distributed system). Alternatively this could be performed via a centralised database.

At step 1140, the modified reconstruction model is applied to each of the frames or representations if transmitted to output higher-resolution frames, else are used to reproduce the higher-resolution frames without a low resolution frame or representations. The reconstruction, or decoding, process involves applying the optimised super resolution convolutional neural network model, or reconstruction model, for each scene in order to recreate higher resolution video having substantially the same quality as the original high-resolution video. Given the corresponding models and if

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transmitted each lower-resolution frame or set of representations, a higher resolution frame that is substantially visually identical to the original higher-resolution frames can be reconstructed with high accuracy.

At step 1150, each of the segments of video are output from the reconstruction process as higher-resolution frames at the same resolution as the original video 210. The quality of the output video 1150 is substantially similar to that of the original video 210, within the error bounds optionally applied by the machine learning process that develops the reconstruction model at step 1060 of the encoding process.

At step 1140, the segments of video are combined such that the video can be displayed. Optionally at step 1140, the video can be re-encoded with the original codec used on the original video 1010 or a more predetermined optimal codec, to enable playback on a decoder or display device.

A modified embodiment of the above-described method is shown in Figures 4 and 5. In this embodiment, the downsampled video is not transmitted from the first node to the second node. Instead, any data required to produce the reconstructed video can be included in the transmitted modifications to a known reconstruction model. It is possible that no data is required and that only the use of a model is required to reconstruct substantially the high-resolution video. The second node reconstructs the video using only the modified reconstruction model obtained by applying the modifications to the known reconstruction model referenced in the transmission and, if required, the data required to produce the reconstructed video. This method can advantageously be used to reduce further the amount of data transmitted across the network, reducing the amount of data required to be transmitted.

Figure 12 shows a further method for encoding video. The initial steps proceed as in Figure 10. The higher resolution video 1210 is prepared by separating it into scenes and down sampling at step 1220. An analysis of each scene is performed in step 1230 to determine which known models will be used as a starting point for the model optimisation process. One or more appropriate models are selected at step 1240 based on a metric of each scene or frame that can be compared to metrics associated with the reconstruction models stored in the library. The selected known models are optimised at step 1260 using machine learning. However, instead of being trained to reproduce the higher resolution video from the downsampled one, they are instead trained to substantially reproduce the higher resolution video 1210 using only the optimised model itself or the optimised model and any data that can be incorporated into the model to seed recreation of the video frame or scene. A reference to the starting known

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reconstruction model together with the modifications required to reproduce the optimised reconstruction model for each scene or frame are transmitted to the second node at step 1260, along with a list of scenes if known.

Figure 13 shows a further method of decoding the received information at the second node to reproduce substantially the higher resolution video. The package transmitted at step 1260 of Figure 12 is received by the second node at step 1310, and unpacked at step 1320. The references to known models are used to locate the known reconstruction models stored in a library at the second node at step 1330. The modifications corresponding to these known reconstruction models are then applied at step 1340 to reproduce the optimised reconstruction model generated by the machine learning process in step 1260 of Figure 12. This model is optimised to substantially reproduce the original higher resolution video 1260 without the need for it to be applied to a corresponding low resolution video sample. Hence the second node can substantially reconstruct the original high resolution video from only the modified reconstruction model. This reconstruction is performed at step 1350, and the resulting reconstructed higher resolution video is output at step 1360.

Specific Description – Artefact Removal

To improve on the above mentioned approaches for image artefact removal, it is proposed to use deep learning techniques and neural networks such as recurrent neural network and convolutional neural network models.

In some cases fully connected neural networks can't scale up to larger sizes of network easily as the computational complexity soon becomes too great as the size of the network scales, but this depends on the application of the neural network and also other factors such as the kernel and filter sizes.

Neural network models can be transmitted along with the low-resolution and/or low-bitrate and/or low quality frames of video data because size of a convolutional neural network model or recurrent neural network model data is small enough to do so compared with the size of a learned dictionary for the same level of accuracy. In comparison, the data size of learned dictionaries means that it is impractical for these dictionaries to be transmitting along with the low-resolution images, especially in where the dictionaries are learned over-complete dictionaries

Figure 22 illustrates an overview of embodiments of a method of generating models for use in image artefact removal. These embodiments can be used in

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combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

In some embodiments, training image or video file is selected at step 2210 from a library of training images or videos stored at a network node and divided up into frames, sub-images or sequences of images (collectively referred to herein as scenes) at step 2220 depending on its content. In these embodiments, the scene type can then be classified into a particular category depending on its content using a metric.

In some embodiments, at step 2230, image artefacts are purposefully generated in the scene by applying aggressive compression and/or quantisation algorithms to the scene, with the level of expected artefacts being controlled by the compression/quantisation level or quality level. This creates a training scene. In some of these embodiments an artefact grading technique is applied to this training scene at step 2240 to quantify the severity of the induced artefacts.

At step 2250, in some embodiments, an image artefact removal model is trained on the training scene using machine learning techniques. In these embodiments the image artefact removal model can be generated such that it substantially cleans the training scene of image artefacts. In some of these embodiments, image quality metrics are used to compare the "cleaned" scene with the original, and the training process can be continued until the comparison produces results within some pre-defined threshold.

In some embodiments, the resulting image artefact removal model is then saved at step 2260, along with metric data relating to the scene type classification and an artefact grade relating to the types and/or severity of the artefacts in the training scene.

The process can be repeated multiple times, depending on the embodiment, on the same training scene with different levels of compression and quantisation in order to train a set of models for different levels of artefact severity.

The process can also be repeated in some embodiments with different training scenes in order to generate a library of different image artefact removal models indexed by both their content type and artefact severity. In these embodiments a "matrix" of library models can be created, where one axis of the matrix can be thought of as the content type, and the other the artefact severity.

Each step of the above method, as used in some embodiments, will now be described in further detail.

The division of the training image or video into a scene or scenes at step 2220 can be achieved in several different ways in different embodiments. The training image or video may already be divided into scenes prior to being stored in the library of training

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images or videos in certain embodiments, hence this step of the method is not always necessary. For the training of the image artefact removal model, in some embodiments only one scene is used for each model generated. In these embodiments a single training image or video may therefore be used to train multiple different image artefact removal models relating to different content types present within the image or video.

Considering first the case of video data, in some embodiments the library video data can be split into single full-resolution frames, i.e. into a sequence of images at the full resolution of the original video data. For some video codecs, in certain embodiments, this will involve "uncompressing" or restoring the video data as, for example, common video compression techniques remove redundant (non-changing) features from sequential frames.

Optionally, in other embodiments the full-resolution frames can be grouped into scenes or sections of frames having common features, otherwise known as "scene selection". In such embodiments, the video data can be split or clustered into scenes to enable more specific training and optimisation. By scene, it is meant a consecutive group or sequence of frames, which at the coarsest level can be the entire video or at the most granular level can be a single frame or portion of a frame depending on embodiment.

For the training of the image artefact removal model, in some embodiments only one scene is used for each model generated. A single training image or video may therefore be used in such embodiments to train multiple different image artefact removal models relating to different content types.

Once a scene has been generated, in some embodiments it is classified using metrics relating to properties of the scene. In embodiments, metrics that can be used for this classification can include probability or distance, depending on the classifier type or clustering used in each embodiment, and some function of the error or differences can be included in the metric depending on embodiment. Example metrics can include the differences between pixels or histogram differences such as the sum of absolute differences or Euclidean distance in these embodiments. Example metrics can also include mean squared error and peak signal-to-noise ratio in some embodiments. Alternatively, in other embodiments classification can be performed according to predetermined trained classifications, for example there could exist predetermined trained classifications for a variety of scenes or objects such as outdoors, indoors, mountains, bike, etc. The probability would be determined by the classifier used in the embodiment, for example embodiments could use a statistical similarity measure such

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as the Kullback-Leibler divergence. In other embodiments, a further alternative would be to use machine learning to develop a metric to be applied to the image-space, which would determine a formula for the distances. This classification using metrics is used to distinguish between scenes containing different content in at least some embodiments. The metric data determined in this way effectively assigns the scene a content type in such embodiments.

After the scene has been generated and classified, in at least some embodiments it is compressed and/or quantised at step 2230. In these embodiments, the compression of the scene can be implemented using any well-known lossy image/video compression algorithm. In such embodiments, the quantisation methods may include both colour quantisation, using for example a median cut algorithm or a clustering algorithm, and frequency quantisation.

In embodiments, the compression or quantisation process introduces image artefacts to the scene, producing a training scene that will be used together with the original uncompressed and unquantised version of the scene to train and/or optimise an image artefact removal model. In these embodiments, different levels of artefact severity can be introduced by varying the level of compression and/or quantisation performed at this stage.

Before the training and optimisation process begins in some embodiments, the artefact severity of the training scene is determined at step 2240 by using an artefact grading algorithm. Examples of such algorithms that can be used in embodiments are found in the paper "No-Reference Image Quality Assessment in the Spatial Domain" by Anish Mittal, Anush Krishna Moorthy and Alan Conrad Bovik published in IEEE TRANSACTIONS ON IMAGE PROCESSING, Vol. 21, No. 12, DECEMBER 2012, which is incorporated herein by reference. By grading the artefact severity of a training scene in embodiments, image artefact removal models can be trained based on both scene content type and the severity of the artefacts present.

At step 250 the model training and optimisation process is performed on the training scene in some embodiments. Super resolution techniques and machine learning techniques are employed in some embodiments to create an image artefact removal model, such that the model can be used to substantially recreate the original "clean" version of the training scene. By employing a deep learning approach to generating the model in at least embodiments, a non-linear hierarchical model can be created to reconstruct the original clean scene from the compressed and/or quantised scene.

An example of a deep learning approach, but in respect of only still images and in

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relation to jpeg compression artefacts (but not, for example, other video artefacts such as motion blur and inter-frame artefacts), but which can be used with or without modification in some embodiments, is described in the paper "Compression Artifacts Reduction by a Deep Convolutional Network" by Chao Dong, Yubin Deng, Chen Change Loy, and Xiaoou Tang published as arXiv:1504.06993v1 [cs.CV] 27 April 2015 and this paper is incorporated herein by reference. This paper is related to generating an improved deep Super Resolution Convolutional Neural Network for image artefact removal from a shallow network model.

In some of the embodiments, the quality of the recreated or cleaned scene can be compared with the original using objective metrics such as error rate, PSNR and SSIM and/or subjective measures. In some of these embodiments, if the quality is found to be within some pre-defined threshold, then the model can be saved along with results from a classifier or outcomes identifying the scene content and the artefact severity that the model relates to. Otherwise, in some embodiments the training process continues until the predefined threshold is met. Alternatively or additionally, in some embodiments a pre-defined number of iterations of the machine learning process can be used to limit the computational time spent training the model.

In some embodiments, the image artefact correction model trained in this way may be one of a non-linear hierarchical algorithm, a convolutional neural network, a recurrent neural network, a multi-layer (neural) network, an artificial neural network, a deep belief network, a dictionary learning algorithm, a parameter, a mapping function, a multi-layer feed-forward network, a non-linear filter, a dictionary, set or series of parameters or functions, or a series of functions.

In some embodiments, the original training scene generated in the scene selection process is used to generate multiple models for the same scene content type by repeating the compression and quantisation process with different levels of compression and/or quantisation, or by using different compression and/or quantisation algorithms. In these embodiments, this approach introduces a different level of artefact severity to the scene. Further, in some of these embodiments the training and optimisation process can then be repeated to generate a new image artefact removal model for the same content, but a different level of artefact severity.

In some embodiments, the trained and/or optimised image artefact removal models are saved to a library of image artefact removal models. In some of these embodiments, each model in the library is associated with a classifier identifying the scene content and the artefact severity that the model was trained on. In these

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embodiments, the library can therefore be thought of as a "matrix" of example based models, with its rows corresponding to the scene content type, and its columns corresponding to the image artefact severity.

The library can be stored on a node within a network in certain embodiments.

Referring now to Figure 23, a method of using the image artefact removal models will now be described according to some embodiments.

A section of video or an image is received from a network at a receiving network node at step 2310 in some embodiments. In these embodiments, the data received depends on how the data was prepared for transmission at a transmitting network node and will include the video/image data or representations of the video/image data. It is possible in some of these embodiments that video data or representations is not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required before the artefact removal process can take place.

In some embodiments, at step 2320, the received video or image data is unpacked and divided into scenes depending on its content using the process described above in relation to the image artefact removal process. In some of these embodiments, the scenes are then classified at step 2330 using metrics to determine the scene content type.

Alternatively, in other embodiments the received video/image data can already have been divided into scenes and classified by the transmitting network node, in which case the data received by the receiving node will contain metadata for each of the scenes contained within it that identifies the scene content type.

In either case, in some embodiments, at step 2330, the received scenes are subjected to an artefact grading algorithm or classifier to determine the level of artefact severity present in the scene. In some of these embodiments the source of these artefacts can be the video/image compression and quantisation process performed by the transmitting node prior to transmission of the video/image data, or they could be introduced by faulty or lossy network transmission.

In some embodiments, the scene content type and image artefact severity are used to select the image artefact removal model from the library of image artefact removal models generated in the model creation process that best matches the scene content type and artefact severity of the received scene. In these embodiments, this matching may be performed at the receiving network node if the library is stored there. Alternatively, in other embodiments, if the library is stored remotely from the receiving network node, a request for the most suitable image artefact removal model may be

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transmitted from the receiving node to the location of the model library. In some of these embodiments the model library will then transmit the relevant image artefact removal model to the receiving network node. If no suitable image artefact removal is stored in the library then a generic model may be used instead. In such embodiments, a suitable model may be determined, for example, by requiring that the metric data relating to the content type and the artefact severity of the received video or image data lie within some predefined range of at least one of the image artefact removal models stored in the library.

In some embodiments, the image artefact removal model identified to be the most suitable (or the generic model in the case that no suitable model is present in the library or if the generic model is the most suitable model) is then applied to the received scene at step 2350 in order to substantially recreate the original video/image file largely free from image artefacts. In such embodiments, this fidelity correction process can result in a clean reconstructed video/image, which is then output by the receiving node at step 2360.

Referring now to Figure 24, an alternative method of using the image artefact removal models according to some embodiments will now be described.

In such embodiments, this method relates to the combined use of image artefact removal and super resolution techniques to reconstruct a video or image from a downsampled (i.e. lower resolution than an original higher resolution) video or image data received from a network.

In some embodiments, firstly, at step 2410, the data package is received from the network. In these embodiments, the data received in the package depends on how the data was prepared for transmission by the transmitting network node and can include downsampled video or image data or representations of the video or image data and/or details of one or more reconstruction models for recreating high-resolution video data from the downsampled video or image data. In such embodiments, these details may be the reconstruction models themselves, or references to known reconstruction models stored at the receiving node or on the network.

In some embodiments, it is possible that the video data or representations, references to the one or more initial reconstruction models and the modifications to those models are not transmitted and/or received simultaneously so some buffering may be required to wait for all of the components required to decode or reconstruct the higher-resolution video from the data transmitted over the network.

Next, at step 2420, the received data is prepared for reconstruction in some

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embodiments. In these embodiments, this step generally involves separating the low-resolution video/image or representations if transmitted from the details of the relevant reconstruction models. Optionally, in other embodiments, the low-resolution video or image is decompressed using the video or image codec used for transmission into full-resolution scenes and each of the frames is matched up with the corresponding reconstruction model, which are also unpacked into scene-by-scene order.

At step 2430, in some embodiments, if the scene content has not already been determined by the transmitting node, then it is now determined by the receiving node.

In some embodiments, the unpacked video or image scenes are then graded to determine their artefact severity using an artefact grading algorithm.

In some embodiments, at step 2440, the scene content type and image artefact severity are used to select the image artefact removal model from the library of image artefact removal models generated in the model creation process that best matches the scene content type and artefact severity of the received scene. In such embodiments, this matching can be performed at the receiving network node if the library is stored there. Alternatively, in other embodiments where the library is stored remotely from the receiving network node, a request for the most suitable image artefact removal model can be transmitted from the receiving node to the location of the model library. In such embodiments the model library will then transmit the relevant image artefact removal model to the receiving network node. If no suitable image artefact removal model is stored in the library then a generic model may be used instead in some of these embodiments.

In some embodiments, the image artefact removal model identified for each scene is then applied to the downsampled scene at step 2450 in order to substantially recreate the original downsampled image transmitted by the transmitting node. Alternatively, in other embodiments the identified model can be used after the upscaling process of step 2460 to substantially remove the upscaled image artefacts from the recreated higher resolution video.

At step 2460, in some embodiments the relevant reconstruction models are then applied to each of the scenes to output higher-resolution scenes. In such embodiments the reconstruction, or decoding, process can involve applying the optimised super resolution convolutional neural network model, or reconstruction model, for each scene in order to recreate higher resolution video or image having substantially the same quality as the original high-resolution video or image from which the downsampled video or image was generated by the transmitting node. Given the corresponding

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reconstruction models and each lower-resolution scene or set of representations, in some embodiments a higher resolution frame that is substantially visually identical to the original higher-resolution frames can be reconstructed with high accuracy.

In some embodiments, the reconstructed higher resolution scene is then output by the receiving node at step 470.

The above-described process is performed as a post-process to the standard decompression process used at the decoding node for received transmissions of, for example, video after the conventional decoding step and therefore "outside" the traditional compression pipeline in at least some embodiments.

Alternatively, in other embodiments, the image artefact removal process can be performed as part of the upscaling process itself. In such embodiments, several reconstruction models can be trained to reproduce the higher resolution image or video at the first node from a number of different downsampled images or videos, each with a different artefact severity. In such embodiments, these can either all be transmitted with the downsampled video, or the required model can be transmitted to the second network node from the first node once a request for the model containing the artefact severity of the received downsampled image or video has been sent from the second node to the first node. In either case, in some embodiments the model best matching the artefact severity of the received downsampled image or video is used to substantially recreate the original high resolution video.

Spatio-temporal Interpolation

In some embodiments, visual data being received may be of a lower than desirable quality, such as at a low resolution or a low frame rate. It will be appreciated other features may render the visual data lower than desirable quality. One or more hierarchical algorithms may be used to increase the quality of the visual data to a more desirable quality. For example, in some embodiments, the hierarchical algorithm may increase the resolution of the received visual data section or sections. In another embodiment the hierarchical algorithm may develop intermediate sections, such as a section to be placed between two received sections of visual data. In yet another embodiment, the hierarchical algorithm any be used to increase the quality of the received visual data by combining the above mentioned embodiments.

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These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

In some embodiments, one or more hierarchical algorithms may be used to estimate higher-resolution versions of received lower-resolution frames. In such embodiments, upon receiving multiple lower-resolution frames, a hierarchical algorithm can be used to estimate a higher resolution version of a particular received frame. In some embodiments, on the receipt of three or more consecutive frames of lower-resolution visual data a hierarchical algorithm may be used to estimate a higher resolution version of one of the middle frames. In such embodiments, this estimation can be based not only on the lower-resolution version of the received frame, but also the lower-resolution version of the previous and subsequent frames also received. Alternatively, in other embodiments the hierarchical algorithm can be used to determine an unknown intermediate frame at the same resolution as previous and subsequent received frames.

Alternatively, in some other embodiments a hierarchical algorithm may be used to estimate higher-resolution versions of the received lower-resolution frames, as well as a higher-resolution version of an unknown intermediate frame. Furthermore, in some embodiments the hierarchical algorithm may also be used to estimate an unknown future or past frame based upon the received lower-resolution frames.

Online training

In some embodiments, new visual data being transmitted from a node to one or more other nodes has no hierarchical algorithms trained to enhance a lower-quality version of the new visual data. For example, in some embodiments this new visual data may be live broadcast video data and in some embodiments the new visual data may be streamed or rendered e-gaming video content. Where there exist no hierarchical algorithms for this new visual data, specific or generic hierarchical algorithms need to be trained in order to enhance lower-quality versions of the new visual data in some of these embodiments and as per some of the embodiments described elsewhere.

In some embodiments, multiple hierarchical algorithms can be trained in parallel on the same visual data. In such embodiments, this allows for wider range of hierarchical algorithms to be explored within a given timeframe. In some of these embodiments, the most suitable algorithm from these developed algorithms can be selected for

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transmission across the network with the visual data. In some embodiments, developing the hierarchical algorithms in parallel can be useful in situations where there is only a limited time available to develop the hierarchical algorithm.

In parallel to the development of hierarchical algorithms (whether singly or multiple in parallel), in some embodiments the visual data can be encoded in an encoder in preparation for its transmission across the network. In this way, the time taken to prepare both the hierarchical algorithm and the visual data for transmission can be reduced when compared to developing the hierarchical algorithm and encoding the visual data in series in such embodiments.

Once generic or specific hierarchical algorithms have been developed or trained, for example for a new game being streamed as e-gaming video content, these can be used to enhance the quality of lower-quality streamed visual data at receiving nodes.

These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

Offline training

In some embodiments, new visual data to be transmitted from a node to one or more other nodes has no hierarchical algorithms trained to enhance a lower-quality version of the new visual data. For example, in some embodiments this new visual data may be new video data such as a new film or television series and in some embodiments the new visual data may be a computer game that will in the future be used to generate streamed e-gaming video content. Where there exist no hierarchical algorithms for this new visual data, specific or generic hierarchical algorithms need to be trained in order to enhance lower-quality versions of the new visual data in some of these embodiments and as per some of the embodiments described elsewhere.

Often, the visual data will be encoded prior to transmission across the network using an encoder in certain embodiments. The encoding process may introduce encoder specific artefacts to the visual data in such embodiments. By refining the hierarchical algorithm by performing further training steps on the encoded video in some embodiments, the hierarchical algorithm can be trained to substantially correct image artefacts introduced by the encoder.

In some embodiments the hierarchical algorithms can be trained using training data corresponding to the exact visual data that will be transmitted across the network.

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In such embodiments, this approach can be particularly useful in situations where the visual data is known in advance, and where the visual data is likely to be transmitted across the network multiple times. For example, in some embodiments the hierarchical models can be trained on sections of an episode of a TV program that will be made available on an on-demand streaming service. In such embodiments the models trained on that particular episode can be transmitted alongside the lower-quality visual data and be used to enhance the lower-quality visual data to a higher-quality version of that episode.

Alternatively, in other embodiments the hierarchical algorithms can be trained on training data that is similar, but not identical, to the expected visual data on which they are to be used. In such embodiment these trained models can be associated with metric data relating to properties of the visual data on which they were trained. In some of these embodiments, this metric data can later be used to select an appropriate hierarchical algorithm to use to enhance visual data for which no specific model has been trained. In some embodiments visual data is being generated and transmitted across the network substantially simultaneously, for example during a live broadcast. In such embodiments, there may not be enough time to generate a specific hierarchical algorithm for the visual data without introducing a substantial delay to the live broadcast. In such embodiments, selecting a hierarchical algorithm that has been pre-trained on similar visual data can reduce this delay.

Once hierarchical algorithms have been trained in order to enhance lower-quality versions of the new visual data these can be stored in order to be sent with the visual data or distributed to receiving nodes in advance of visual data being sent, depending on the embodiments.

These embodiments can be used in combination with other embodiments, and alternative and optional portions of embodiments, described elsewhere in this specification.

Strided Convolutions

Optionally, Figure 18 shows an alternative method 1800 of the method 1500 shown in Figure 15 according to some embodiments. In these embodiments, once the visual data 1510 has been separated into individual frames at step 1520, the dimension of the full resolution images 2110 extracted may be reduced based on at least one predetermined factor at step 1810. In these embodiments, at step 1810, the at least one

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predetermined factor may be used to select individual pixels from the extracted full resolution images 2110 to form a lower resolution representation 2120 of the extracted full resolution images 2110. For example, in some embodiments, a predetermined factor of 2 may indicate every other pixel in both the horizontal and vertical dimensions is selected, as shown in Figure 21. It will be appreciated that other values of the predetermined factor may be used in other embodiments, furthermore in some of these other embodiments both the horizontal and vertical dimensions may each have a different predetermined factor applied.

In some embodiments, the reduced dimension visual data may be concatenated in step 1820, to form a lower resolution representation 2120 of the extracted full resolution images 2110. In these embodiments, the lower resolution representation 2120 can then be used as a basis for any image enhancement techniques and analysis allowing for the use of larger super resolution networks without compromising the runtime. In some embodiments, different predetermined factors and sizes of super resolution network can be used to obtain optimum performance.

Alternatively, in other embodiments, Figure 19 shows a method 1900 based upon the method 1600 shown in Figure 16. In method 1900 of these other embodiments, steps 1810 and 1820 can occur after the frames are grouped into scenes in step 1610.

Referring now to Figure 20, a modified process 2000 according to some embodiments (based on process 1900 but which could equally be a modified version of process 1800) is shown.

In these embodiments, process 1900 is modified with further steps. Specifically, in some of these embodiments, step 1710 can begin with a high resolution visual data, for example at HD resolution. Then, at step 1720 of these embodiments, the visual data can be down-sampled to, for example, SD resolution to enable transmission over a bandwidth-restricted network. At step 1730 of these embodiments, the lower-resolution visual data can be transmitted over a network thus becoming the input visual data 310 of either process 1800 or 1900 described above in relation to Figures 18 or 19 respectively.

Specific Description – Flexibility of described aspects and embodiments

Any system feature as described herein may also be provided as a method feature, and vice versa.

As used herein, means plus function features may be expressed alternatively in terms of their corresponding structure.

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In particular, method aspects may be applied to system aspects, and vice versa.

Furthermore, any, some and/or all features in one aspect can be applied to any, some and/or all features in any other aspect, in any appropriate combination.

It should also be appreciated that particular combinations of the various features described and defined in any aspects of the invention can be implemented and/or supplied and/or used independently.

In alternative embodiments, the input visual data concerned may be media for playback, such as recorded visual data or live streamed visual data, or it can be videoconference video or any other visual data source such as video recorded or being recorded on a portable device such as a mobile phone or a video recording device such as a video camera or surveillance camera.

It should also be appreciated that the term 'visual data', may refer to a single image, a sequence of images, video, or a section of visual data.

It should further be appreciated that the term "enhancing" may refer to upscaling, increasing the resolution and/or quality of visual data. References to enhancing or increasing the quality of visual data can refer to upscaling or using enhancement techniques of the possible embodiments described. References to down sampling can refer to reducing the resolution and/or quality of visual data (for example by quantisation to lower the bit rate of the visual data).

It should also be appreciated that the term 'frame', particularly in reference to grouping multiple frames into scenes, can refer to both an entire frame of a video and an area comprising a smaller section of a frame.

In aspects and/or embodiments, the terms algorithms and/or models and/or parameters can be used interchangeably or exchanged with each other. Further, in aspects and/or embodiments, the terms hierarchical algorithm, hierarchical model and hierarchical parameter can be exchanged with the terms convolutional neural networks and/or convolutional neural network model, convolutional neural network algorithm, convolutional neural network parameter.

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CLAIMS:

1. A method for developing an enhancement model for low-quality visual data, the method comprising the steps of:

receiving one or more sections of higher-quality visual data

training a hierarchical algorithm, wherein the hierarchical algorithm is operable to increase the quality of one or more sections of lower-quality visual data to substantially reproduce the one or more sections of higher-quality visual data; and

outputting the hierarchical algorithm.

2. A method according to claim 1, wherein the hierarchical algorithm is trained using a learned approach.

3. A method according to claim 2, wherein the learned approach comprises machine learning techniques.

4. A method according to any preceding claim, wherein the hierarchical algorithm is a non-linear hierarchical algorithm.

5. A method according to claim 4, wherein the non-linear hierarchical algorithm comprises one or more convolutional neural networks.

6. A method according to any preceding claim, wherein the hierarchical algorithm is developed from a known hierarchical algorithm.

7. A method according to any preceding claim, wherein the method is performed at a first network node within a network.

8. A method according to claim 7, wherein the hierarchical algorithm is transmitted to a second network node in the network.

9. A method according to any preceding claim, wherein the one or more sections of lower-quality visual data are generated from the one or more sections of higher-quality visual data.

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10. A method according to claim 9, wherein the one or more sections of lower-quality visual data are generated from the high-quality visual data using a process comprising downsampling.

11. A method according to any of claims 9 or 10, wherein the one or more sections of lower-quality visual data are generated from the one or more sections of higher-quality visual data using a process comprising compression and/or quantisation.

12. The method according to any previous claim, wherein the hierarchical algorithm performs image enhancement, preferably using super-resolution techniques.

13. The method according to any previous claim, wherein the hierarchical algorithm uses a spatio-temporal approach.

14. The method according to any previous claim, wherein the lower-quality visual data comprises a plurality of frames of video.

15. The method according to any previous claim, wherein the hierarchical algorithm comprises a plurality of layers.

16. The method according to claim 15, wherein the layers are any of sequential, recurrent, recursive, branching or merging.

17. A method for reducing the amount of data to be transferred when communicating visual data over a network from a first node to a second node, the method at the first node comprising the steps of:

reducing the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data;

developing at least one example based model operable to increase the quality of the one or more sections of lower-quality visual data using the one or more sections of higher-quality visual data to optimise the developed at least one example based model, wherein the developed at least one example based model corresponds to the one or more sections of lower quality visual data;

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transmitting the one or more sections of lower-quality visual data to the second node; and

transmitting to the second node the developed at least one example based model that corresponds to the one or more sections of lower-quality visual data transmitted to the second node;

wherein the second node is able to substantially reproduce the one or more sections of higher-quality visual data from the transmitted one or more sections of lower-quality visual data using the developed at least one example based model that corresponds to the one or more sections of lower-quality visual data.

18. A method for increasing the quality of a section of visual data communicated over a network from a first node to a second node, the method at the second node comprising the steps of:

receiving one or more sections of lower-quality visual data via a network;

receiving a corresponding at least one example based model operable to increase the quality of the one or more sections of lower-quality visual data, the at least one example based model developed with the knowledge of one or more sections of higher-quality visual data from which the one or more sections of lower-quality visual data was generated; and

using the at least one example based model to increase the quality of the one or more sections of lower-quality visual data to substantially recreate the one or more sections of higher-quality visual data.

19. A system for reducing the amount of data transferred when communicating visual data over a network, the system comprising two or more nodes wherein a first node is configured to:

reduce the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data;

develop at least one example based model operable to increase the quality of one or more sections of lower-quality visual data using the one or more sections of higher-quality visual data to optimise the developed at least one example based model, wherein the developed at least one example based model corresponds to the one or more sections of lower quality visual data;

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transmit the one or more sections of lower-quality visual data to the second node; and

transmit to the second node the developed at least one example based model that corresponds to the one or more sections of lower-quality visual data transmitted to the second node;

wherein the second node is configured to:

receive one or more sections of lower-quality visual data via a network;

receive a corresponding developed at least one example based model operable to increase the quality of the one or more sections of lower-quality visual data, the developed at least one example based model developed with the knowledge of one or more sections of higher-quality visual data from which the one or more sections of lower-quality visual data was generated; and

use the developed at least one example based model to increase the quality of the one or more sections of lower-quality visual data to substantially recreate the one or more sections of higher-quality visual data.

20. A method or system respectively according to any of claims 17 to 19, wherein the example based model comprises any or a combination of any of: a non-linear algorithm; or an hierarchical algorithm; or a convolutional neural network; or a recurrent neural network, or a deep belief network, or a dictionary learning algorithm; or a parameter; or a mapping function.

21. A method or system respectively according to any of claims 17 to 20 wherein the high-quality visual data is divided into smaller sections based on similarities between a plurality of frames of the high-quality visual data.

22. A method or system respectively according to any of claims 17 to 21 wherein the one or more sections comprise any of: a single frame, a sequence of frames and a region within a frame or sequence of frames.

23. A method or system respectively according to any of claims 17 to 22, wherein the visual data is converted into a sequence of images, optionally before the quality is lowered.

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24. A method or system respectively according to any of claims 17 to 23, wherein down-sampling is used to reduce the quality of one or more sections of higher-quality visual data to one or more sections of lower-quality visual data.

25. A method or system respectively according to any of claims 17 to 24, wherein the steps of transmitting the one or more sections of lower-quality visual data to the second node and transmitting to the second node the developed at least one example based model that corresponds to the one or more sections of lower-quality visual data transmitted to the second node occur substantially simultaneously.

26. A method or system respectively according to any of claims 17 to 25, wherein the developed example based model is developed for each section of visual data to be transferred over the network.

27. A method or system respectively according to any of claims 17 to 26, wherein the developed example based model is developed using a method of machine learning.

28. A method or system respectively according to any of claims 17 to 27, wherein the example based model comprises a plurality of connected layers.

29. A method or system respectively according to claim 28 wherein the layers are sequential.

30. A method or system respectively according to any of claim 28 or claim 29, wherein a last of the layers is operable to increase the quality of the one or more sections of lower-quality visual data.

31. A method or system respectively according to any of claims 17 to 30, wherein the example based model is a neural network and preferably uses a spatio-temporal approach.

32. A method of training image artefact removal models, the method comprising the steps of:

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generating a plurality of training visual data from an original visual data;

developing an example based model for each of the training visual data operable to substantially recreate the original visual data from the training visual data the example based model was developed from; and

storing the example based models in a library of example based models;

wherein the training visual data contain a predetermined amount of artefacts.

33. A method according to claim 32, wherein the original visual data is divided into smaller sections based on similarities between a plurality of sections of the original visual data.

34. A method according to any of claims 32 to 33, wherein the example based model comprises any of: a non-linear hierarchical algorithm; or a convolutional neural network; or a recurrent neural network; or a deep belief network; or a dictionary learning algorithm; or a parameter; or a mapping function.

35. A method according to any of claims 32 to 34, wherein the training visual data are generated using at least one compression and/or quantisation algorithm.

36. A method according to any of claims 32 to 35, wherein the example based model is developed using a method of machine learning.

37. A method according to any of claims 32 to 36, comprising the additional step of determining a content type of the original visual data using metric data.

38. A method according to claim 37, comprising the additional step of determining a measure of artefact severity for each of the training visual data.

39. A method according to claim 38, wherein the example based models are classified in the library of example based models using metric data associated with the content type and the measure of artefact severity of the training visual data from which the example based models were developed.

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40. A method or system respectively according to any preceding claim, wherein the visual data comprises at least one of: an image, a sequence of images, or a section of video.

41. The method according to any previous claim, wherein a section of visual data comprises any of: a single frame of visual data, a sequence of frames of visual data, and a region within a frame or sequence of frames of visual data.

42. The method according to any previous claim, wherein the higher-quality visual data is at a higher-resolution than the lower-quality visual data.

43. A method according to any preceding claim, wherein the one or more sections of lower-quality visual data have a greater amount of artefacts than the one or more sections of higher-quality visual data.

44. The method of any previous claim, where in enhancing the quality of visual data means upscaling the quality of the visual data.

45. A system substantially as hereinbefore described in relation to Figures 2 to 6.

46. A method substantially as hereinbefore described in relation to Figures 2 to 6.

47. Apparatus for carrying out the method of any preceding claim.

48. A computer program product comprising software code for carrying out the method of any of claims 1 to 44.

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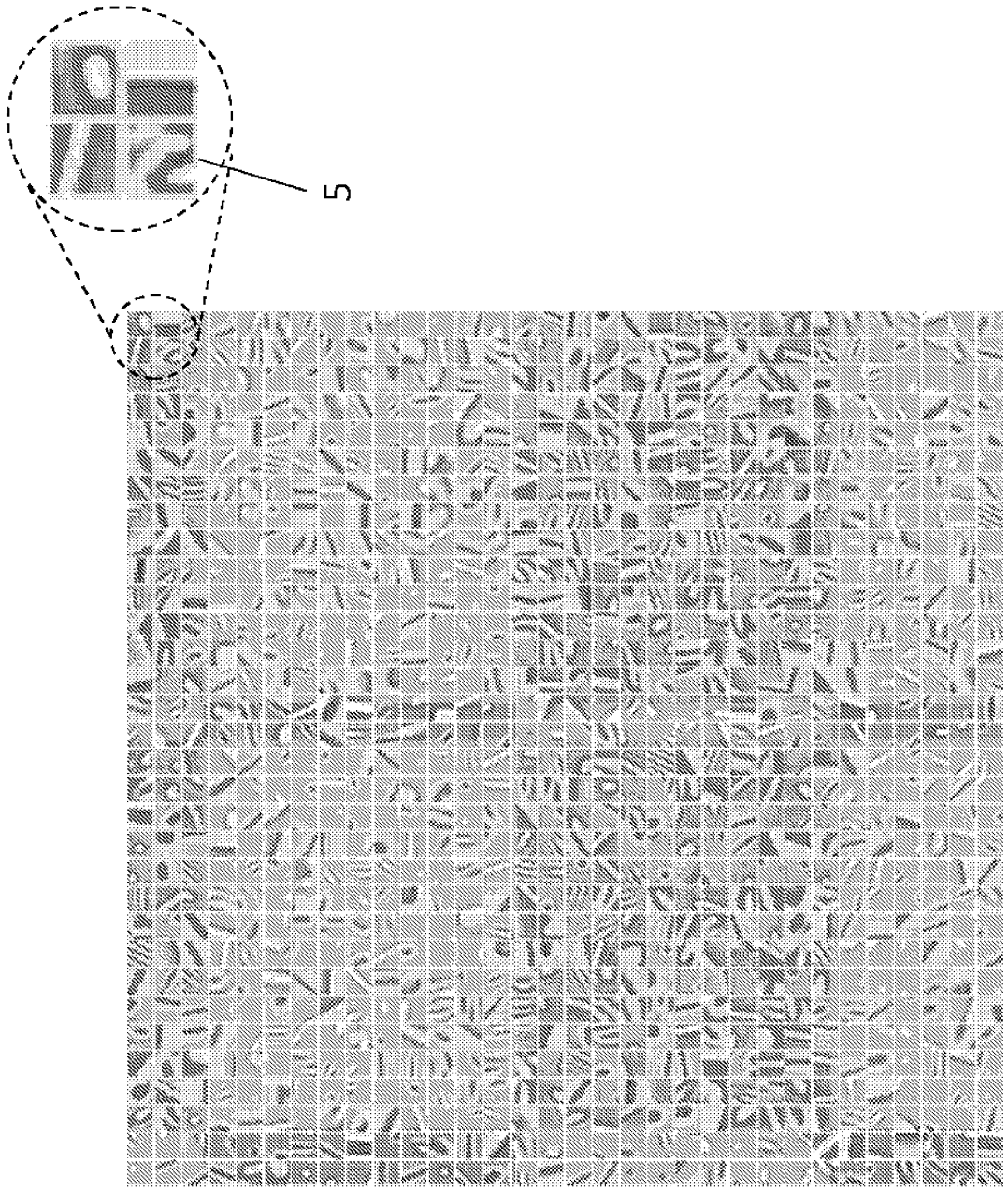

Fig. 1

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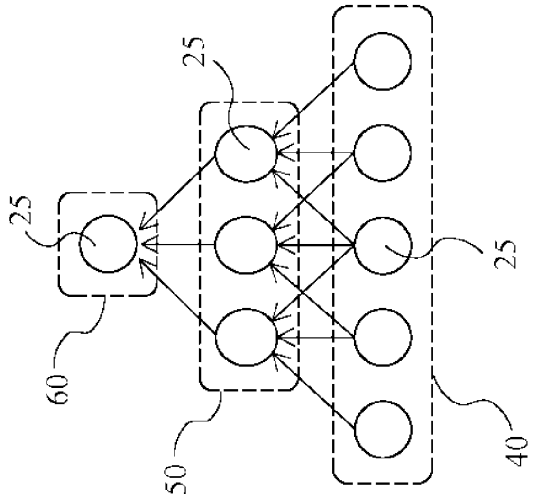

Fig. 2b

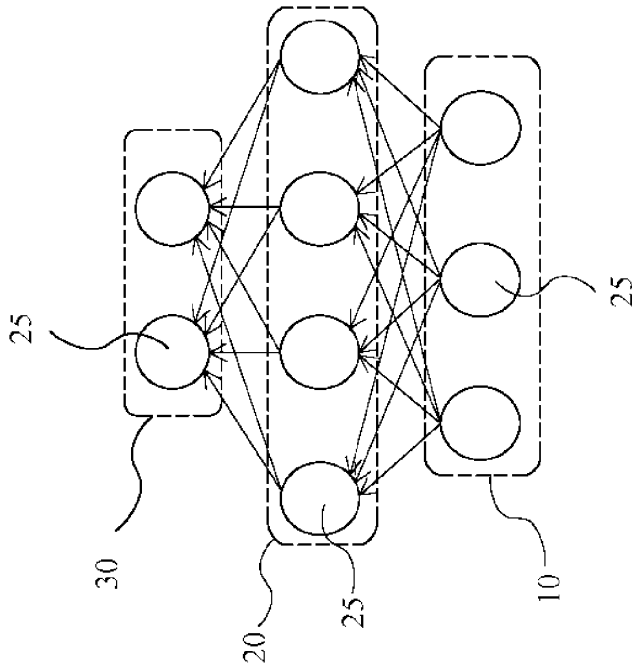

Fig. 2a

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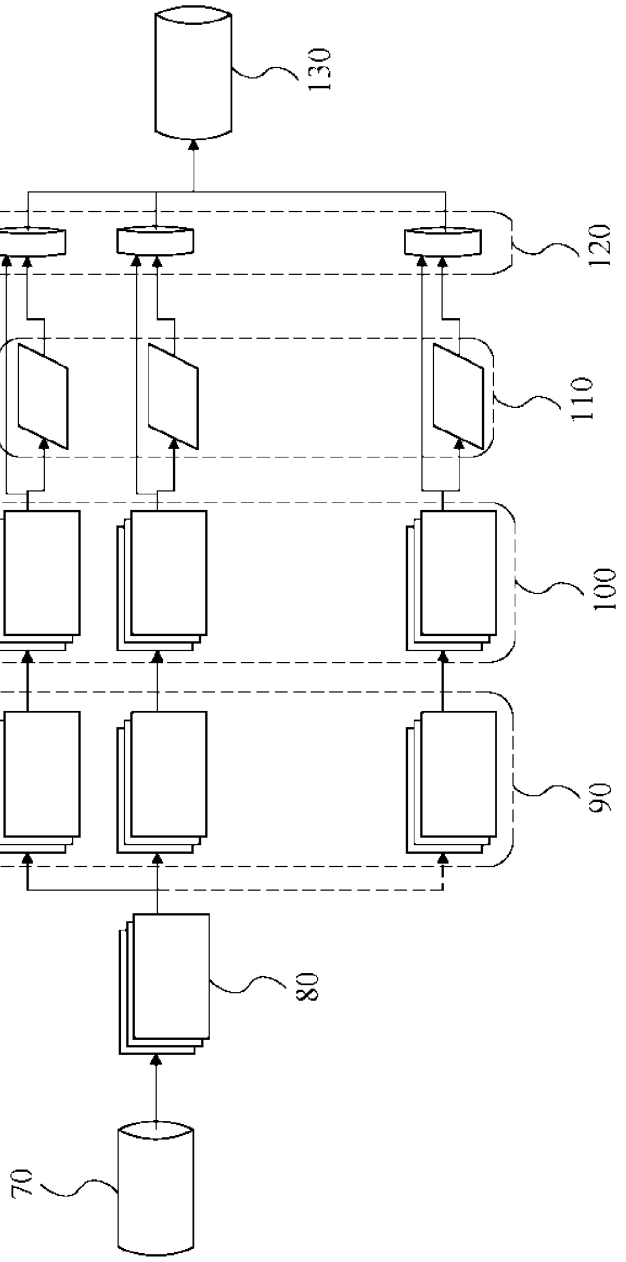

Fig. 3

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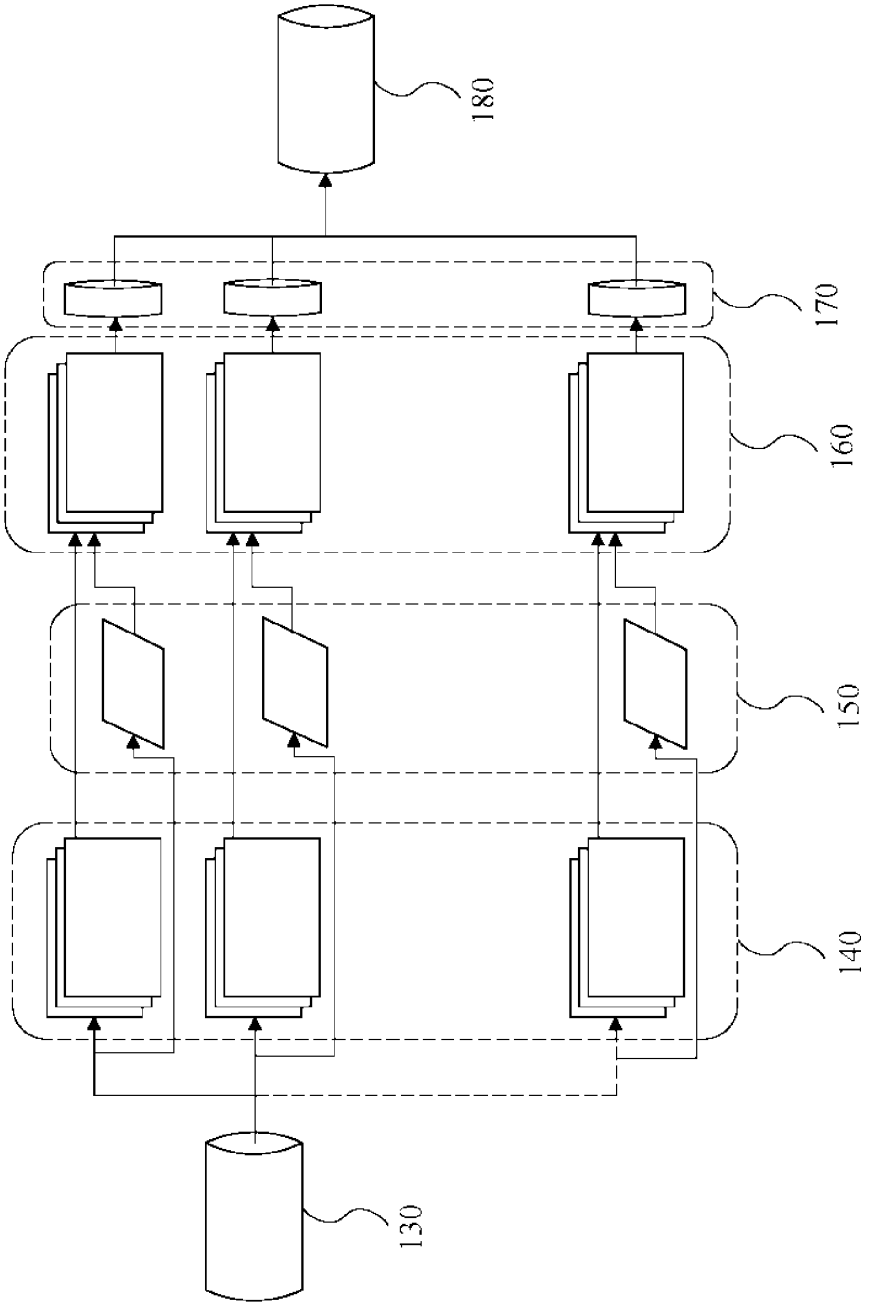

Fig. 4

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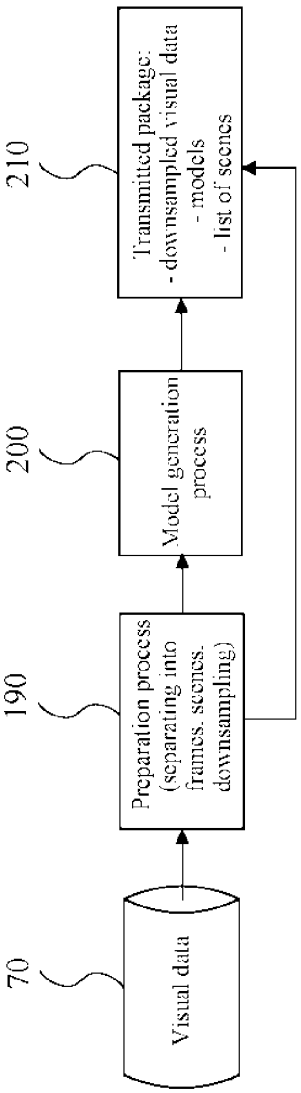

Fig. 5

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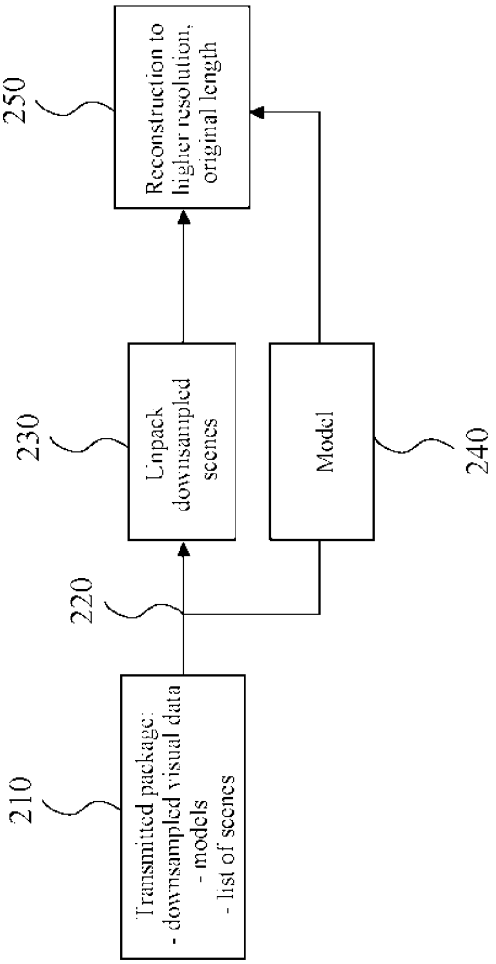

Fig. 6

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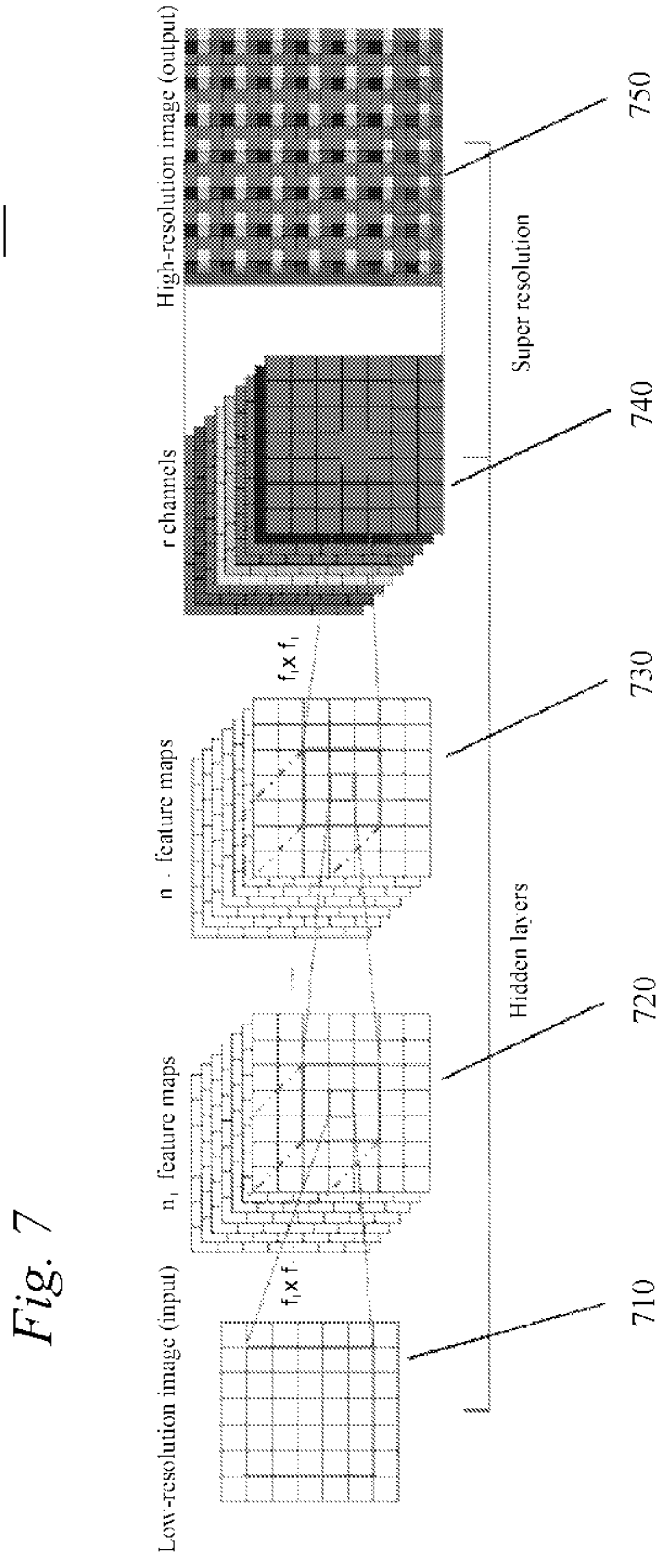

Fig. 7

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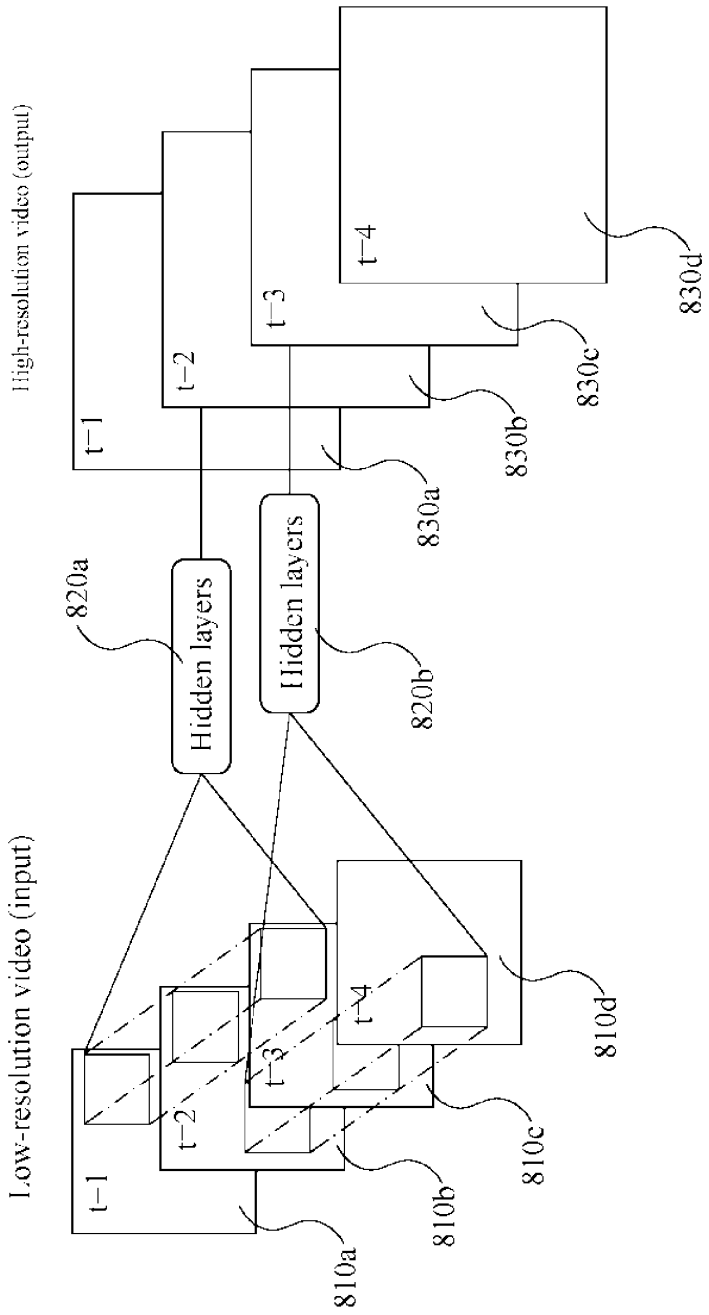

Fig. 8

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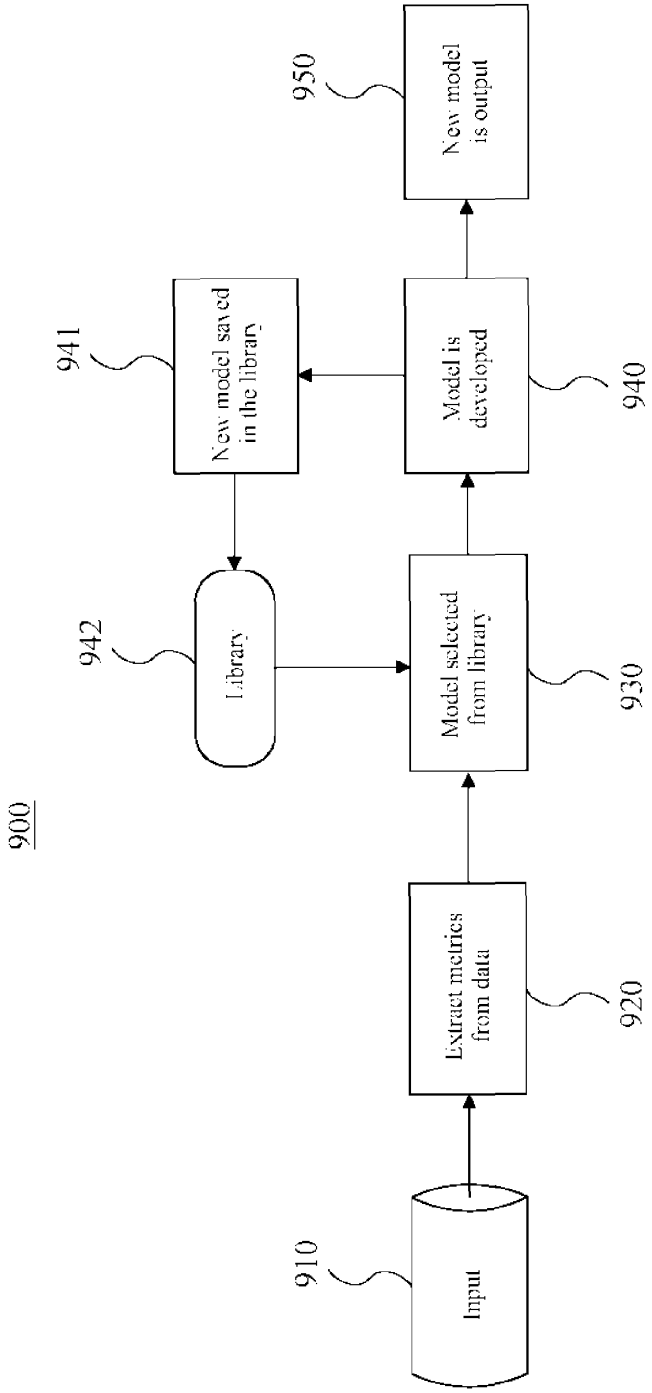

Fig. 9

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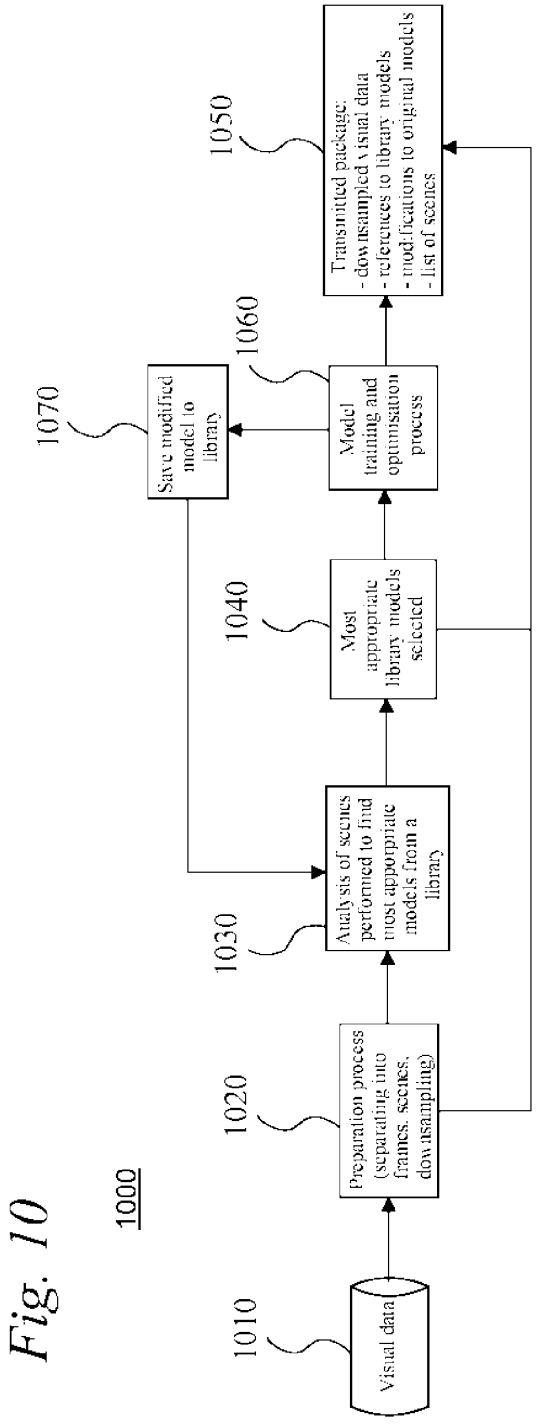

Fig. 10

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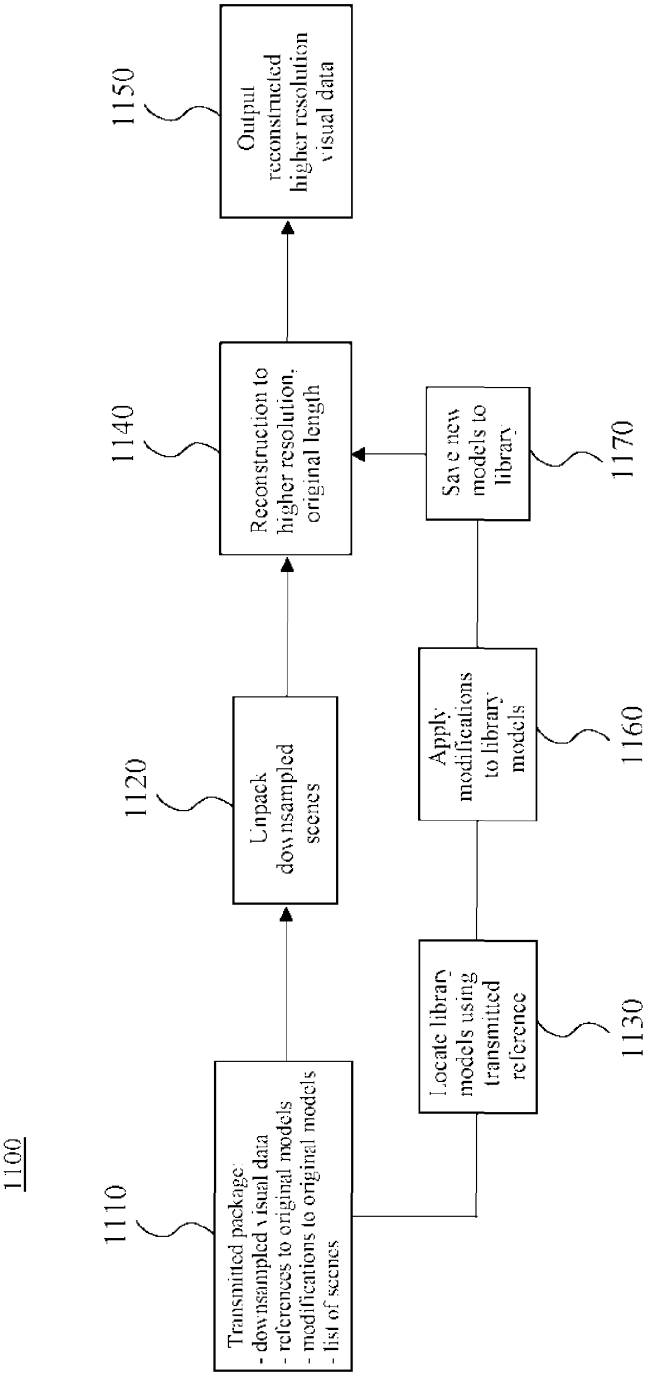
Fig. 11



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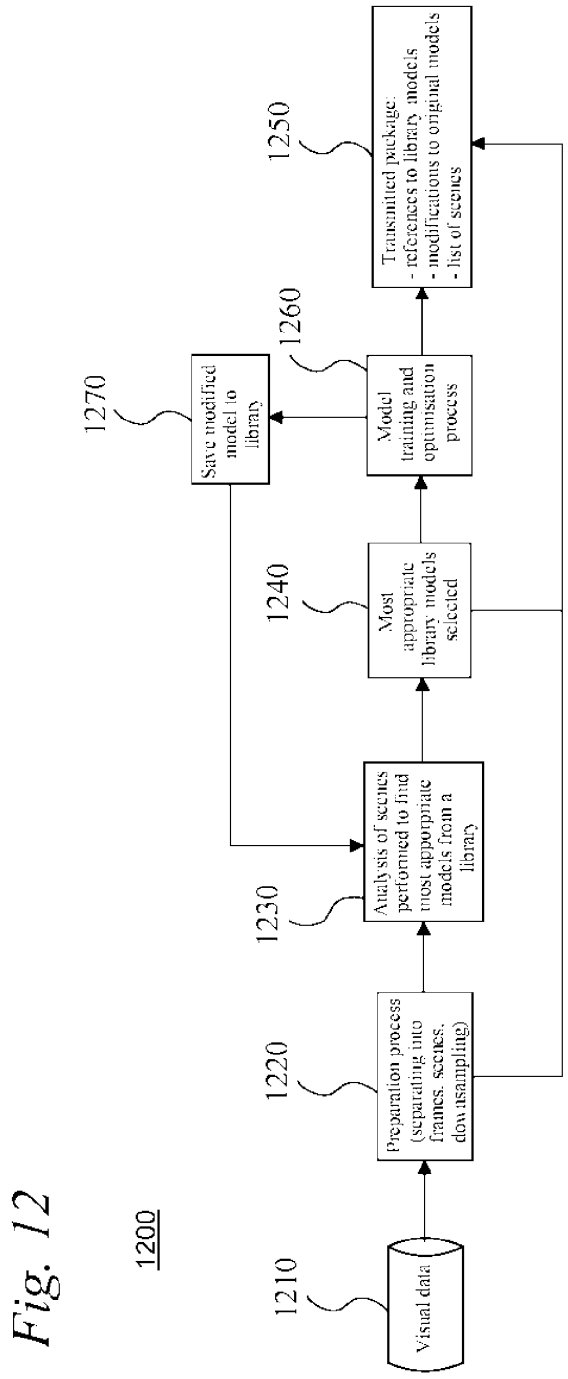

Fig. 12

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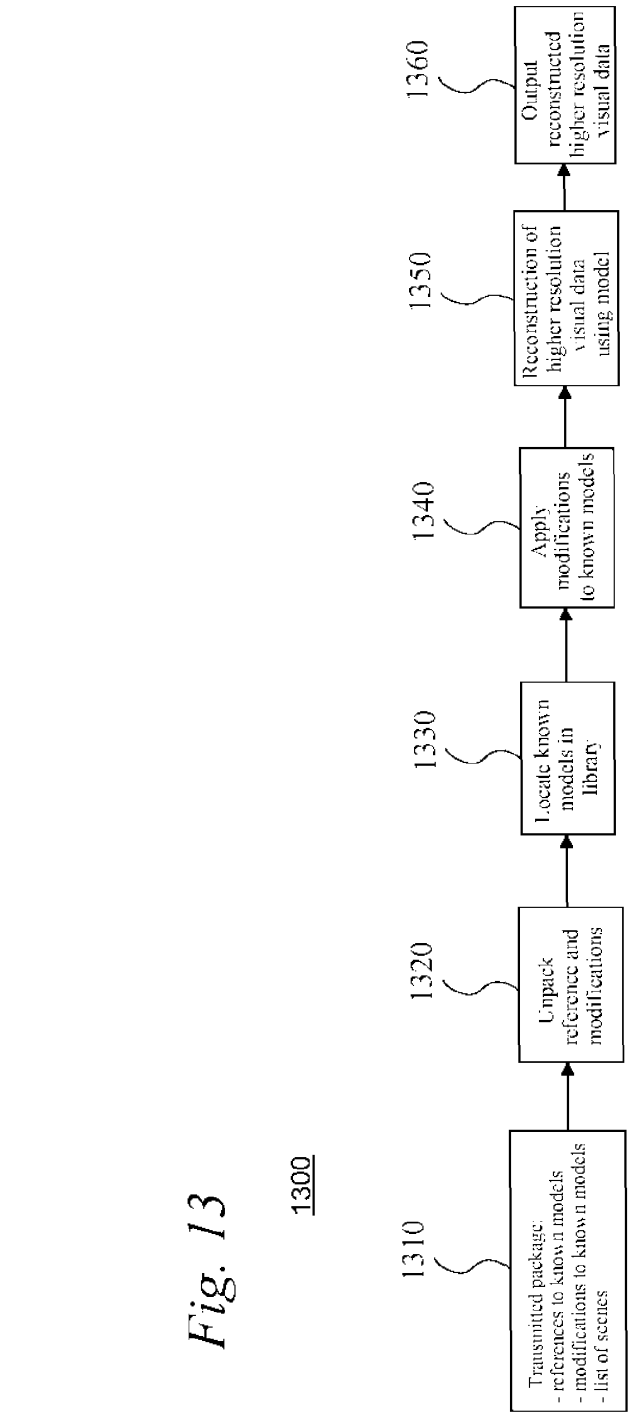
Fig. 13



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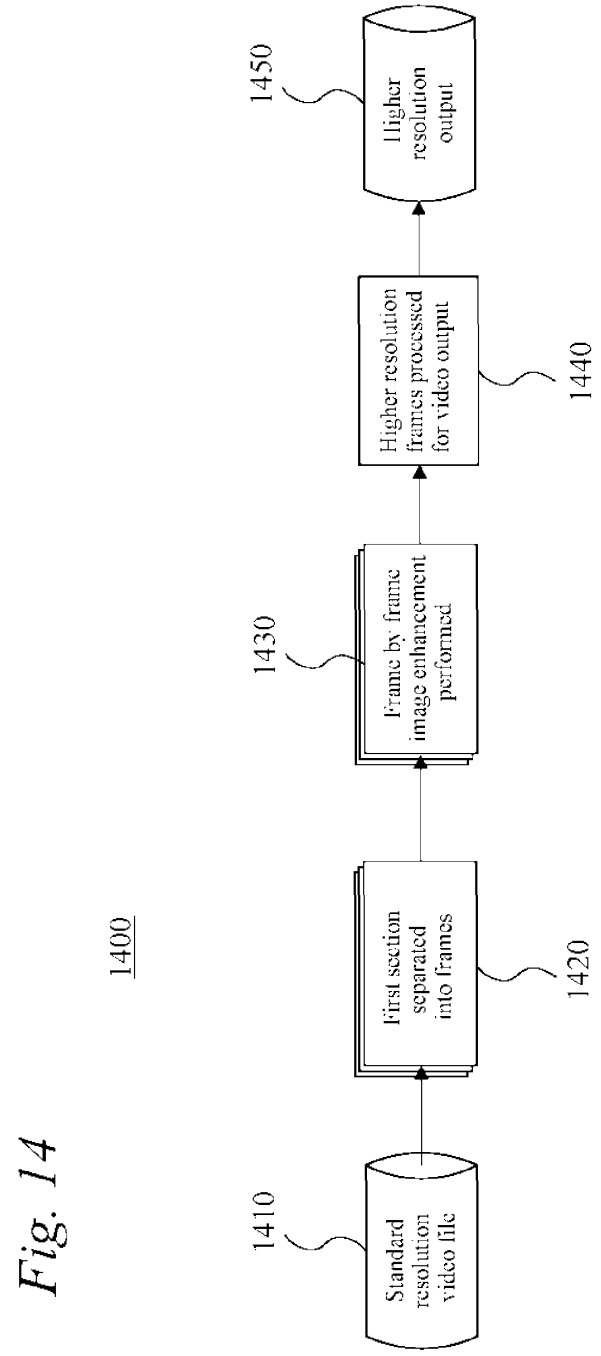

Fig. 14

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Fig. 15

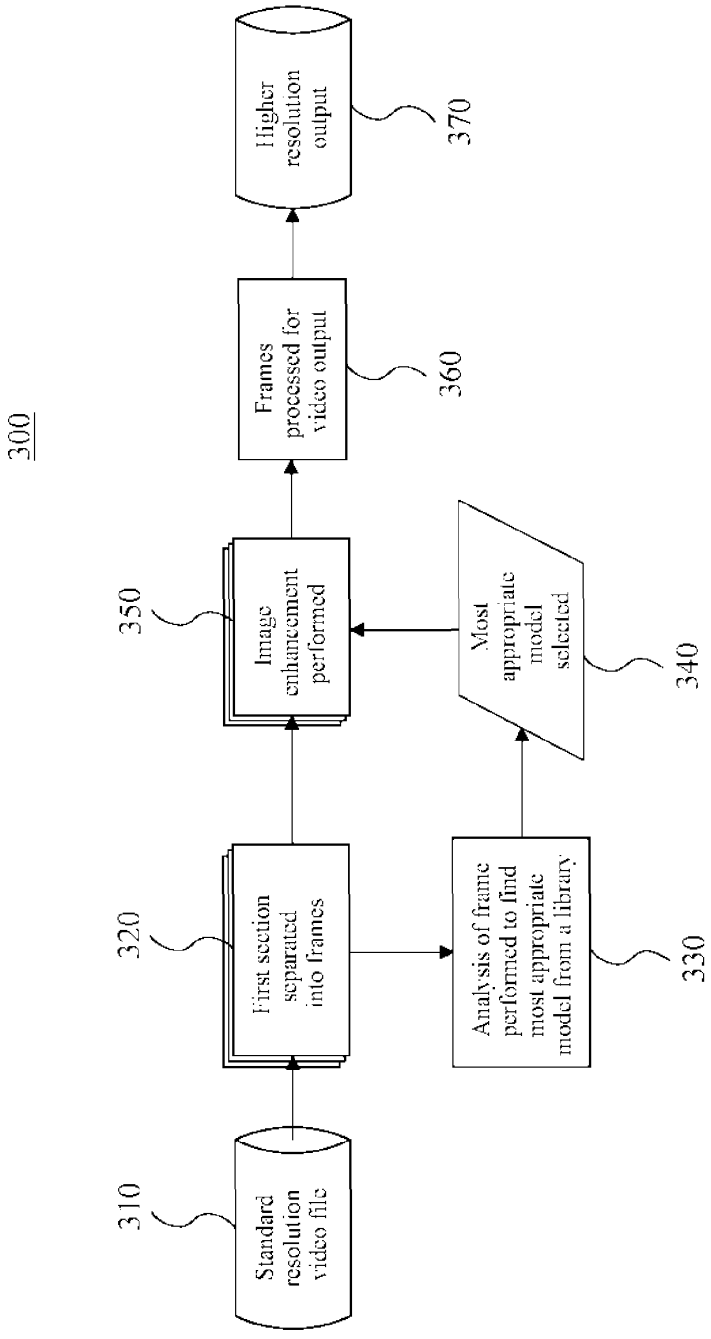

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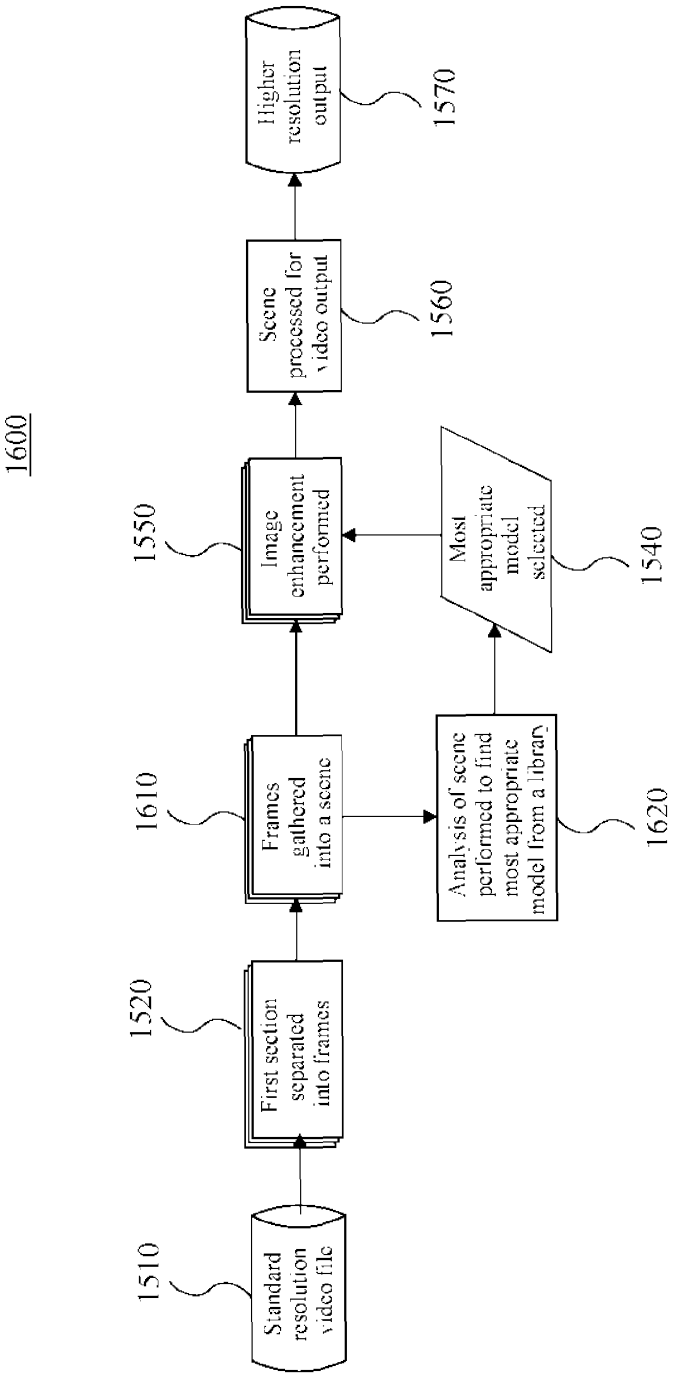
Fig. 16



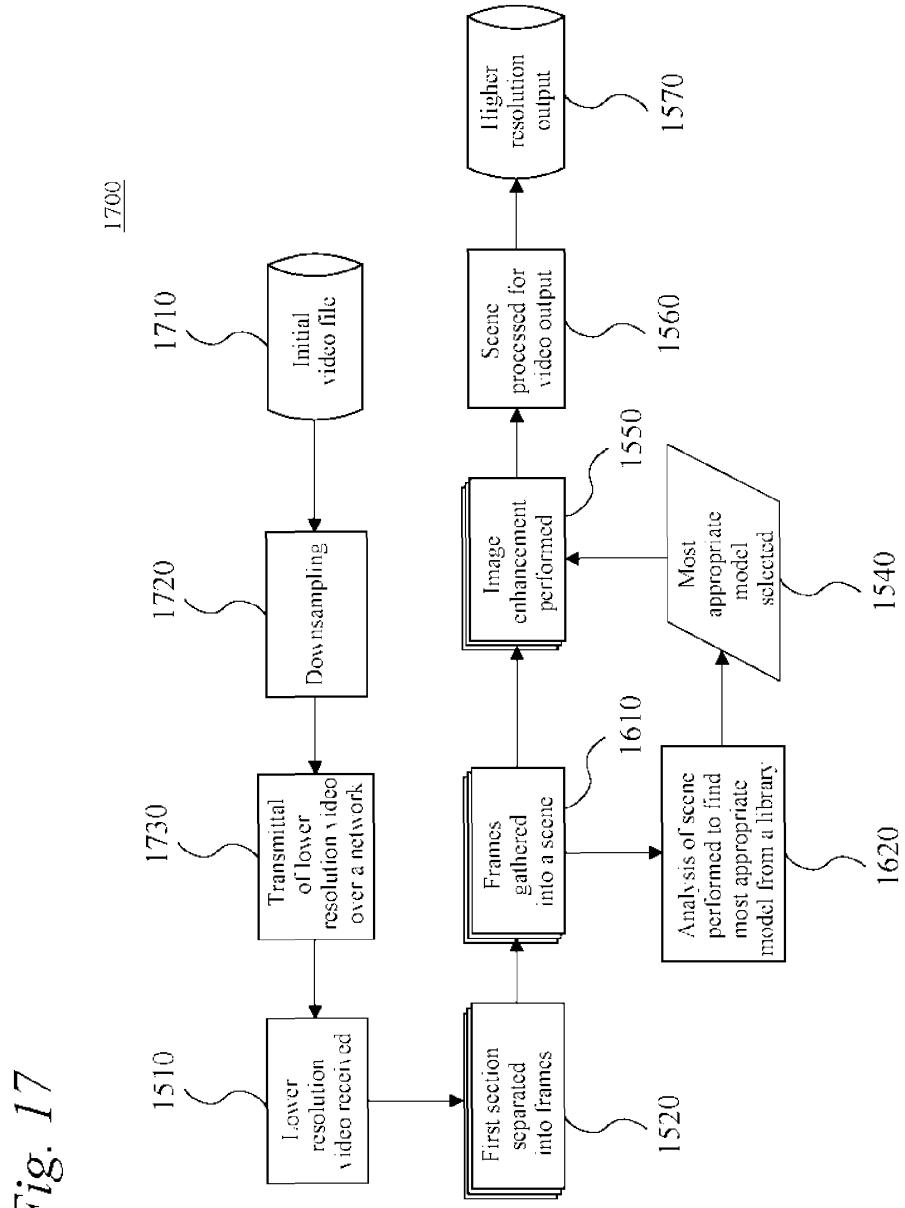


Fig. 17

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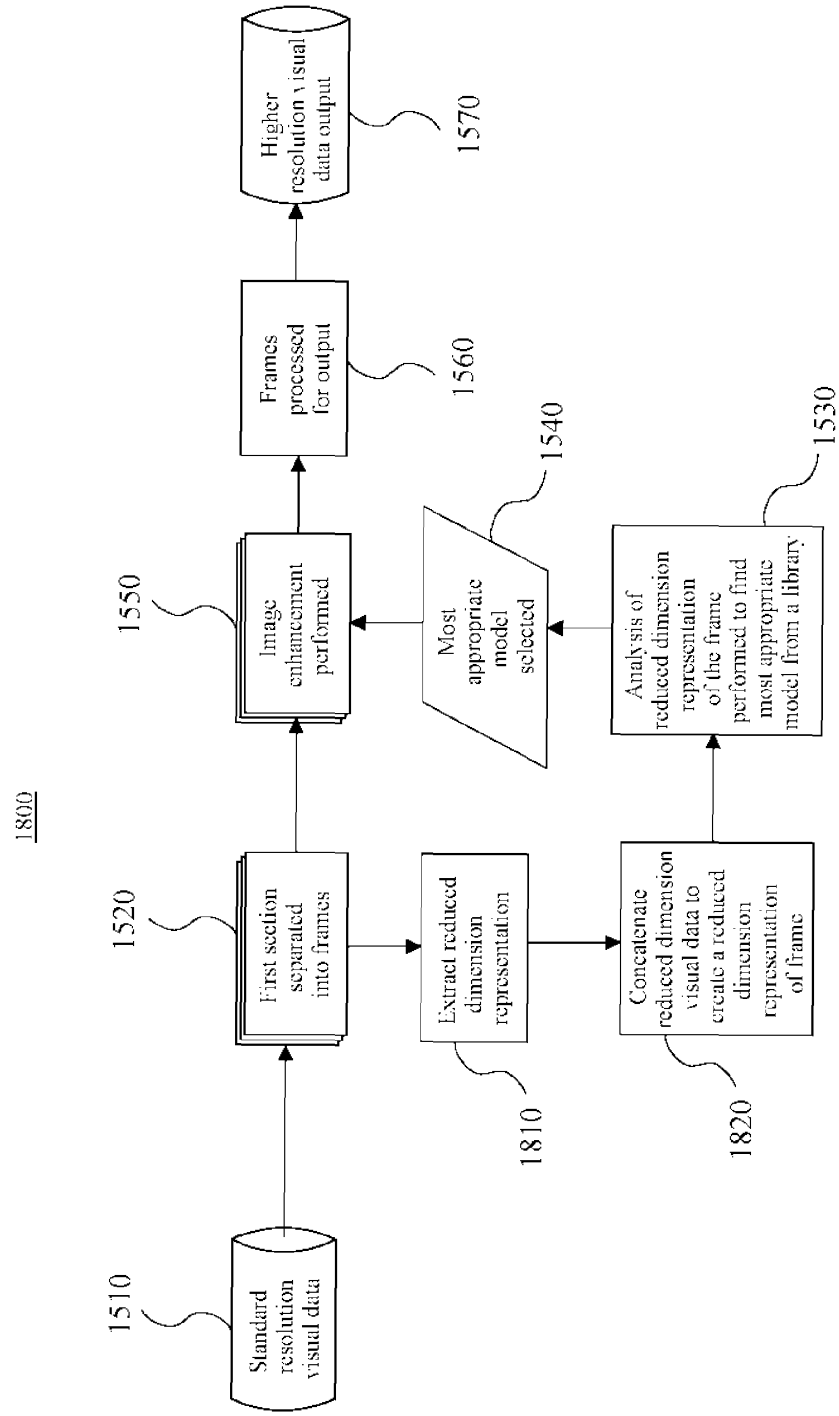

Fig. 18

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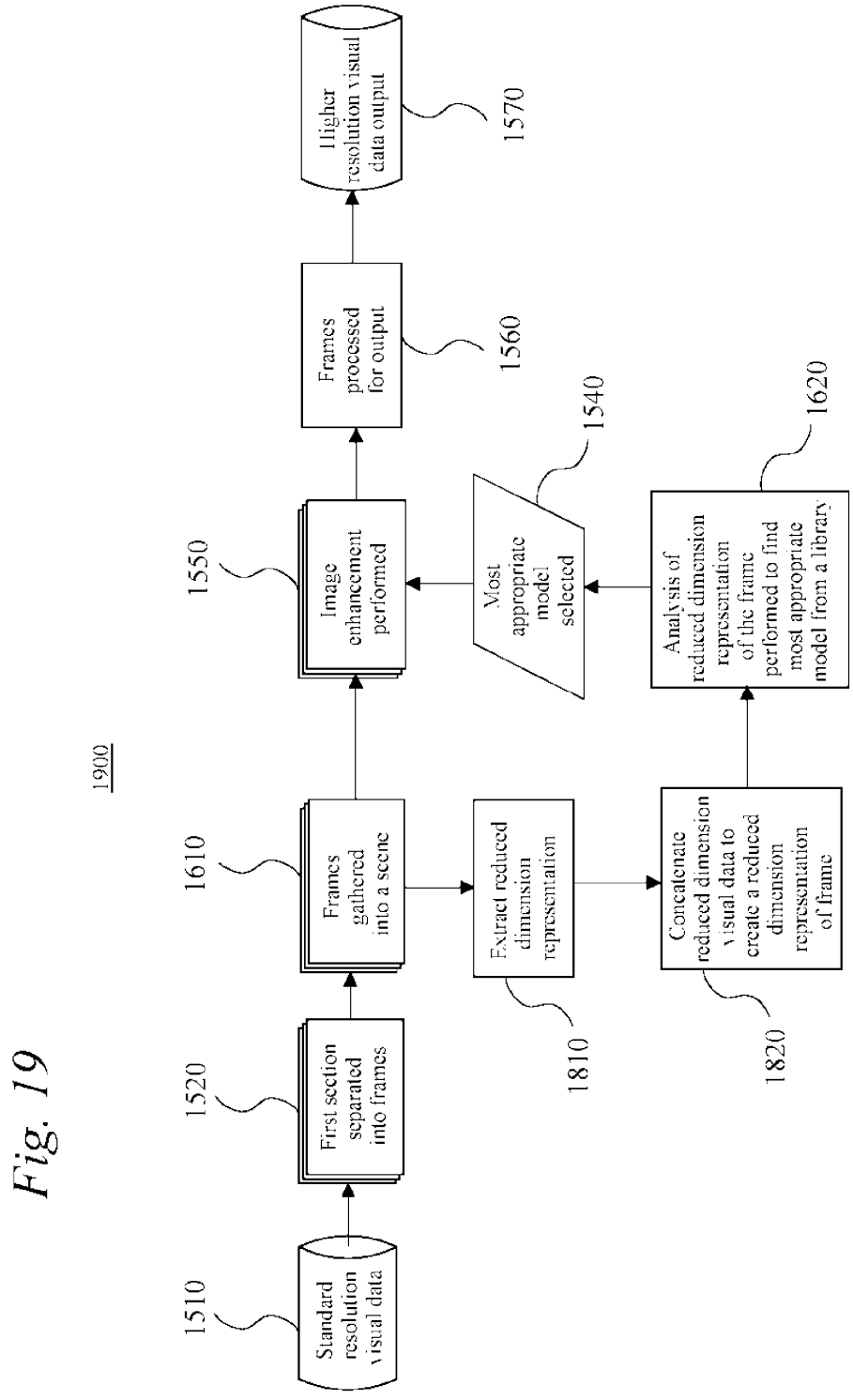

Fig. 19

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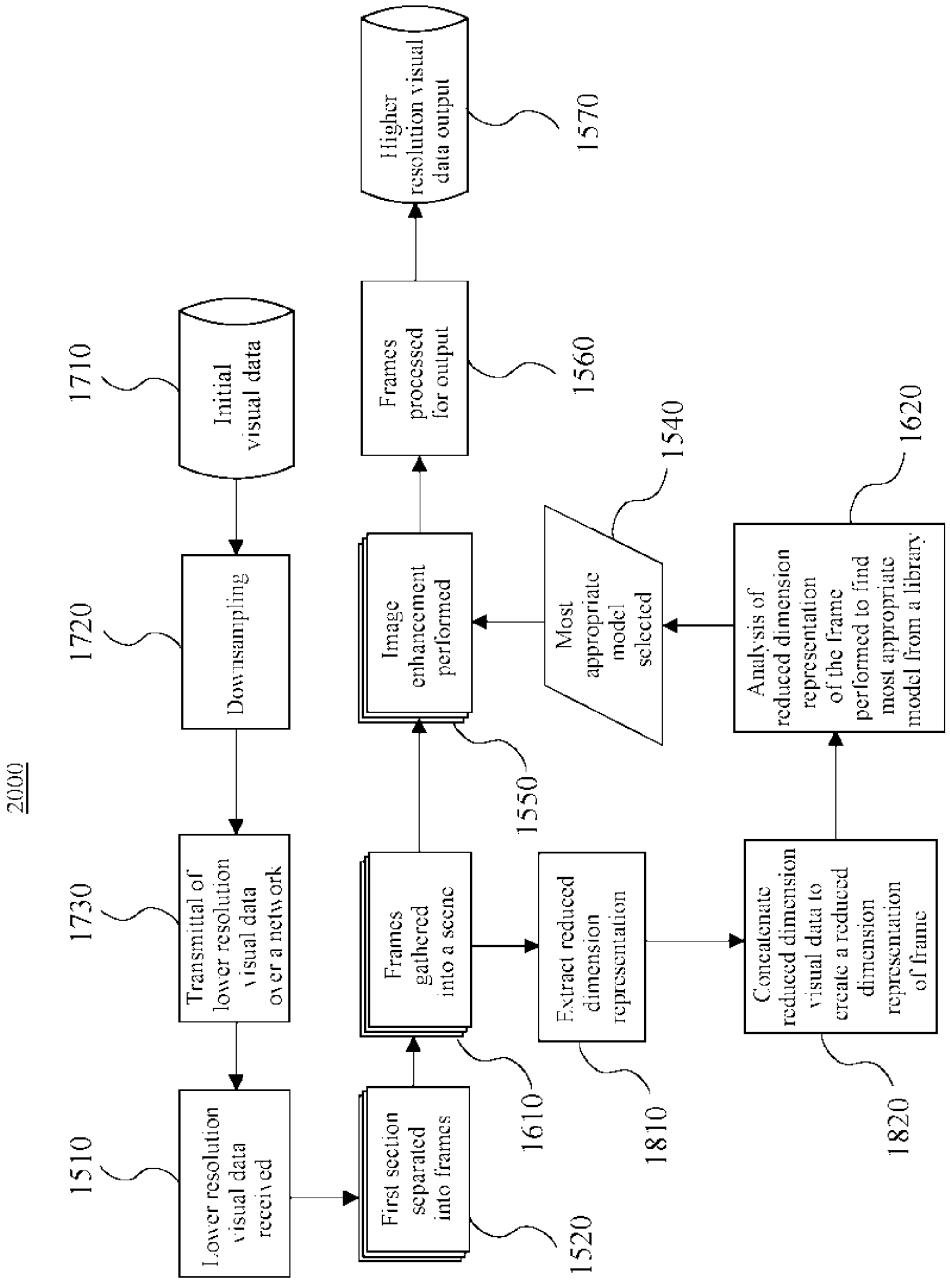
Fig. 20



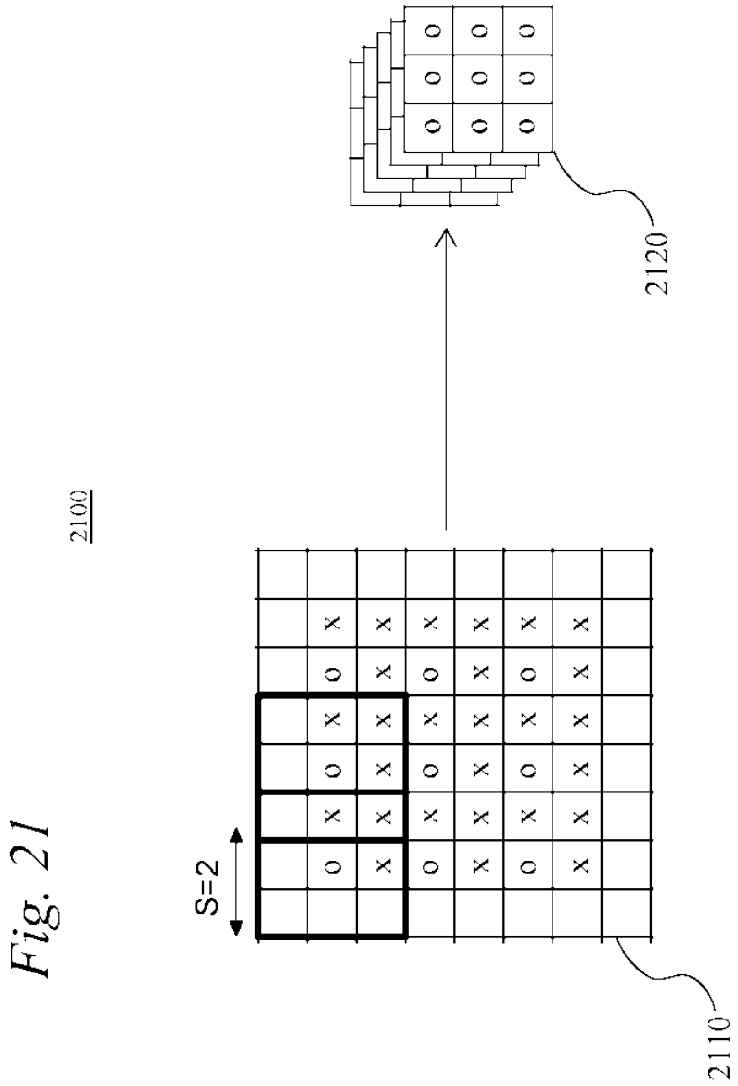


Fig. 21

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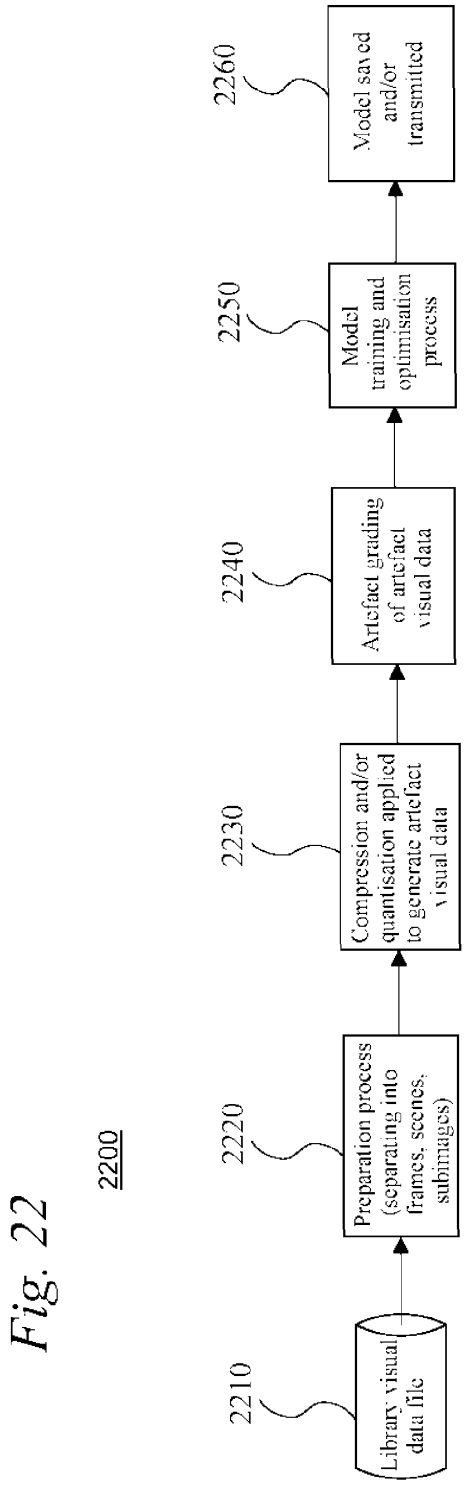

Fig. 22

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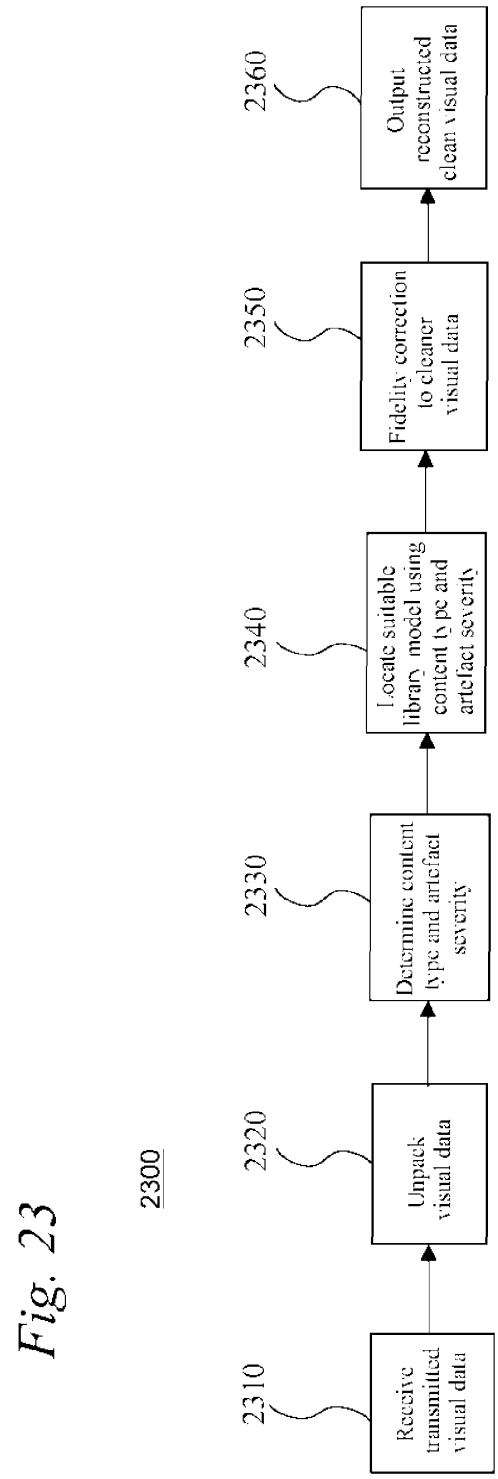

Fig. 23

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Fig. 24

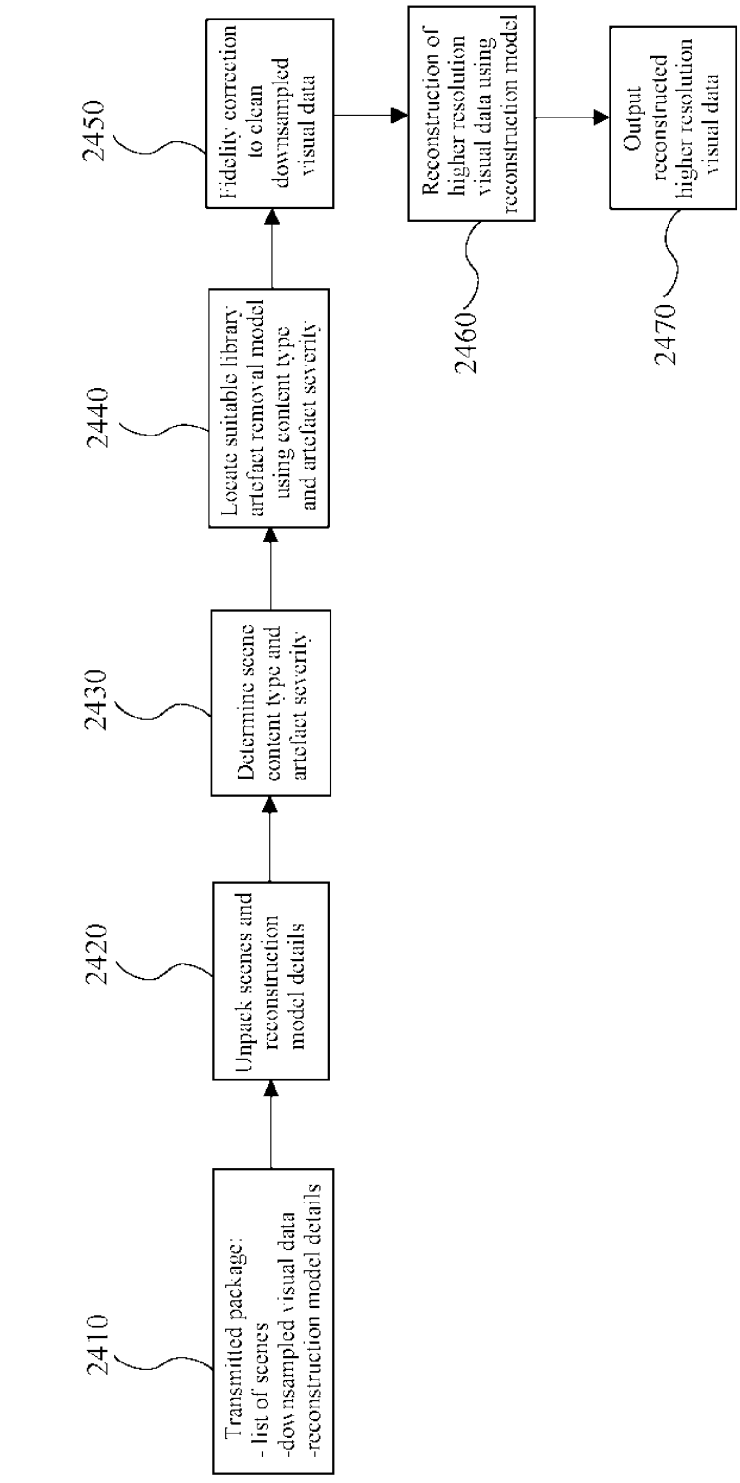

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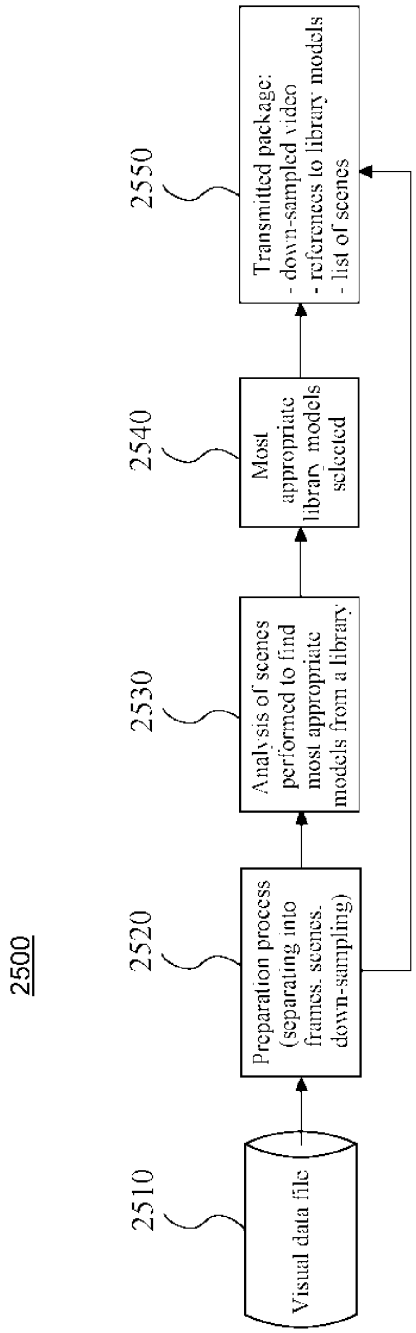
Fig. 25



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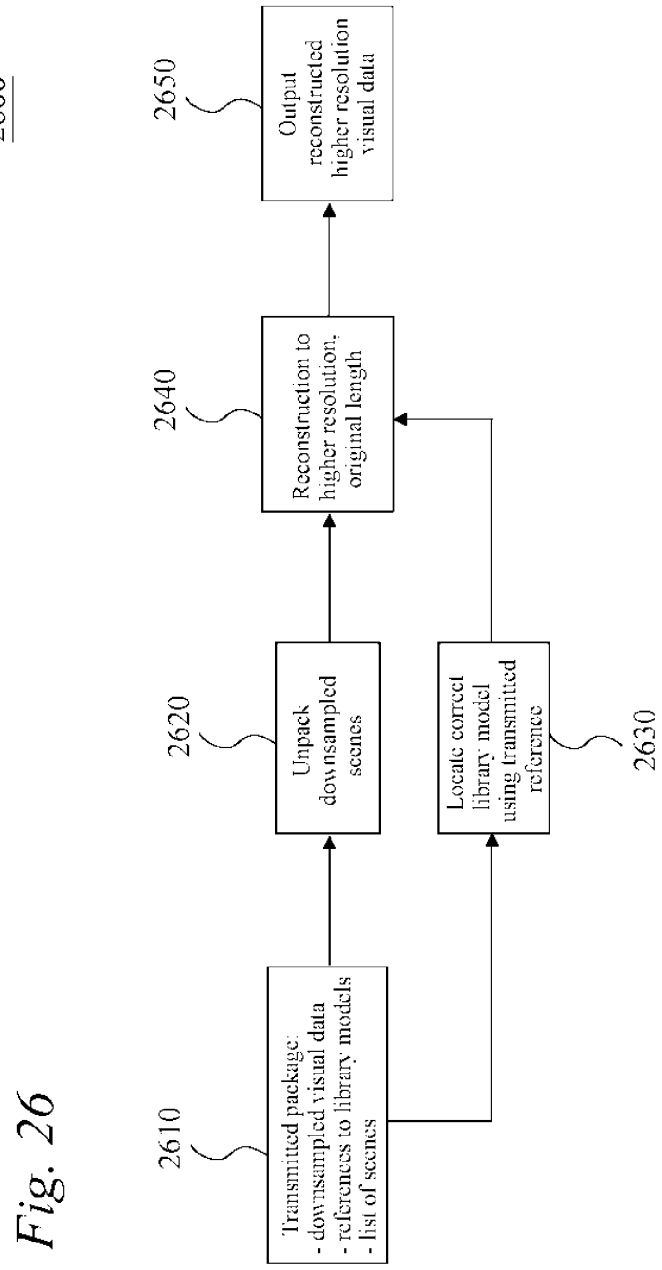

Fig. 26

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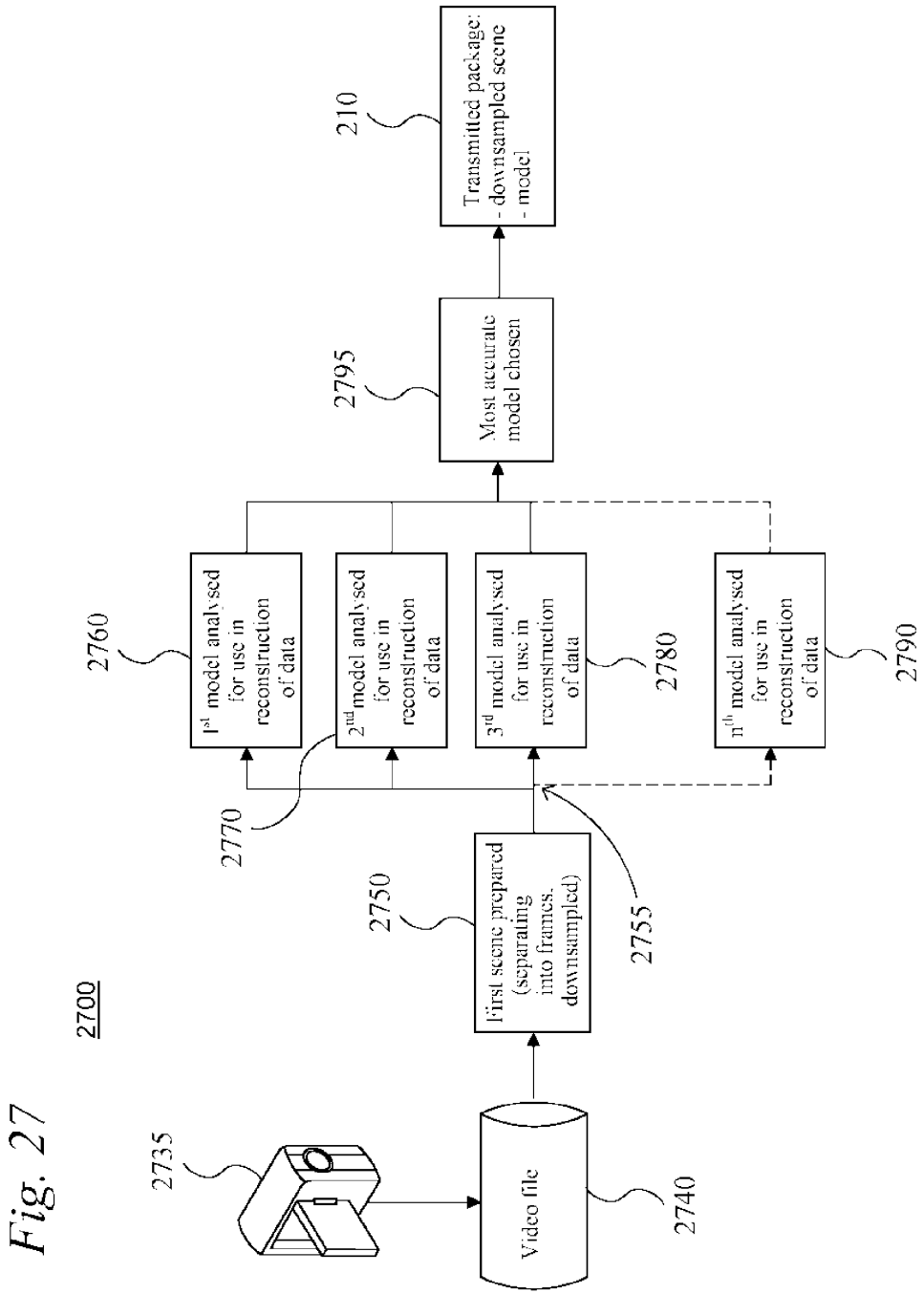

Fig. 27

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/050426

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N19/117 H04N19/177
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DONG CHAO ET AL: "Learning a Deep Convolutional Network for Image Super-Resolution", 6 September 2014 (2014-09-06), CORRECT SYSTEM DESIGN; [LECTURE NOTES IN COMPUTER SCIENCE; LECT.NOTES COMPUTER], SPRINGER INTERNATIONAL PUBLISHING, CHAM, PAGE(S) 184 - 199, XP047296566, ISSN: 0302-9743 ISBN: 978-3-642-24570-1	1-7,9, 10,12, 15,16, 32-48
Y	the whole document	8,11,13, 14,17-31

Y	US 2013/128111 A1 (CORRAL-SOTO EDUARDO R [CA]) 23 May 2013 (2013-05-23) paragraph [0027] - paragraph [0029]	8

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 May 2016	13/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Willems, Brigitte

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Form PCT/ISA/210 (second sheet) (April 2005)

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/200757 A1 (PICA ALBERTA [US] ET AL) 15 September 2005 (2005-09-15) paragraph [0020] - paragraph [0035]; figures 1-3	11,13, 14,17-31
A	SHUYUAN YANG ET AL: "Single-Image Super-Resolution Reconstruction via Learned Geometric Dictionaries and Clustered Sparse Coding", IEEE TRANSACTIONS ON IMAGE PROCESSING, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 21, no. 9, 1 September 2012 (2012-09-01), pages 4016-4028, XP011492170, ISSN: 1057-7149, DOI: 10.1109/TIP.2012.2201491 the whole document	1-39

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2016/050426

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013128111 A1	23-05-2013	NONE	
US 2005200757 A1	15-09-2005	US 2005200757 A1	15-09-2005
		WO 2005072337 A2	11-08-2005

Form PCT/ISA/210 (patent family annex) (April 2005)

Espacenet

Bibliographic data: JP2005181914 (A) — 2005-07-07

DISPLAY DEVICE AND DISPLAY METHOD, AND EQUIPMENT USING THEM

Inventor(s): ADACHI MASAYA; ITO OSAMU; KOMURA SHINICHI ± (ADACHI MASAYA, ; ITO OSAMU, ; KOMURA SHINICHI)

Applicant(s): HITACHI LTD; HITACHI DISPLAYS LTD ± (HITACHI LTD, ; HITACHI DISPLAYS LTD)

Classification: - international: ***G02B27/22; G09G5/00; H04N13/00;*** (IPC1-7): G02B27/22
- cooperative: **G02B27/2278**; **H04N13/0425**; **H04N13/0495**

Application number: JP20030426108 20031224 Global Dossier

Priority number (s): JP20030426108 20031224

Also published as: JP4408368 (B2) US2005156813 (A1) US7605981 (B2)

Abstract of JP2005181914 (A)

PROBLEM TO BE SOLVED: To provide a display device for optically superposing and displaying a plurality of observation objects existing at different depth positions as seen from an observer, which is thinned by reducing the number of parts and realizes brighter display. ;SOLUTION: The display device is equipped with a single liquid crystal display element whose display surface is divided to a long distance display area and a short distance display area, a polarized light separating element arranged on the front surface of the short distance display area, a polarized light changing element arranged on the front surface of the long distance display area, and a total reflection mirror reflecting video light radiated from the long distance display area toward the polarized light separating element.; In the display device, the video light radiated from the short distance display area is transmitted through the polarized light separating element and observed by the observer, and the video light radiated from the long distance display area passes through the polarized light changing element, is reflected by the total reflection mirror and then reflected by the polarized light separating element so as to be observed by the observer. ;COPYRIGHT: (C)2005,JPO&NCIPI

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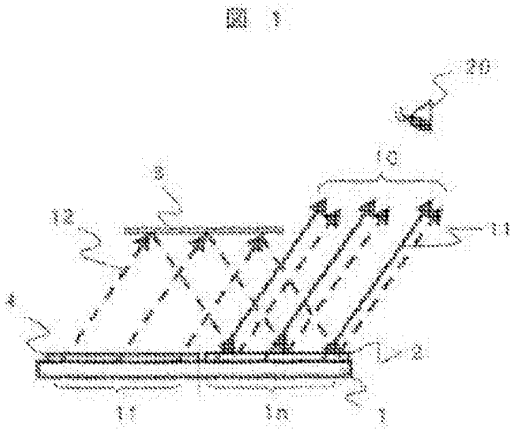

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JP,2005-181914,A

PAJ Detail Image
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DRAWINGS CORRECTION OR AMENDMENT

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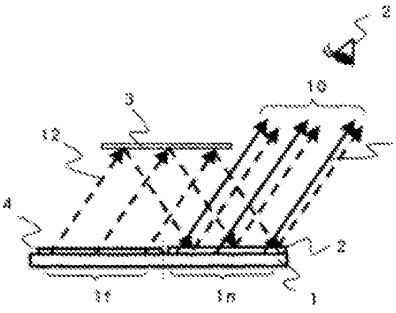
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
The present invention relates to the display device which can observe optically in piles a plurality of observing objects in the position where distance (depth) differs, the method of presentation in which depth is given, and apparatus provided with these from the viewpoint of an observer.
[Background of the Invention]
[0002]
As equipment which displays video information, it is CRT (Cathod-Ray Tube) as a display device. There are a display device of a direct viewing type provided with a plasma display panel, a liquid crystal display element, an organic electroluminescence display device, etc. and a projection type display device which carries out extended projection of the optical image which the small display device formed to a screen.
[0003]
Each of these display devices displays a two-dimensional image based on two-dimensional video information fundamentally. Here, the display device hereafter provided with the display device and this which display a two-dimensional image is called a two-dimensional display device and a two-dimensional display device, respectively.
[0004]
The display device provided especially with a liquid crystal display element among these display devices is broadly used for game machines, such as a thin shape, a big-screen TV since it is lightweight, a monitor for personal computers, a mobile phone, a game machine or pachinko, and a pachislot, etc.
[0005]
By the way, from the former, a plurality of two-dimensional display devices or the display surface of a two-dimensional display device is arranged in the position (distance) where depth differs from the viewpoint of an observer, and there is a display device which makes an observer perceive depth sensation and a cubic effect by displaying in piles optically. Such a display device has high power of expression compared with the display device which only displays a two-dimensional image, and it can realize the display which has presence more.
[0006]
There is a display device which arranges the display surface of a plurality of two-dimensional display devices and the two-dimensional display device observed by having a half mirror and transmitting a half mirror and the display surface of the two-dimensional display device observed by reflecting by a half mirror as a typical structure of such a display device in the position where depth differs. Fig.43 is an outline cross sectional view of the display device which shows an example of such a prior art and is provided with two display devices and half mirrors. The display device which depth has arranged in the distant position from the viewpoint of an observer here using a liquid crystal display element as a two-dimensional display device. The image lights (it is also hereafter called long distance image lights) from (hereinafter, also calling it the display device for long distances) transmit a half mirror, and are observed, The image lights (it is also hereafter called short-distance image lights) from the display device (it is also hereafter called the display device for short distances) which depth has arranged in the near position show the case where it is reflected and observed by a half mirror, from the viewpoint of an observer. In this case, from the viewpoint of an observer, the image displayed

図 1



Representative drawing

Representative drawing

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on two display surfaces arranged in the position where depth differs is optically synthesized by a half mirror, and is observed in the state where it lapped.
[0007]
With such a structure, when the number of the display surfaces arranged to different depth (distance) is two, two two-dimensional display devices are needed. That is, with such a structure, since same number as the number of the display surfaces arranged to different depth of two-dimensional display devices are needed, the number of parts increases, and there is a defect that equipment will be enlarged. When using thin display devices, such as a liquid crystal display element and an organic electroluminescence display device, especially as a two-dimensional display device, the characteristics of the thin shape cannot be harnessed sufficiently.
[0008]
Although a synthesis of long distance image lights and short-distance image lights is performed via a half mirror in a prior art, as for a half mirror, the sum total of T% of transmissivity and R% of reflectance will be 100% at the maximum generally. For this reason, respectively R % and T% of light did not result in the observer, but the long distance image lights and the short-distance image lights which are emitted from a display device turned into loss light, and the image lights which reach an observer had the problem of decreasing below in half of the light emitted from a display device.
[0009]
The display device which comprises a plurality of projectors which project a two-dimensional image on a plurality of reflection type holographic diffusion boards arranged to a different depth position from the viewpoint of an observer and each reflection type holographic diffusion board is disclosed in the Patent document 1. The light from the projector which gets blocked and corresponds is reflected [the fixed direction to which the reflection type holographic diffusion board was set, and], it is scattered about, and the light reflected and scattered about with the reflection type holographic diffusion board arranged in an incident light, for example, a back face, from the direction of other transmits. For this reason, it is observed after the image projected on a plurality of reflection type holographic diffusion boards arranged in the position where depth differs has lapped.
[0010]
In this case, if the transmissivity of a reflection type holographic diffusion board is not 100%, by the time the image lights projected on the reflection type holographic diffusion board which depth arranges in a distant position result in an observer, a loss will produce them.
[0011]
Since it is necessary to separate and put in order the same distance as the depth observed by the observer in a plurality of reflection type holographic diffusion boards, equipment becomes thick to a depth direction. Since same number as further a plurality of reflection type holographic diffusion boards of projectors are needed, the number of parts increases and equipment becomes large-sized.
[0012]
The method of presentation which makes an observer perceive a three-dimensional stereoscopic model is disclosed in the Patent document 1 and the Patent document 2. It expresses as this method so that it may lap, when the two-dimensional image (image) formed in the display surface of several display devices from which depth differs from the viewpoint of an observer sees from one on the line which connects an observer's right eye and left eye. As for the two-dimensional image (image) displayed on each display surface from which depth furthermore differs, a three-dimensional stereoscopic model is perceived by the observer by adjusting the luminance according to the distance from the depth position of a displaying object, i.e., the observer of a displaying object, keeping constant the luminance at the time of seeing from an observer.
[0013]
Although this method can inhibit inconsistency between the physiological factors of a corporal vision and it is expected as the new three-dimensional display method which can moreover lessen the amount of information, the position of the observer whom a three-dimensional stereoscopic model can observe satisfactorily is limited. When an observer's viewpoint changes largely, it becomes impossible that is, to observe a good three-dimensional stereoscopic model.
[0014]
[Patent document 1] Japanese Published Patent Application No. 2003-57595 (JP2003-57595A)
[Patent document 2] Japanese Published Patent Application No. 2000-214413 (JP2000-214413A)
[Patent document 3] International Publication number: WO 95/No. 27919
[Description of the Invention]
[Problem to be solved by the invention]
[0015]
When realizing the display device which displays optically in piles a plurality of observing objects arranged in the position (distance) where depth differs from the viewpoint of an observer, the number of parts of the problem which the present invention tends to solve increases, and it is at the point which equipment enlarges. That is, it is in the issue which the present invention tends to solve reducing the number of parts, and miniaturizing or thinning equipment in the display device which displays optically in piles a plurality of observing objects arranged in the position (distance) where depth differs from the viewpoint of an observer. The second problem which the present invention tends to solve, Before the image lights which emit a plurality of observing objects, such as a display surface etc. of the two-dimensional display device arranged in the position (distance) where depth differs from the viewpoint of an observer, from a two-dimensional display device in the equipment displayed in piles optically reach an observer, it is in the part losing. That is, there is the second issue which the present invention tends to solve in realizing a brighter display device by making the image lights

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emitted from a two-dimensional display device reach an observer efficiently.
[0015]
The position where the 3rd issue that the present invention tends to solve differs in depth from the viewpoint of an observer
It is in realizing the method of presentation which does not impair depth sensation even if a viewpoint changes in the equipment which displays optically in piles a plurality of observing objects, such as a display surface etc. of the two-dimensional display device arranged in (distance). About the problem of others of the present invention, and the new characteristics, it clarifies with reference to description and the accompanying drawing of this Description.
[Means for solving problem]
[0017]
From the viewpoint of an observer, the present invention is a display device which displays optically in piles a plurality of observing objects in the position where depth differs, and is provided with a plurality of observing objects which carried out arranging in parallel, and a plurality of reflectors. One of the reflectors of said plurality of is a total reflection mirror, and other reflectors are half mirrors. The aforementioned half mirror is arranged from the viewpoint of an observer to the front-face side of observing objects other than the observing object arranged in the most distant position. From the viewpoint of an observer, the aforementioned total reflection mirror is arranged so that the light from the observing object arranged in the most distant position may be turned to the aforementioned half mirror and it may reflect.
[0018]
The light from the observing object arranged in the still nearer position from the viewpoint of an observer, The light from observing objects other than the observing object which was transmitted and observed and has arranged the half mirror arranged in the front face of the observing object arranged in the nearest position from the viewpoint of an observer in the nearest position from the viewpoint of an observer, it is reflected and observed from the viewpoint of an observer by the half mirror arranged in the front face of the observing object arranged in the nearest position.
[0019]
Said plurality of observing objects are arranged on the same plane or a substantially identical plane.
[0020]
Under the present circumstances, the aforementioned display device is from 0 degree to the substantially identical plane where it arranges in so that the reflective surface of said plurality of reflectors may become each other substantially parallel, and said plurality of { reflective surface / aforementioned } observing objects are arranged further.
The angle of 45 degrees is made.
[0021]
The aforementioned display device is a display surface of the two-dimensional display device of plurality { observing objects / said plurality of }, and, as for the a plurality of two-dimensional display devices, at least one of component members is commonalized. Or the aforementioned display devices are several different display areas in the display surface of a two-dimensional display device with said plurality of single observing objects.
[0022]
Said plurality of observing objects are the display surfaces of several different display areas in the display surface of a single two-dimensional display device, or a plurality of two-dimensional display devices, and the aforementioned two-dimensional display device emits predetermined polarization as image lights. The polarization component from which the polarization component of the aforementioned half mirror predetermined in at least one is furthermore reflected, the polarized light separating element which the polarization component from which this and a polarization condition differ transmits, or a predetermined polarization component is transmitted, and this and a polarization condition differ is a polarized light separating element to reflect.
[0023]
In this case, it emanates from the aforementioned two-dimensional display device, and those 80% or more of an incident light is reflected or transmitted to the aforementioned polarized light separating element.
[0024]
The method of presentation of the present invention is the method of presentation of the display device which displays optically in piles a plurality of observing objects in the position where depth differs from the viewpoint of an observer, When said plurality of observing objects are the display surfaces of several different display areas in the display surface of a single two-dimensional display device, or a plurality of two-dimensional display devices, it displays as follows.
(1) Don't display the same displaying object on a different display area or a display surface simultaneously. What furthermore exists in the distance is displayed on the display area or display surface corresponding to the distance, and displays a near thing on the display area or display surface corresponding to the distance.
(2) It is depth far from an observer about the displaying object which exists continuously over different depth. That is, the portion which is in a long distance from an observer is displayed only on the display area or display surface corresponding to the depth (distance), and displays from an observer near depth, i.e., the portion which is in a short distance from an observer, only on the display area or display surface corresponding to the depth (distance). The portion equivalent to the mid-position of different depth is displayed in each display area or display surface more darkly than the other portion. Under the present circumstances, the portion equivalent to the mid-position of different depth is displayed so that luminance may fall continuously, as it approaches between different depth.
(3) When the displaying object in the position where depth differs laps, the portion which is

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closely alike relatively among the displaying objects which exist in the distance relatively, and is shielded by a certain displaying object, In the display area or display surface which displays the displaying object which exists in the distance relatively, at least one copy of the portion equivalent to the region which is closely alike relatively and is shielded by a certain displaying object is displayed darkly. Under the present circumstances, the portion shielded displays darkly continuously toward a central part from the periphery of that shield part.
[0025]
Suppose that it is clear by the following description about other means.
[Effect of the Invention]
[0026]
From the viewpoint of an observer, the display device of the present invention can observe a plurality of observing objects which carried out arranging in parallel on the same plane or the substantially identical plane, after a plurality of observing objects in the position where depth differs have lapped optically. For this reason, there is an advantage that depth more nearly actual than the depth which an observer perceives is small, and it can realize a thin display device.
[0027]
There is an advantage that there is little number of parts and it can realize a thin display device at low lost by making several different display areas in the display surface of a single two-dimensional display device into a plurality of observing objects.
[0028]
At least one observing object uses predetermined polarization as the display surface of the two-dimensional display device emitted as image lights among said plurality of observing objects, If a polarization component which a predetermined polarization component reflects the half mirror arranged in the front face of this display surface, transmits the polarized light separating element which transmits a different polarization component from this, or a predetermined polarization component, and is different from this is used as the polarized light separating element to reflect, Most image lights emitted from this display surface at least can be synthesized with the light from the observing object which has the distance from an observer in a position more distant (long) than this display surface, without losing. For this reason, compared with the case where a polarized light separating element is not used for a half mirror, there are few losses of image lights and it can realize a brighter display device.
[0029]
It is made not to display the same displaying object on the display surface from which depth differs simultaneously from the viewpoint of an observer in the display type of the present invention. The tolerance of the viewpoint which can detect depth sensation by this spreads, and even if a viewpoint changes somewhat, there is an advantage that the display with depth sensation is maintainable.
[0030]
In apparatus provided with the display device of the present invention, there is an advantage that depth more nearly actual than the depth which an observer perceives is small, and thin apparatus can realize the display with the depth sensation which cannot be expressed in the usual two-dimensional display device.
[Best Mode of Carrying Out the Invention]
[0031]
The present invention relates to the display device and the method of presentation which display optically in piles a plurality of observing objects in the position where depth differs, and apparatus provided with this from the viewpoint of an observer.
[0032]
A plurality of observing objects are arranged substantially in parallel on the same plane. This is very effective arrangement, in order to make thin thickness of the depth direction of the display device seen from the observer.
[0033]
The observing object can use the display surface of the display device (henceforth, two-dimensional display device) which displays two-dimensional images, such as CRT, a liquid crystal display element, an organic electroluminescence display device, and a plasma display panel. Or the display surface etc. of the display device to which a pattern is switched can be considered by rotating the reel which has arranged a plurality of patterns to the outer peripheral surface used on a slot machine etc. as an observing object.
[0034]
Although an observing object in particular is not limited, for the miniaturization of equipment, it is desirable to use the display surface of thin two-dimensional display devices, such as a liquid crystal display element or an organic electroluminescence display device.
[0035]
A plurality of observing objects are desirable in order that considering it as several different display areas in the display surface of a single two-dimensional display device may lessen the number of parts. An observing object will be naturally arranged at the same plane by carrying out like this.
[0036]
Here, hereafter, using a liquid crystal display element as an observing object, although the case where observing objects are two different display areas in the display surface of a single liquid crystal display element is described, the present invention is not limited to this.
[0037]
The display device of the present invention is provided with a plurality of observing objects and a plurality of reflectors. One of the reflectors is taken as a mirror (it is hereafter called a total reflection mirror) with high reflectance to the light from the observing object arranged in the most distant position from the viewpoint of an observer at least. Let reflectors other than this be half mirrors. In order to describe the case where the number of observing objects is two

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here, a reflector is two, an observing object and the same number, and a half mirror and another reflector of one reflector are total reflection mirrors.
[0038]
Depth arranges a half mirror from the viewpoint of an observer between the observing object and observer who have the distance from an observer in a short position closely. That is, depth arranges a half mirror among the display surfaces of a liquid crystal display element in the front face of the display area (it is hereafter called a short-distance display area) corresponding to the observing object in a near position.
[0039]
On the other hand, depth arranges a total reflection mirror from the viewpoint of an observer in the position which turns to a half mirror the light from the observing object which has the distance from an observer in a long position far, and it reflects. That is, depth arranges a total reflection mirror among the display surfaces of a liquid crystal display element in the position which turns the light from the display area (it is hereafter called a long distance display area) corresponding to the observing object used as a distant position to a half mirror, and it reflects. When an observer observes a short-distance display area, let the total reflection mirror be the form used as hindrance.
[0040]
A half mirror bears the function which synthesizes the image lights (it is hereafter called long distance image lights) from the image lights (it is hereafter called the short-distance image lights) and the long distance display area from a short-distance display area of a liquid crystal display element. That is, short-distance image lights transmit a half mirror, and are observed by the observer, and long distance image lights are reflected and observed by a half mirror.
[0041]
A total reflection mirror has a function which turns to a half mirror the image lights emitted from the long distance display area of a liquid crystal display element, and it reflects. For this reason, the total reflection mirror is important in order to acquire an image with bright considering it as a mirror with high reflectance to long distance image lights at least.
[0042]
As a liquid crystal display element, it can have a backlight and can use the transmission type liquid crystal display element which displays an image by adjusting the transmitted light amount of the light from a backlight. The liquid crystal display element which performs graphic display by having especially a polarizing plate and controlling the polarization condition of an incident light to a liquid crystal layer is desirable from the high image of a contrast ratio being acquired by a comparatively low drive voltage. The image lights emitted from such a liquid crystal display element turn into linear polarized light.
[0043]
For this reason, as for the linear polarized light with which emanate from the short-distance display area of a liquid crystal display element, and incident linear polarized light transmits in a half mirror in order to obtain image lights bright as a half mirror, and linear polarized light and this and a polarization axis cross at right angles, it is desirable to use the polarized light separating element to reflect. It is desirable in order to acquire an image with bright arranging the polarization conversion element converted to the light of the polarization condition by which it furthermore emanates from a long distance display area between a long distance display area and a half mirror, and a half mirror reflects incident image lights in a half mirror.
[0044]
As a functioning polarized light separating element, the dielectric multilayer which laminated the thing which has arranged the phase difference film, or the dielectric in which refractive indices differ can be used for the table and the reverse side of the double reflex reflection type polarizing film currently disclosed in the Patent document 3, or a cholesteric liquid crystal film as a half mirror.
[0045]
As a polarization conversion element, the optical rotation element and 1/2 wavelength plate which are made to rotate 90 degrees of polarization axes of incident linear polarization can be used for this.
[0046]
A reflective surface is a plane and, as for both a half mirror and a total reflection mirror, it is desirable to arrange so that a mutual reflective surface may become parallel. This is for the image of a long distance display area to be observed by the observer in form [**** / the image of a short-distance display area], even if optical members, such as a lens, are not added or it does not make the reflective surface of a reflector into a curved surface. Although it does not eliminate that the present invention adds optical members, such as a lens, or makes form of a reflective surface any curved surface shape, in order to lessen the number of parts and to realize a low cost display device, it is desirable to have the above-mentioned composition.
[0047]
A half mirror and a total reflection mirror have and arrange parallel or inclination to the display surface of a liquid crystal display element. Here, the case where lean a half mirror and 45 degrees of total reflection mirrors, and they are arranged to the display surface of a liquid crystal display element with reference to Drawings is described hereafter. Although the angle of the half mirror to the display surface of a liquid crystal display element and a total reflection mirror has a respectively suitable angle by a use, about this, it describes in detail in the below-mentioned working example.
[0048]
Fig.21 is an outline cross sectional view showing an example of the display device of the present invention, and shows the case where lean the half mirror 2 and 45 degrees of total reflection mirrors 3, and they are arranged to the display surface of the liquid crystal display element 1.
[0049]

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By having the above-mentioned composition, the image lights 11 emitted from 1n of short-distance display areas of the liquid crystal display element 1 are transmitted without almost being reflected by the half mirror 2, and are observed by the observer 20. On the other hand, it reflects by the half mirror 2 and the image lights 12 emitted from 1f of long distance display areas of the liquid crystal display element 1 are observed by the observer 20, after reflecting by the total reflection mirror 3.

[0050]

Under the present circumstances, since that most is converted to the linearly polarized light component which 90 degrees of polarization axes rotated by operation of the polarization conversion element 4 arranged between 1 f of long distance display areas and the half mirror 2, that most reflects by the half mirror 2, and the long distance image lights 12 are observed by the observer 20 by it.

[0051]

That is, since it is observed by the observer 20, without almost losing both the short-distance image lights 11 and the long distance image lights 12 by having a polarization conversion element further, using a polarized light separating element as the half mirror 2, the bright display which does not almost have the loss of image lights is obtained.

[0052]

Compared with 1 n of short-distance display areas, as for 1 f of long distance display areas, the distance from the observer 20 becomes far only the part of the distance from the total reflection mirror 3 to the half mirror 2. For this reason, in this display device, from the viewpoint of the observer 20, where two two-dimensional images arranged in the position where depth differs are piled up, it can display.

[0053]

Under the present circumstances, actually, since the observing object from which depth differs from the viewpoint of an observer is arranged on the same plane, it can realize a thin display device with small thickness of a depth direction more nearly actual than the depth perceived by the observer.

[0054]

By the way, when displaying in piles the two-dimensional image from which depth differs, the display which has a cubic effect with devising the method of presentation is attained.

[0055]

Fundamentally, the one method displays the same displaying object on both 1 f of long distance display areas, and 1 n of short-distance display areas, and it displays it so that the displaying object displayed on each display area may lap, when it sees from one on the line which connects an observer's right eye and left eye.

[0056]

Under the present circumstances, after maintaining so that the luminance of that sum total may become equal to the luminance of a displaying object when the two-dimensional image displayed on 1 f of long distance display areas and 1 n of short-distance display areas is seen from an observer, Among displaying objects, from the viewpoint of an observer, the portion in far depth makes high luminance in a long distance display area, and it makes low luminance in a short-distance display area. The portion which is in near depth from an observer among displaying objects makes high luminance in a short-distance display area, and it makes low luminance in a long distance display area.

[0057]

Thus, a three-dimensional stereoscopic model is perceived by the observer by performing the brilliance control according to the depth position seen from the observer of the displaying object, i.e., the distance from an observer. This method changes an observer's viewpoint, and when the relative position of the displaying object displayed on 1 f of long distance display areas and 1 n of short-distance display areas deviates, it becomes impossible however, to observe a good three-dimensional stereoscopic model. Then, it is good to display the seal of alignment for an observer to distinguish easily the view position which a three-dimensional stereoscopic model can observe satisfactorily as appropriate on both a long distance display area and a short-distance display area, or to make it display on the frame part of a region observable out of a display area, for example, a display area.

[0058]

As a seal of alignment, the seal which crosses to four-directions omnidirections, such as combination of a cross which is illustrated to Fig.8, and L character, a concentric circle which is illustrated to Fig.9 and a circle in the air, and can check alignment may be used.

[0059]

Reproducing correctly an observing object called observation of medical application and a work of art is not a use demanded. For example, if it expresses an image as the following methods in realizing the display which has depth sensation as a method of heightening the power of expression of a display device in game machines, such as a game machine and pachinko, even if a viewpoint will change somewhat, the display with depth sensation can be maintained. Here describes the case where a plurality of observing objects are used as the display surface of several different display areas in the display surface of a single two-dimensional display device, or a plurality of two-dimensional display devices.

[0060]

(1) Don't display the same displaying object on a different display area or a display surface simultaneously. What furthermore exists in the distance is displayed on the display surface corresponding to the distance, or a display area (for example, long distance display area), and displays a near thing on the display surface corresponding to the distance, or a display area (for example, short-distance display area).

(2) It is depth far from an observer about the displaying object which exists continuously over different depth. That is, the portion which is in a long distance from an observer is displayed only on the display surface or display area (for example, long distance display area)

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corresponding to the depth (distance), Near depth, i.e., the portion which is in a short distance from an observer, is displayed only on the display surface or display area (for example, short-distance display area) corresponding to the depth (distance) from an observer. The portion equivalent to the mid-position of different depth is displayed in each display surface or a display area more darkly than the other portion. Under the present circumstances, since displaying darkly continuously, that is, displaying so that luminance may fall continuously does not give unnaturalness as it approaches between different depth, the portion equivalent to the mid-position of different depth is desirable.
(3) When the displaying object in the position where depth differs laps, the portion which is closely alike relatively among the displaying objects which exist in the distance relatively, and is shielded by a certain displaying object, In the display surface or display area which displays the displaying object which exists in the distance relatively, at least one copy of the portion equivalent to the region which is closely alike relatively and is shielded by a certain displaying object is displayed darkly. Under the present circumstances, since displaying darkly continuously toward a central part from the periphery of that shield part, that is, displaying so that luminance may fall continuously does not give unnaturalness, the portion shielded is desirable.
[0061]
The image displayed on a display surface or a display area is good to use the psychological factor of depth perception positively. For example, the aerial perspective which displays a near thing clearly and displays a far thing vacantly, The method expressing depth sensation can be used by the inclination of the texture using becoming so high that the density of the linear perspective using it seeming that the width of the way which goes in the distance becomes narrow gradually, or the element which constitutes texture going in the distance, and attaching the shade.
[0062]
Even if a viewpoint changes somewhat by using the method using these psychological factors, and the method of the description to the above (1), (2), and (3) as appropriate, the display device which can maintain the display with depth sensation is realizable.
[0063]
Since the display device of the present invention displays in piles the observing object from which depth actually differs, it can realize the display device which can detect depth automatically with focus regulation of the eye which is a physiological factor of depth perception, congestion, a binocular disparity, etc.
[0064]
In the display device of the present invention, since an observing object is arranged at the same plane, a thin display device with the small length of a depth direction more nearly actual than the depth perceived by the observer is realizable. The number of parts can be lessened by furthermore using an observing object as a single two-dimensional display device.
[0065]
As a use of the display device of the present invention, the application to the apparatus for eyesight training other than game machines, such as a game machine and pachinko, can be considered. This is because the position which displays an image can be switched in the display device of the present invention in any position where depth (distance) differs from the viewpoint of an observer. That is, they are idea ** when the focus function of eyes, i.e., training of eyesight, can be performed, since he will perform the focus of eyes whenever an observer changes the display position of an image if the position where an image is displayed from the viewpoint of an observer changes.
[Work example 1]
[0066]
Hereinafter, with reference to Drawings, it describes about the working example of the present invention. Fig.1 and Fig.2 are the outline cross sectional views showing one working example of the display device of the present invention. Fig.3 is an outline perspective view showing one working example of the display device of the present invention similarly.
[0067]
From the viewpoint of an observer, this display device is a display device which displays optically two observing objects from which depth differs in piles, and is provided with the display device 1, the half mirror 2, the total reflection mirror 3, and the polarization conversion element 4. Since the subject of the present invention is in the composition of an optical system, the description of a signal system, an electric system, a mechanism system, the structural member supporting these, etc. is omitted.
[0068]
The display device 1 displays an image based on video information, and the display surface functions from the viewpoint of the observer 20 as two observing objects arranged in the position where depth differs. For this reason, the display surface of the display device 1 has two display areas corresponding to two observing objects. That is, it has 1 n (it is hereafter called 1 n of short-distance display areas) of display areas corresponding to the observing object used as the position where depth is near, and 1 f (it is hereafter called 1 f of long distance display areas) of display areas corresponding to the observing object used as the position where depth is distant from the viewpoint of an observer from the viewpoint of an observer.
[0069]
As the display device 1, it is desirable a thin shape and to use a liquid crystal display element and an organic electroluminescence element, since it is lightweight because of thinning of the whole display device. In order to make as small as possible the loss in a synthesis of the image lights by the half mirror 2 mentioned below, what emits polarization light as image lights as the display device 1 is desirable, and it is suitable to use a liquid crystal display element as such a display device 1. Here, since the case where a liquid crystal display element is used as the display device 1 is described hereafter, the code 1 is used also to a liquid crystal display

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element.
[0070]
A liquid crystal display element comprises a backlight and a liquid crystal display panel which displays an image by adjusting the transmission quantity of the light emitted from a backlight. As a liquid crystal display element, they are for example, TN (Twisted Nematic) system, a STN (Super Twisted Nematic) system, and ECB (ElectricalControlled Birefringence). A system etc. can be used. An IPS (In Plane Switching) system, VA (Vertical Alingned) system, etc. which are characterized by a wide viewing angle can be used. These liquid crystal display elements are provided with a polarizing plate, an image is displayed by controlling the polarization condition of an incident light to a liquid crystal layer, and the high image of a contrast ratio is acquired by a comparatively low drive voltage.
[0071]
Next, with reference to Fig.4, it describes about the liquid crystal display element 1. Although the case where an IPS system is used as the liquid crystal display element 1 is described hereafter here, the present invention is not limited to this.
[0072]
Fig.4 is an outline cross sectional view of the liquid crystal display element 1. The liquid crystal display element 1 comprises the liquid crystal display panel 200 and the backlight 100 arranged at the back face.
[0073]
The backlight 100 illuminates the display area of the liquid crystal display panel 200, and there are an edge light system (transparent material system), a direct lower part type (light reflector system), a source system of sheet-like light, etc. The backlight 100 should just choose the optimal system in accordance with the size of a use, the object, and a display area from these system and other systems. Here, although described about the backlight of an edge light system, the present invention is not limited to this.
[0074]
The transparent material 103 which consists of the transparent resin in which the backlight 100 formed in the back surface a means to change the moving direction of lights, such as dot printing by a white pigment or minute uneven shape, and lens shape, It has the optical films 105,106, such as the light source 101 arranged to the end face of the transparent material 103, the reflective sheet 104 arranged to the back surface side of the transparent material 103, a prism sheet and a diffusion sheet which have been arranged to the surface side of the transparent material 103.
[0075]
As the light source 101, point light sources of a cold cathode tube, a hot cathode tube, etc., such as a linear light source and LED, can be used. Although the case where a cold cathode tube is used as the light source 101 is described hereafter here, the present invention is not limited to this.
[0076]
When using a cold cathode tube as the light source 101, in order to enter the light from a light source in a transparent material efficiently, it is good to arrange the lamp cover 102 so that a light source may be covered.
[0077]
In this composition, the light emitted from the light source 101 enters into the transparent material 103, after reflecting by direct or the lamp cover 102. Although the inside of the transparent material 103 is spread carrying out total internal reflection of the light which entered into the transparent material 103, the light which resulted in a means to change the moving direction of light given to the back surface of the transparent material 103 changes the moving direction, and it emits it from the transparent material 103 surface side. The light emitted from the transparent material 103 is irradiated to the liquid crystal display panel 200, after distribution of the degree of emitting angle and the luminance distribution in a surface are adjusted with optical films, such as a prism sheet and a diffusion sheet.
[0078]
It is [that the liquid crystal display panel 200 is flat and] transparent, and has the first transparent base 201 which consists of isotropic glass or a plastic, and the second transparent base 202 optically. The color filter and the alignment film (all are not shown) which consists of a polyimide system polymer are laminated on the transparent base 201. Switching elements (all are not shown) which form an alignment film and a pixel, such as an electrode, a signal electrode, and a thin film transistor, are formed in the second transparent base 202.
[0079]
Fig.5 is an outline front view showing 1 pixel of composition of the liquid crystal display panel 200 of this example. The common electrode 2003 and the scanning signal electrode 2004 in which 1 pixel of the liquid crystal display panel 200 was formed on the transparent base 202, it has the video signal electrode 2001 and the picture element electrode 2002 which were formed via the gate dielectric film which is not illustrated in these upper layers, and TFT(Thin Film Transistor)2006 as a switching element which it was amorphous or was formed with the polycrystal silicon film etc.
[0080]
The picture element electrode 2002 overlaps the common electrode 2003 in part, and forms retention volume. The common electrode 2003 and the picture element electrode 2002 are dividing stroke matter into four regions, and they are a zigzagged type, maintaining an approximately regulated gap each other. The zigzag degree gamma of angle of inclination of the common electrode 2003 to the display area dividing direction in the display surface of a liquid crystal display element and the picture element electrode 2002 is about **10 degrees. Furthermore a protective layer is formed in these upper layers, and an alignment film is formed on it.
[0081]

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Space is formed in an inside by adhering the circumference with the sealing material of frame shape, after the transparent base 201,202 of two sheets has provided the fixed gap for the alignment film forming surface with facing each other and the spacer which is not illustrated. The liquid crystal layer 203 is provided because dielectric anisotropy encloses and seals a positive nematic liquid crystal to this space.

[0082]

The orientation direction of the liquid crystal element major axis is prescribed by the orientation treatment performed to the alignment film in which the liquid crystal layer 203 was formed on the transparent base 201,202 of two sheets. Let the direction of liquid crystal orientation of the liquid crystal layer 203 be what is called homogeneous orientation that does not have a twist between the transparent bases 201,204 of two sheets.

[0083]

At the front face of the transparent base 201, and the back face of the transparent base 202, the polarizing plates 204 and 205 are arranged, respectively.

[0084]

Fig.6 is the figure showing an example of the orientation direction of the transmission axis of the linear polarization of the polarizing plate 204 and the polarizing plate 205, and the liquid crystal element major axis of the liquid crystal layer 203. In the orientation direction 203a of a liquid crystal layer, an illustrated passage presupposes hereafter that it is parallel to a display area dividing direction here. The transmission axis 204a of the linear polarization of the polarizing plate 204 presupposes that it is parallel to the orientation direction 203a of the liquid crystal layer 203, and the transmission axis 205a of the linear polarization of the polarizing plate 205 describes the case orthogonal to the orientation direction 203a of the liquid crystal layer 203.

[0085]

90 degrees of transmission axes of the linear polarization of the polarizing plate 204,205 may be rotating [as opposed to / both / the direction illustrated to Fig.6].

[0086]

As the polarizing plate 204 and the polarizing plate 205, what gave the protective layer of triacetyl cellulose can be used for both sides of the film which gave the polarizing function by making iodine adsorb to the polyvinyl alcohol extended, for example. The polarizing plate 204 and the polarizing plate 205 are adhered to the transparent base 201 and the transparent base 202 by transparent adhesives, respectively.

[0087]

After the light from the backlight 100 transmits the polarizing plate 205, it passes the liquid crystal layer 203 and enters into the polarizing plate 204. Under the present circumstances, the quantity of the light which changes the polarization condition of the light which passes the liquid crystal layer 203 by applying the voltage corresponding to the video information transmitted from video information generating part (not shown) to a common electrode and a picture element electrode, and transmits the polarizing plate 204 is controllable. Thereby, the image lights of the request which consists of the linear polarization which transmits the polarizing plate 204 can be formed.

[0088]

The liquid crystal display element 1 realizes two observing objects by dividing one continuous display surface into 1 n of short-distance display areas, and 1 f of long distance display areas for convenience. Since the observing object which this has arranged to two different depth by the single display device is realizable, the number of parts becomes fewer. Since two observing objects will be arranged on the same plane, there is an advantage that the length of a depth direction is small and it can realize a thin display device, from the viewpoint of an observer.

[0089]

At this example, the half mirrors 2 are the image lights from 1n of short-distance display areas of the liquid crystal display element 1.

It has a function which synthesizes the image lights 12 (it is hereafter called the long distance image lights 12) from 11 (it is hereafter called the short-distance image lights 11) and 1f of long distance display areas. The total reflection mirror 3 has a function which turns to the half mirror 2 the image lights 12 emitted from 1f of long distance display areas of the liquid crystal display element 1, and it reflects. For this reason, the total reflection mirror 3 is desirable in order to acquire an image with bright considering it as a mirror with high reflectance to the incident long distance image lights 11 at this at least.

[0090]

Here, a reflective surface is a plane and both the half mirror 2 and the total reflection mirror 3 describe the case where it arranges so that it may become each other parallel. This newly adds optical members, such as a lens, or makes a curved surface the reflective surface of a half mirror or a total reflection mirror. Or it is for observing the image of a long distance display area, and the image of a short-distance display area in form [****] to an observer, even if it does not carry out changing the form of a long distance display area or a short-distance display area etc. Although it does not eliminate that the present invention adds optical members, such as a lens, or makes the reflective surface of a half mirror or a total reflection mirror any curved surface shape, in order to lessen the number of parts and to realize a low cost display device, it is desirable to have the above-mentioned composition.

[0091]

The half mirror 2 and the total reflection mirror 3 have and arrange parallel or inclination to the display surface of the liquid crystal display element 1. Here, the case where the half mirror 2 and the total reflection mirror 3 are arranged in parallel to the display surface of the liquid crystal display element 1 is described hereafter.

[0092]

In this case, the half mirror 2 is arranged in the front face of 1 n of short-distance display areas of the liquid crystal display element 1. The case where stick the half mirror 2 to the display

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surface of the liquid crystal display element 1, and it is arranged is described especially here. The size of the half mirror 2 should just be a necessary minimum size, and if it uses the same size as a short-distance display area in assembling and shining with high accuracy of position, a member-surfaces product will serve as necessary minimum, and it will lead to cost reduction covering 1 n of short-distance display areas. However, as for the size of the half mirror 2, it is realistic to double and to enlarge a little rather than the size of 1 n of short-distance display areas in consideration of a gap.

[0093]

The total reflection mirror 3 is a front-face side of the liquid crystal display element 1, and it arranges it in the position where only a suitable distance separated from the display surface of the liquid crystal display element 1 according to the direction of the observer who assumes.

[0094]

Hereinafter, with reference to Fig.2 and Fig.3, it describes about the locating position of the total reflection mirror 3. Here, to a direction with the observer 20 vertical to the display surface of the liquid crystal display element 1, it is parallel to a display area dividing direction, and, moreover, assumes the case where it observes from the direction leaning [angle (it is also hereafter called an observing angle)] which is predetermined, to the direction on the short-distance display area 1n side (the figure the direction of right-hand side).

[0095]

In this case, from the viewpoint of the observer 20, the total reflection mirror 3 does not interrupt 1 n of short-distance display areas, but, moreover, 1 f of long distance display areas and 1 n of short-distance display areas arrange it in the position which laps and is visible via the half mirror 2.

[0096]

When sticking the half mirror 2 on the display surface of the liquid crystal display element 1 and arranging it, the reflective surface of the half mirror 2 exists in the position very near the display surface of the liquid crystal display element 1. Then, it is assumed that the reflective surface of the half mirror 2 and the display surface of the liquid crystal display element 1 exist in the same plane. They are W1, 1 f of long distance display areas, and a short-distance display area about width [in / the shortest distance from the reflective surface of the half mirror 2 to the reflective surface of the total reflection mirror 3 can be set to H, and / for an observing angle / the display area dividing direction of theta and 1 f of long distance display areas]. Distance of a 1-n crevice is set to W0. In this case, if the distance H has satisfied expression (several 1), the observer 20 can observe the image of 1 f of long distance display areas via the half mirror 2.

[0097]

(Several 1)

H=(W0+W1) /2/tantheta -- (1)

For example, if it is referred to as H = about 71.4 mm if W0+W1=100mm and theta= 35 degrees, the observer 20 can observe the image of 1 f of long distance display areas via the half mirror 2.

[0098]

The display surface of the liquid crystal display element 1 and the reflective surface of the half mirror 2 are not necessarily actually located at the completely same plane. For this reason, if a limited distance between the reflective surface of the half mirror 2 and the display surface of the liquid crystal display element 1 is taken into consideration, when the image of 1 f of long distance display areas can be observed via the half mirror 2, the distance H satisfies expression (several 2).

[0099]

(Several 2)

H>= (W0+W1) / 2-/tantheta -- (2)

Under the present circumstances, when the observer assumed observes 1 n of short-distance display areas, let the position of the end on the short-distance display area 1n side of the total reflection mirror 3 (end of the inside of the figure, and right-hand side) be a position used as hindrance. If the size as 1 f of long distance display areas whose total reflection mirror 3 is the same when the size of the reflective surface should just be a size of 1f or more of long distance display areas at least, and assembling and shining in high doubling accuracy is used, a member-surfaces product will become small at necessary minimum, and a rope will become cost reduction. However, as for the size of the reflective surface of the total reflection mirror 3, it is realistic to enlarge a little from 1 f of long distance display areas in consideration of a doubling gap.

[0100]

The short-distance image lights 11 transmit the half mirror 2, and are observed by the observer 20. It reflects by the half mirror 2 and the long distance image lights 12 are observed by the observer 20. For this reason, as for the half mirror 2, for an observer acquiring a bright image, it is desirable for transmissivity to be high to the incident short-distance image lights 11 to this, and for reflectance to be high to the long distance image lights 12.

[0101]

So, in the present invention, the polarized light separating element which separates an incident light into the light from which a polarization condition differs by a penetration and reflection is used as the half mirror 2. When a polarized light separating element is put in another way, it has a function which synthesizes unidirectionally the light from which an incident polarization condition differs from a 2-way by a penetration and reflection.

[0102]

Here, since the liquid crystal display element 1 emits linear polarization as image lights, as the half mirror 2, the linearly polarized light component emitted from the liquid crystal display element 1 is transmitted, and the linearly polarized light component a linearly polarized light component and this and a polarization axis cross at right angles uses the polarized light

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separating element to reflect.
[0103]
Under the present circumstances, in order to acquire a brighter image by using a polarized light separating element, the sum of a polarized light separating element of the transmissivity to predetermined linear polarization and the reflectance to the linear polarization linear polarization and this and a polarization axis cross at right angles needs to be larger than 100%. As for a polarized light separating element, in order to abolish the loss of the image lights in a half mirror completely, it is desirable for the sum of the transmissivity to predetermined linear polarization and the reflectance to the linear polarization linear polarization and this and a polarization axis cross at right angles to be 200%.
[0104]
For this reason, if the sum of the transmissivity to the predetermined linear polarization of a polarized light separating element and the reflectance to the linear polarization linear polarization and this and a polarization axis cross at right angles is made into TR%, it is necessary to use the polarized light separating element used as 100%<TR%<=200% as the half mirror 2.
[0105]
Since the polarized light separating element is expensive compared with the usual half mirror which is not a polarized light separating element, when cost effectiveness is taken into consideration, it is desirable to use the polarized light separating element used as 160%<TR% <=200% as the half mirror 2. In this case, the short-distance image lights 11 and long distance image lights
As for the transmissivity to the predetermined linear polarization of a polarized light separating element, and the reflectance to the linear polarization linear polarization and this and a polarization axis cross at right angles, in order to make the luminosity of 12 comparable, it is desirable at both 80% or more that it is a comparable value.
[0106]
In the following descriptions, in order to describe the case where a polarized light separating element is used as the half mirror 2, the same code 2 as the half mirror 2 is used also to a polarized light separating element.
[0107]
The linear polarization emitted from the liquid crystal display element 1 transmits the polarized light separating element 2, and the linear polarization linear polarization and this and a polarization axis cross at right angles uses what is reflected.
[0108]
It is the double reflex reflection type polarizing film which laminated the two or more layers high polymer film which has different birefringence currently disclosed in the Patent document 3 as such a polarized light separating element 2. Or the polarizing filter by the dielectric multilayer which laminated the thing which has arranged the phase difference film, or the dielectric in which refractive indices differ on the table and the reverse side of the cholesteric liquid crystal film, or a metal wire grid can be used.
[0109]
In the case of a double reflex reflection type polarizing film, a predetermined linearly polarized light component is transmitted among incident lights to this, the film to reflect is marketed with a trade name called DBEF from 3M company (U.S.), and the linearly polarized light component the linearly polarized light component and this and a polarization axis cross at right angles can use this as the polarized light separating element 2. Under the present circumstances, it is important in order to acquire an image with clear using that into which processing in which an image fades like mat treatment is not made.
[0110]
When what has arranged the phase difference film is used for the table and the reverse side of a cholesteric liquid crystal film as the polarized light separating element 2, The back side of a cholesteric liquid crystal film, i.e., the phase difference film arranged to the liquid crystal display element 1 side, uses what the image lights emitted from the liquid crystal display element 1 convert to the elliptically polarized light (circular light is included) which transmits a cholesteric liquid crystal film. On the other hand, the phase difference film arranged to the side front { of a cholesteric liquid crystal film }, i.e., observer, side, After emanating from 1f of long distance display areas and reflecting by the total reflection mirror 3, what converts incident image lights to the elliptically polarized light (circular light) reflected with a cholesteric liquid crystal film is used for the polarized light separating element 2.
[0111]
Cholesteric liquid crystal shows the unique optical property based on helical molecular arrangement, the light which entered at the angle a little leaning to the helical axis reflects the elliptically polarized light of one hand of cut according to the hand of cut of a cholesteric spiral, and another side shows the selective reflection of transmitting. The wavelength band of selective reflection needs to laminate and use several cholesteric liquid crystal from which a pitch differs, in order to make it selective reflection happen throughout a visible wavelength region, since it is decided by the pitch of molecular arrangement. Or it is Asia in order to acquire selective reflection throughout a visible wavelength region.
Display 95 Digest, p735, The Institute of Television Engineers of Japan (ITE) & The Society for Information Display (SID) . The cholesteric liquid crystal to which a pitch which is boiled and described was changed continuously may be used.
[0112]
On a transparent base material, the polarized light separating element by a dielectric multilayer laminates the dielectric membrane in which refractive indices differ, and a prism type and a plate type are.
[0113]
The polarizing filter by a metal wire grid is what is 100 A in pitch more than 1000, and formed

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the conductive metal wire-like pattern of silver, aluminum, chromium, etc. on the transparent base material, and if a transparent base material is used as a plate, a plate type polarized light separating element is realizable.

[0114]

As the polarized light separating element 2, like a double reflex reflection type polarizing film and a cholesteric liquid crystal film, when using the component of film state, it is desirable that it is cautious of the following points.

[0115]

That is, an image may be distorted by distortion of a film only by having arranged the polarized light separating element 2 of film state in the front face of the liquid crystal display element 1, since surface smoothness is low as it is. Then, when using the component of film state as the polarized light separating element 2, it is desirable for rigidity to be high like a glass plate or a plastic sheet, and for it to be flat and transparent, to carry out adhesive fixing to an isotropic transparent base material optically, and to make it there be no distortion via a transparent binder. Or in order to fix the polarized light separating element 2 in the flat state, not using a new transparent base material, it may be made to carry out adhesive fixing of the polarized light separating element 2 on the display surface of the liquid crystal display element 1 via a transparent binder.

[0116]

The image lights emitted from 1f of long distance display areas arrange a polarization conversion element in the optical path which results in the polarized light separating element 2 via the total reflection mirror 3. A polarization conversion element is emitted from 1f of long distance display areas, and converts incident image lights to the polarized light separating element 2 at the light of the polarization condition which the polarized light separating element 2 reflects.

[0117]

Here, the case where stick the polarization conversion element 4 to the front face of 1 f of long distance display areas, and it is arranged is described. In this case, the polarization conversion element 4 is converted to the linear polarization in which that polarization axis rotated 90 degrees of linear polarization emitted from 1f of long distance display areas. That is, as the polarization conversion element 4, the rotatory-polarization child who makes this rotate 90 degrees of polarization axes of incident linear polarization, and 1/2 wavelength plate may be used. In this case, the size of the polarization conversion element 4 should just be a size of necessary minimum [cover / 1 f of long distance display areas] from the viewpoint of the observer 20. The polarization conversion element 4 is arranged at the display surface of the liquid crystal display element 1, and parallel, and if it uses the same size as 1 f of long distance display areas in assembling and shining with high accuracy of position, a member-surfaces product will serve as necessary minimum, and will lead to cost reduction. However, as for the size of the polarization conversion element 4, it is realistic to double and to enlarge a little rather than the size of 1 f of long distance display areas in consideration of a gap.

[0118]

As the polarization conversion element 4, a liquid crystal layer can be enclosed between the transparent bases of two sheets by which orientation treatment was carried out, and the liquid crystal cell in the state where 90 degrees of molecule major axes of the liquid crystal were twisted between the transparent bases of two sheets can be used. In this case, the liquid crystal cell which realizes a polarization conversion element is constituted so that the conditions of a wave guide may be satisfied to the long distance image lights 12. The conditions of the wave guide are described in the paper by 1575-1584-page C.H.Gooch of J.Phys.D:Appl.Phys.Vol.8 (1975), and H.A.Tarry, for example.

[0119]

Since the conditions of a wave guide do not change in extraordinary light mode and ordinary light mode, the orientation direction of the liquid crystal element major axis on the liquid crystal display element side of the liquid crystal cell used as the polarization conversion element 4 may be parallel to the transmission axis of the linear polarization of the polarizing plate 304 of the liquid crystal display element 1, or may be vertical, or whichever may be sufficient as it.

[0120]

In addition to this as a polarization conversion element, 1/2 wavelength plate and the twist structure by lamination of a phase difference film can be used.

[0121]

It is a film of the polymer which carried out uniaxial stretching which has high transmissivity in a visible wavelength region as 1/2 wavelength plate. For example, the phase difference film consisting of resin of polyvinyl alcohol, polycarbonate, Pori Sail John, polystyrene, polyarylate, or a norbornene system, etc. can be used. In addition, the liquid crystal layer etc. which arranged mica, crystal, or a molecule major axis unidirectionally, and carried out orientation can be used.

[0122]

It is difficult to constitute the phase difference plate which functions as 1/2 wavelength plate over wavelength range with a wide visible wavelength with one kind of phase difference plate by the wavelength dependency (following, wavelength dispersion) of the refractive index of the material which generally constitutes 1/2 wavelength plate. Then, what was constituted so that it might function as 1/2 wavelength plate in a wide wavelength band by pasting together at least two kinds of phase difference plates with which wavelength dispersion differs so that the optical axis may cross may be used. Or the high polymer film which has a property which a double reflex enlarges, and which is called what is called anomalous dispersion may be used, so that wavelength becomes short. Two or more twist structures by lamination of a phase difference film are realized [phase difference film / which has 1/2 wave of phase contrast, for example] in laminating, while shifting continuously in the optical axis. As a phase difference film, the high polymer film used for the 1/2 above-mentioned wavelength plate can be used. As

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for the polarization conversion element illustrated here, light functions vertically most effectively in the incident case. Therefore, consideration is required, when the half mirror (polarized light separating element) 2 and the total reflection mirror 3 are arranged in parallel to the display surface of the liquid crystal display element 1 like this example and the observing angle theta does not change with 0 degree.

[0123]

That is, it is desirable only for the same angle theta as the observing angle theta to assume to lean and arrange the polarization conversion element 4 to the display surface of a liquid crystal display element as it illustrates to Fig.7, when using ** 1 / 2 wavelength plate and a twist structure, if it is as a polarization conversion element from the above-mentioned rotatory-polarization child or the phase difference film that carried out uniaxial stretching. Here, Fig.7 is an outline cross sectional view showing one working example of the display device of the present invention.

[0124]

In this case, if the long distance image lights 12 emitted from 1f of long distance display areas are at right angles to the polarization conversion element 4 from the above-mentioned rotatory-polarization child and the phase difference film that carried out uniaxial stretching for an incident reason, the polarization conversion element 4 realized by ** 1 / 2 wavelength plate or a twist structure comes to function most effectively. when only the angle theta furthermore leans and arranges the polarization conversion element 4 to the display surface of the liquid crystal display element 1, compared with the case where the polarization conversion element 4 is arranged in parallel with the display surface of the liquid crystal display element 1, the necessary minimum size of the polarization conversion element 4 can be made small only costheta twice.

[0125]

The present invention does not except the case where a polarization conversion element is arranged in parallel to the display surface of the liquid crystal display element 1 as it is illustrated from Fig.1 to Fig.3. If the observing angle theta is small even if it is a case where the above-mentioned rotatory-polarization child, and 1/2 wavelength plate and twist structure which consists of a phase difference film that carried out uniaxial stretching are used as a polarization conversion element, a polarization conversion element will function effectively.

[0126]

However, if the observing angle theta is enlarged in this case, the function of the polarization conversion element 4 will be deteriorated, the reflectance in the half mirror (polarized light separating element) 2 of the long distance image lights 12 will be deteriorated, and the luminosity of the long distance image lights observed by the observer 20 is deteriorated. Therefore, even if light enters aslant in this case, it is good to use the polarization conversion element which functions effectively. That is, what functions effectively to the degree theta of incidence angle of light may be used as a polarization conversion element. If such a polarization conversion element is for example, 1/2 wavelength plate, it is realizable by using the phase difference film of biaxial anisotropy.

[0127]

When arranging the polarization conversion element 4 in parallel to the display surface of the liquid crystal display element 1, if adhesion fixing of the polarization conversion element 4 is carried out by a transparent adhesive material etc. on the display surface of the liquid crystal display element 1, an excessive attachment component becomes unnecessary and it can reduce the number of parts.

[0128]

The total reflection mirror 3 has a function which turns to the half mirror 2 the long distance image lights 12 emitted from 1f of long distance display areas of the liquid crystal display element 1, and it reflects. For this reason, the total reflection mirror 3 is important in order to acquire an image with bright considering it as a mirror with high reflectance to the long distance image lights 12 at least.

[0129]

As the total reflection mirror 3, things which formed the reflective surface in the isotropic and transparent flat substrate with the metal film with high reflectance, such as silver and aluminum, optically, such as glass and a plastic, and the thing which formed the reflective surface by the dielectric multilayer can be used.

[0130]

Or it may be a polarization reflection mirror which reflects the light of the polarization component corresponding to the incident long distance image lights 12 in the total reflection mirror 3. As a polarization reflection mirror, the same polarized light separating element as the half mirror 2 can be used.

[0131]

Next, it describes about operation of this display device. By having the above-mentioned composition, the short-distance image lights 11 emitted from 1n of short-distance display areas of the liquid crystal display element 1 are transmitted without almost being reflected by the half mirror (polarized light separating element) 2, and are observed by the observer 20. On the other hand, the most reflects by the half mirror (polarized light separating element) 2, and the long distance image lights 12 emitted from 1f of long distance display areas of the liquid crystal display element 1 are observed by the observer 20, after a polarization axis serves as linear polarization rotated 90 degree and reflects by the total reflection mirror 3, when passing the polarization conversion element 4.

[0132]

That is, since it is observed by the observer 20, without almost losing both the short-distance image lights 11 and the long distance image lights 12 by using a polarized light separating element as the half mirror 2, a bright display is obtained. Under the present circumstances, as for 1 f of long distance display areas, the distance which saw only the part of the distance from

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1f of long distance display areas to the total reflection mirror 3 and the distance from the total reflection mirror 3 to the half mirror 2 from the observer 20 compared with 1 n of short-distance display areas becomes far. For this reason, from the viewpoint of the observer 20, after two two-dimensional images arranged in the position where depth differs have lapped, it will be observed.

[0133]

Especially in the display device of the present invention, actually, since the observing object in the position where depth differs from the viewpoint of an observer is arranged on the same plane, its thickness of a depth direction more nearly actual than the depth perceived by the observer is small, and it can realize a thin display device. The number of parts can be lessened by furthermore using an observing object as a single display device.

[0134]

As for a plurality of observing objects, in order to reduce the number of parts, it is desirable to consider it as the display surface of a single liquid crystal display element, but it may be made to realize a plurality of observing objects by the display surface of a plurality of liquid crystal display elements arranged in parallel. In this case, as for a plurality of liquid crystal display elements which carried out arranging in parallel, in order to reduce the number of parts, it is desirable to commonalize a part of components, such as the component which constitutes it, for example, a backlight and a housing, a light source which constitutes a backlight, a transparent material, a reflective sheet, and an optical film.

[0135]

In this example, the liquid crystal display element 1 stated the case where the linear polarization which has a polarization axis was emitted as image lights in the direction which is parallel or intersects perpendicularly with a display area dividing direction. This is based on the following Reasons. The light which enters aslant and it reflects in a reflective surface generally produces phase contrast of an s-polarized light component and a p-polarized light component to a reflective surface. For this reason, if lights other than the linear polarization which turns into s-polarized light or p-polarized light to a reflective surface enter into a reflective surface aslant, that polarization condition will change before and after a reflection.

[0136]

Although the long distance image lights 12 emitted from the liquid crystal display element 1 enter into the total reflection mirror 3 aslant in this display device, in order that the liquid crystal display element 1 may emit the linear polarization which has a polarization axis in the direction which is parallel or intersects perpendicularly with a display area dividing direction as image lights, the long distance image lights 12 enter as p-polarized light or s-polarized light to the total reflection mirror 3. In this case, since a polarization condition does not change in the case of the reflection by the total reflection mirror 3, in the half mirror (polarized light separating element) 2, it is reflected efficiently, and the long distance image lights 12 can acquire a bright image.

[0137]

Supposing it emits the polarization of those other than the linear polarization which has a polarization axis on the other hand in the direction to which a display area dividing direction and the liquid crystal display element 1 are parallel, or crosses at right angles as image lights, long distance image lights will change the polarization condition, before and after reflecting by a total reflection mirror. For this reason, in the half mirror (polarized light separating element) 2, in order to reflect image lights efficiently, it will be necessary to add the component which newly controls the polarization condition of image lights.

[0138]

That is, a brighter image is realizable by fewer components like the display device of this example by making it emit the linear polarization which has a polarization axis in the direction to which a display area dividing direction and the liquid crystal display element 1 are parallel, or crosses at right angles as image lights.

[0139]

Since the form of the display surface of the liquid crystal display element 1 is generally rectangular, if 1 f of long distance display areas and 1 n of short-distance display areas are the rectangles of the same size, a display area can be used effectively. However, although 1 f of long distance display areas and 1 n of short-distance display areas lap and are observed in this display device, Since there are 1 f of long distance display areas in the distance from the viewpoint of the observer 20, when the actual size of 1 f of long distance display areas and 1 n of short-distance display areas is the same, 1 f of long distance display areas are observed smaller than 1 n of short-distance display areas by the observer 20. It is thought that this state is permitted depending on a use if an unnecessary light is made not to be observed by making black the circumference of 1 f of long distance display areas by a light absorption member.

[0140]

After the size of 1 f of long distance display areas seen from the observer and 1 n of short-distance display areas fixes an observer's viewpoint for making it look similarly the neither more nor less, it is good to be as follows.

[0141]

Here, width of the direction which goes direct width { in / for the width of the direction which goes the width in the display area dividing direction of 1 f of long distance display areas direct with W1 and this / the display area dividing direction of W3 and 1 n of short-distance display areas } with W2 and this is set to W4 as shown in Fig.2 and Fig.3. Distance from 1n of short-distance display areas which furthermore saw the distance from the observer 20 to the central part of 1 n of the short-distance display areas from L1 and the observer 20 to 1f of long distance display areas is set to L2.

[0142]

In this case, when the ratio of the size of 1 f of actual long distance display areas in the liquid crystal display element 1 and 1 n of short-distance display areas, i.e., W1/W2, and W3/W4

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satisfies expression (several 3), 1 f of long distance display areas and 1 n of short-distance display areas are visible to the same size from the viewpoint of an observer.
[0143]
(Several 3)
W1-/W2=W3/W4=(L1+L2)/L1=L2/L1+1 -- (3)
When carrying out adhesion arrangement of the half mirror 2 on the display surface of the liquid crystal display element 1, the reflective surface of the half mirror 2 exists in the position very near the display surface of the liquid crystal display element 1. Then, L2 is denoted by expression (several 4), when it assumes that it exists in the same plane, and the shortest distance from the reflective surface of the half mirror 2 to the reflective surface of the total reflection mirror 3 is set to H and the reflective surface of the half mirror 2 and the display surface of the liquid crystal display element 1 set an observing angle to theta.
[0144]
(Several 4)
L2=2H/costheta -- (4)
for example, the case of L1=500mm, theta= 35 degrees, and H= 71.4 mm -- expression (several 3) -- and
(Several 4) to W1/W2 and W3/the value of W4 is set to about 1.35, and the size of each display area which saw the long distance display area from the observer when the width was enlarged about 35% to the short-distance display area looks equal.
[0145]
Depth perception may be impaired if the size of 1 f of long distance display areas seen from the observer enlarges rather than the size which is 1n of short-distance display areas. If the size of 1 f of actual long distance display areas is made smaller than the size of 1 n of short-distance display areas, a useless region will produce in the display surface of the liquid crystal display element 1. Then, as for W1/W2, and W3/W4, in order to make small the unnecessary region which does not impair depth perception and is made further at the display surface of the liquid crystal display element 1, it is desirable to set up to satisfy expression (several 5).
[0146]
(Several 5)
1 <=W1-/W2=W3/W4 <=L2/L1+1 -- (5)
When displaying in piles the image of the display area in the position where depth differs from the viewpoint of an observer, the display which has a cubic effect with devising the method of presentation is attained.
[0147]
Fundamentally, the image displayed on the display area which has the one method in the position where depth differs is made into the same displaying object, and it is displayed so that it may lap, when it sees from one on the line which connects an observer's right eye and left eye. Under the present circumstances, the thing in depth far from an observer makes luminance of a long distance display area high, and the two-dimensional image (image) displayed on a long distance display area and a short-distance display area makes luminance of a short-distance display area low, after maintaining so that the luminance of the sum total at the time of seeing from an observer may become equal to the luminance of a displaying object. What is in near depth from an observer makes luminance of a short-distance display area high, and it makes luminance of a long distance display area low.
[0148]
Thus, a three-dimensional stereoscopic model is perceived by the observer by carrying out the brilliance control according to the depth position of the displaying object. When an observer's viewpoint changes, it becomes impossible however, for this method to observe a good three-dimensional stereoscopic model. Then, it is good to display the seal of alignment for an observer to distinguish easily the view position which a three-dimensional stereoscopic model can observe satisfactorily as appropriate on both a long distance display area and a short-distance display area, or to make it display on the frame part of a region observable out of a display area, for example, a display area.
[0149]
As a seal of alignment, as illustrated to Fig.8, it is a cross displayed on a long distance display area or its frame part, and a short-distance display area or its frame part, and the figure which combined four L characters displayed on the position corresponding to the position where the above-mentioned cross is displayed can be used. Or as illustrated to Fig.9, it is a circle displayed on a long distance display area or its frame part, and a short-distance display area or its frame part, and the above-mentioned circle displayed on the position corresponding to the position where the above-mentioned circle is displayed, and a concentric hollow circle can be used. The seal of alignment should just be a seal which is not limited to these, crosses to a four-directions omnidirection, and can do alignment.
[0150]
Reproducing correctly an observing object called observation of medical application and a work of art is not a use demanded, For example, if it creates the image of each display area by the following methods in realizing the display which has depth sensation as a method of heightening the power of expression of a display device in game machines, such as a game machine and pachinko, even if a viewpoint will change somewhat, the display with depth sensation can be maintained.
[0151]
(1) Don't display the same displaying object on the display area in the position where depth differs simultaneously from the viewpoint of an observer. That is, what exists in the distance (displaying object) is displayed on a long distance display area, and displays a near thing on a short-distance display area. Under the present circumstances, if what exists in the distance is displayed small and a near thing is displayed largely, bigger depth perception will be obtained.
(2) From the viewpoint of an observer, display the portion in depth with a displaying object far

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from an observer which exists continuously over different depth only on a long distance display area, and display the portion which is in near depth from an observer only on a short-distance display area. The portion equivalent to the mid-position of different depth is displayed in each display area more darkly than the other portion. Under the present circumstances, since displaying darkly continuously, that is, displaying so that luminance may fall continuously does not give unnaturalness as it approaches between different depth, the portion equivalent to the mid-position of different depth is desirable.
(3) When the displaying object in the position where depth differs laps, the portion shielded by the displaying object which is close among the displaying objects which exist in the distance displays darkly at least one copy of the portion equivalent to the region shielded by the near displaying object in a long distance display area. Under the present circumstances, since displaying darkly continuously toward a central part from the periphery of that shield part, that is, displaying so that luminance may fall continuously does not give unnaturalness, the portion shielded is desirable. The image displayed on each display area is good to use the psychological factor of depth perception positively. For example, the aerial perspective which displays a near thing clearly and displays a far thing vacantly, it is good to use the inclination of the texture using becoming so high that the density of the linear perspective using it seeming that the width of the way which goes in the distance becomes narrow gradually, or the element which constitutes texture going in the distance, and the method of expressing depth sensation by attaching the shade.
[0152]
Fig.10 is the figure showing the display example in the display surface of the liquid crystal display element 1. Thus, the displaying object (here a tree and a way) which exists close is more brightly displayed on 1n of short-distance display areas more largely, and it is made to display darkly gradually as a displaying object keeps away. A way is displayed so that the width may become narrow continuously, as it keeps away.
[0153]
On the other hand, the displaying object which exists in the distance is more brightly displayed on 1f of long distance display areas smaller, and it is made to display darkly gradually as a displaying object approaches. Long distance display area
It is made not to display the same displaying object on 1 f and 1n of short-distance display areas simultaneously.
[0154]
Fig.11 is the figure showing the image observed by the observer simulated, when the image illustrated to Fig.10 is displayed on the liquid crystal display element 1. Thus, although the object which is placed between two different depth is displayed on an observer a little darkly, even if a viewpoint deviates somewhat, it can inhibit that an image with depth sensation is impaired.
[0155]
Fig.12 to Fig.14 is a display example of the liquid crystal display element 1 in case the second displaying object a first displaying object is a way extended straight, and is the upper part of a first displaying object and which moreover has it far away approaches gradually.
[0156]
The second displaying object 1o displays the second displaying object 1o largely gradually as it is small displayed on 1 f of long distance display areas and approaches them, when there is this in the distance, as illustrated to Fig.12.
[0157]
If the second displaying object 1o further approaches as illustrated to Fig.13, the region which displays the second displaying object 1o will be switched from 1f of long distance display areas to 1 n of short-distance display areas.
[0158]
It seems that depth sensation is seldom impaired at this time even if it does not display darkly, when it exists in a position corresponding between two different depth to the displaying object which moves.
[0159]
Even if a viewpoint deviates somewhat here, in order to impair neither depth sensation nor depth perception, it is important not to display one displaying object on the display area which is simultaneously equivalent to two different depth in a position. That is, it is not displaying one displaying object simultaneously on both a long distance display area and a short-distance display area.
[0160]
When the second displaying object 1o displayed on 1 n of short-distance display areas and the first displaying object displayed on 1 f of long distance display areas lap as illustrated to Fig.14, The portion (it is hereafter called 1 s of shield parts) shielded by the second displaying object 1o which is close among the first displaying objects that exist in the distance displays darkly. Under the present circumstances, even if a viewpoint deviates some sizes of 1 s of shield parts seen from the observer, in order that sense of incongruity may not produce, Or it makes it smaller than the size of the portion shielded by the second displaying object 1o, it is desirable to display darkly continuously toward the central part of 1 s of the shield parts from the periphery of 1 s of the shield part, that is, to make luminance low continuously.
[0161]
By using these methods, this display device can maintain the display with depth sensation, even if a viewpoint changes somewhat. Since this display device displays in piles the observing object in the position where depth actually differs from the viewpoint of an observer, it can realize the display device which can detect depth with focus regulation of the eye which is a physiological factor of depth perception, congestion, a binocular disparity, etc.
[Work example 2]
[0162]

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Next, with reference to Fig.15, it describes about other working examples of the display device of the present invention. Fig.15 is an outline cross sectional view showing an example of the display device of the present invention.

[0163]

Since this example is fundamentally the same in the display device described with reference to Fig.3 from Fig.1 in (working example 1) except having changed the structure and the locating position of the polarization conversion element, the same code is attached to the same portion and a detailed description is omitted.

[0164]

In this example, the polarization conversion element 4b is arranged so that the reflective surface of the total reflection mirror 3 may be covered. As the total reflection mirror 3, it is flatness, such as glass and a plastic, and uses what moreover formed the metal film with high reflectance, such as silver and aluminum, in the isotropic transparent base optically.

[0165]

It emanates from 1f of long distance display areas, and the polarization conversion element 4b in the present invention is a half mirror.

(Polarized light separating element) It converts to the light which reflects the incident long distance image lights 12 in 2 with high reflectance in the half mirror (polarized light separating element) 2. That is, the polarization conversion element 4b is converted to the linear polarization in which the polarization axis rotated 90 degrees of long distance image lights 12 emitted from 1f of long distance display areas.

[0166]

1/4 wavelength plate can be used as such a polarization conversion element 4b. It is a film of the extended polymer which has high transmissivity in a visible wavelength region as 1/4 wavelength plate. For example, the phase difference film consisting of resin of polyvinyl alcohol, polycarbonate, Pori Sall John, polystyrene, polyarylate, or a norbornene system, etc. can be used.

[0167]

It is difficult to constitute the phase difference film which functions as 1/4 wavelength plate over wavelength range with a wide visible wavelength with one kind of phase difference film by the wavelength dependency (wavelength dispersion) of the refractive index of the material which generally constitutes 1/4 wavelength plate.

[0168]

Then, the thing constituted so that it might function as 1/4 wavelength plate in a wide wavelength band by pasting together at least two kinds of phase difference films in which wavelength dispersion differs so that the optical axis may cross, Or it is good to use what was constituted so that it might function as 1/4 wavelength plate in a wide wavelength band by pasting together the functioning phase difference film and the phase difference film which functions as 1/2 wavelength plate so that the optical axis may cross as 1/4 wavelength plate.

[0169]

Or the phase difference film which consists of the high polymer film which has a property called what is called anomalous dispersion which a double reflex enlarges may be used, so that wavelength becomes short.

[0170]

The long distance image lights 12 emitted from 1f of long distance display areas enter at the same angle as the observing angle theta to the polarization conversion element 4b. For this reason, if the observing angle theta is set up largely, when using 1/4 wavelength plate realized with the phase difference film of uniaxial anisotropy as the polarization conversion element 1b, that function will be deteriorated, the reflectance in the half mirror 2 of the long distance image lights 12 will be deteriorated, and a display will become dark.

[0171]

Therefore, in setting up the observing angle theta largely, even if light enters aslant, it is desirable to use the polarization conversion element which functions effectively. Such a polarization conversion element is realizable by using the phase difference film of biaxial anisotropy.

[0172]

If adhesion fixing of the polarization conversion element 4b is carried out to the total reflection mirror 3 by a direct and transparent adhesive material etc., an excessive attachment component becomes unnecessary and it can reduce the number of parts.

[0173]

Also in this example, since an observing object is arranged at the same plane like (the working example 1), a thin display device with the small length of a depth direction more nearly actual than the depth perceived by the observer is realizable. The number of parts can be lessened by furthermore using an observing object as a single two-dimensional display device. Since the long distance image lights 12 and the short-distance image lights 11 are synthesized in the half mirror (polarized light separating element) 2 and are observed by the observer, without losing almost, they can acquire a bright image.

[Work example 3]

[0174]

Next, with reference to Fig.16, it describes from Fig.16 about other working examples of the display device of the present invention. This example loses a polarization conversion element in the (working example 1) or the (working example 2), since it is the same composition as the above-mentioned working example fundamentally except having added the partial change to the polarizing plate of the liquid crystal display element 1, the same code is attached to the same portion and a detailed description is omitted.

[0175]

Fig.16 is an outline cross sectional view showing an example of the display device of the present invention. An illustrated passage does not arrange the polarization conversion element

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which changes the polarization condition of the long distance image lights 12 in this display device. Instead, the transmission axis of the linear polarization of the polarizing plate which constitutes the liquid crystal display element 1 is differently by 1 f of long distance display areas, and 1 n of short-distance display areas.

[0176]

Fig.17 is an outline cross sectional view of the liquid crystal display element 1 which constitutes this display device. The liquid crystal display element 1 comprises the liquid crystal display panel 200 and the backlight 100 arranged at the back face. Although a polarizing plate is arranged, respectively at the front face of the transparent base 201 and the back face of the transparent base 202 which constitute the liquid crystal display panel 200, the polarizing plate in which the transmission axes of linear polarization differ, respectively in the region corresponding to 1n of short-distance display areas and 1 f of long distance display areas is arranged here.

[0177]

The polarizing plate 204A is arranged in the region which is a front face of the transparent base 201 and is equivalent to 1 f of long distance display areas, and the polarizing plate 204B is arranged in the region equivalent to 1 n of short-distance display areas. The polarizing plate 205A is arranged in the region which is a back face of the transparent base 202 and is equivalent to 1 f of long distance display areas, and the polarizing plate 205B is arranged in the region equivalent to 1 n of short-distance display areas.

[0178]

Fig.18 -- a polarizing plate -- 204 -- A -- 204 -- B -- and -- a polarizing plate -- 205 -- A -- 205 -- B -- linear polarization -- a transmission axis -- a liquid crystal layer -- 203 -- a liquid crystal element -- a major axis -- an orientation direction -- an example -- being shown -- the figure -- it is . An illustrated passage is a liquid crystal layer.

The orientation direction 203a of 203 is made parallel with a display area dividing direction. Transmission-axis 204Aa of the linear polarization of the polarizing plate 204A makes it intersect perpendicularly with the orientation direction 203a of the liquid crystal layer 203, and transmission-axis 204Ba of the linear polarization of the polarizing plate 204B presupposes that it is parallel to the orientation direction 203a of the liquid crystal layer 203. Supposing that transmission-axis 205Aa of the linear polarization of the polarizing plate 205A is parallel to the orientation direction 203a of the liquid crystal layer 203, transmission-axis 205Ba of the linear polarization of the polarizing plate 205B makes it intersect perpendicularly with the orientation direction 203a of the liquid crystal layer 203.

[0179]

The long distance image lights 12 emitted from 1f of long distance display areas by having the above-mentioned composition and the short-distance image lights 11 emitted from 1n of short-distance display areas turn into linear polarization linear polarization and each-other polarization axis crossed at right angles.

[0180]

In this case, the short-distance image lights 11 emitted from 1n of short-distance display areas are transmitted without losing almost by the half mirror (polarized light separating element) 2, and are observed by the observer 20. Although the long distance image lights 12 emitted from 1f of long distance display areas enter aslant to the total reflection mirror 3, Since the long distance image lights 12 are linear polarization which turns into s-polarized light to the reflective surface of the total reflection mirror 3, they result in the half mirror (polarized light separating element) 2 in the case of the reflection by the total reflection mirror 3, with a polarization condition maintained.

[0181]

For this reason, it is reflected by the half mirror (polarized light separating element) 2 that there is almost no loss, and the long distance image lights 12 are observed by the observer 20.

[0182]

That is, even if it does not have a polarization conversion element in this display device, the short-distance image lights 11 and the long distance image lights 12 are synthesized in the half mirror (polarized light separating element) 2 that there is almost no loss, and he is an observer.

Since it is observed by 20, a bright image can be displayed.

[0183]

If incident long distance image lights are s-polarized light or p-polarized light to the reflective surface of the total reflection mirror 3, the polarization condition will be maintained by the total reflection mirror 3 in the case of the reflection by a total reflection mirror. For this reason, the transmission axis of the linear polarization of a polarizing plate may rotate the transmission axis of all the polarizing plates 90 degree to the direction illustrated to Fig.18, and it may arrange it.

[0184]

However, since s-polarized light tends to make reflectance high generally than p-polarized light, the total reflection mirror 3 with higher reflectance can be realized by having more composition illustrated to Fig.18.

[0185]

In this example, since two polarizing plates in which polarization axes differ on the surface of the liquid crystal display element 1 are arranged, if a polarizing plate is not arranged in high accuracy, a gap will be made between two polarizing plates. If a gap is made between two polarizing plates, the light from the backlight 100 leaks through this gap, and may degrade image quality.

[0186]

For this reason, it is desirable to arrange the shielding member for preventing light leakage in a position corresponding among the polarizing plates 204A and 204B or among the polarizing plates 205A and 205B.

[0187]

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The shielding member should just prevent the light leakage between two polarizing plates. Therefore, it may be made to prevent light leakage by arranging the component which has a light shielding among the polarizing plates 204A and 204B or among the polarizing plates 205A and 205B, for example, the resin film which contains a metallic foil, black paints, and a color, as a shielding member. When using a metallic foil as a shielding member, it is good to make black the surface by the side of an observer at least, so that an unnecessary light may not be reflected.

[0188]

Or in [as illustrated to Fig.17] the transparent base 201 or the transparent base 202, It may be made to realize the shielding member 210 by providing the resin layer which mixed metal films and black paints, such as chromium, and a color in the position corresponding among the polarizing plates 204A and 204B or among the polarizing plates 205A and 205B.

[0189]

Also in this example, since an observing object is arranged at the same plane like (the working example 1), a thin display device with the small length of a depth direction more nearly actual than the depth perceived by the observer is realizable. The number of parts can be lessened by furthermore using an observing object as a single two-dimensional display device.

[0190]

Especially in this example, since it is not necessary to provide a polarized light separating element like the above-mentioned working example, the number of parts can be lessened more.

[0191]

Each display device described in (working example 3) from (the working example 1) is observed in the state which is predetermined where the angle (observing angle theta) inclined, from the direction perpendicular to the display surface of the liquid crystal display element 1. For this reason, it is desirable for deterioration of a contrast ratio to use few liquid crystal display elements 1 as the liquid crystal display element 1, even if it observes from an oblique direction. As such a liquid crystal display element, the IPS system described in the above-mentioned working example or a VA system is desirable, and it may use a TN system provided with the phase difference film for expanding an OCB system and an angle of visibility.

[0192]

When the actual form of 1f of long distance display areas and 1 n of short-distance display areas is a rectangle, an observer's display area will be visible to an observer at a trapezoid, in order to observe the liquid crystal display element 1 from an oblique direction.

[0193]

It may be desirable for the display area which is visible to an observer depending on the use of a display device to be a rectangle. In this case, it is good to correct so that it may be visible to an observer at a rectangle by the side of the one distant from the viewpoint of an observer making a long trapezoid actual form of 1f of long distance display areas, and 1 n of short-distance display areas.

[0194]

In order for less power consumption to realize a brighter display, it is desirable to give directivity so that more lights emitted from the backlight 100 which constitutes the liquid crystal display element 1 may be emitted in the direction of an observer, i.e., the direction to which only the observing angle theta inclined.

[0195]

The directivity of the light emitted from the backlight 100 is the form of a minute structure of changing the moving direction of lights, such as minute uneven shape, lens shape, etc. which are formed in the back surface of the transparent material 103. Or it is controllable by changing the vertical angle of the prism of the optical film 105 arranged on the transparent material 103, for example, a prism sheet.

[Work example 4]

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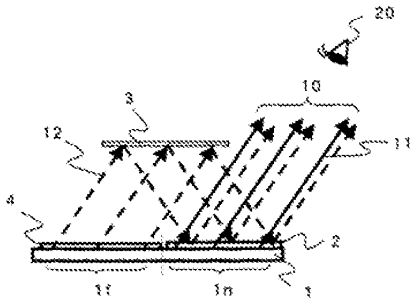
最終頁に続く

(54)【発明の名称】表示装置および表示方法およびこれらを用いる機器

(57)【要約】
【課題】
観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置において、部品点数を削減し、装置を薄型化し、より明るい表示を実現する。
【解決手段】
表示面を遠距離表示領域と近距離表示領域に分けた単一の液晶表示素子と、近距離表示領域の前面に配置する偏光分離素子と、遠距離表示領域の前面に配置する偏光変換素子と、遠距離表示領域から放射する映像光を偏光分離素子に向けて反射する全反射ミラーを備える表示装置であって、近距離表示領域から放射する映像光は偏光分離素子を透過して観察者に観察され、遠距離表示領域から放射する映像光は偏光変換素子を通過し、全反射ミラーで反射した後、偏光分離素子で反射して観察者に観察される表示装置。
【選択図】図１

図１



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【特許請求の範囲】
【請求項１】
並列配置した複数の観察対象と、複数の反射鏡とを備え、前記複数の反射鏡のひとつは全反射ミラーであり、その他の反射鏡はハーフミラーであり、前記ハーフミラーは観察者からみて最も遠い位置に配置した観察対象以外の観察対象の前面側に配置し、前記全反射ミラーは観察者からみて最も遠い位置に配置した観察対象からの光を前記ハーフミラーに向けて反射するように配置し、観察者からみて最も近い位置に配置した観察対象からの光は、観察者からみて最も近い位置に配置した観察対象の前面に配置したハーフミラーを透過して観察され、観察者からみて最も近い位置に配置した観察対象以外の観察対象からの光は、観察者からみて最も近い位置に配置した観察対象の前面に配置したハーフミラーで反射して観察されることを特徴とする表示装置。
【請求項２】
前記複数の観察対象が同一平面上、或いは略同一平面上に配置されることを特徴とする請求項１に記載の表示装置。
【請求項３】
前記複数の反射鏡はその反射面が互いに平行であり、さらに、前記反射面は前記複数の観察対象が配置される平面に対して、０°から４５°の角度で配置することを特徴とする請求項１に記載の表示装置。
【請求項４】
前記複数の観察対象が複数の２次元表示素子の表示面であり、前記複数の２次元表示素子はその構成部材の少なくともひとつが共通化されていることを特徴とする請求項１に記載の表示装置。
【請求項５】
前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域であることを特徴とする請求項１に記載の表示装置。
【請求項６】
前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子は映像光として所定の偏光を放射するものであり、前記ハーフミラーの少なくとも一つが所定の偏光成分は反射し、これと偏光状態が異なる偏光成分は透過する偏光分離素子、あるいは、所定の偏光成分は透過し、これと偏光状態が異なる偏光成分は反射する偏光分離素子であることを特徴とする請求項１に記載の表示装置。
【請求項７】
前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子は映像光として所定の直線偏光を放射するものであり、前記ハーフミラーの少なくとも一つが所定の直線偏光成分は反射し、これと偏光軸が直交する直線偏光成分は透過する偏光分離素子、あるいは所定の直線偏光成分は透過し、これと偏光軸が直交する直線偏光成分は反射する偏光分離素子であることを特徴とする請求項１に記載の表示装置。
【請求項８】
前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子は映像光として所定の直線偏光を放射するものであり、前記ハーフミラーの少なくとも一つが所定の直線偏光成分は反射し、これと偏光軸が直交する直線偏光成分は透過する偏光分離素子であり、
前記偏光分離素子をその前面に配置する２次元表示素子の表示面、もしくは表示領域と、前記偏光分離素子の間に、入射する光の直線偏光の偏光軸を９０°回転させる偏光変換素子を配置することを特徴とする請求項１に記載の表示装置。
【請求項９】
前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子は映像光として所定

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の直線偏光を放射するものであり、前記ハーフミラーのうち、観察者からみて２番目に遠い位置に配置した観察対象の前面に配置するハーフミラーが所定の直線偏光成分は反射し、これと偏光軸が直交する直線偏光成分は透過する偏光分離素子であり、この偏光分離素子と観察者からみて最も遠い位置に配置した観察対象との間に、入射する光の直線偏光の偏光軸を９０°回転させる偏光変換素子を配置することを特徴とする請求項１に記載の表示装置。

【請求項１０】

前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子は映像光として所定の直線偏光を放射するものであり、前記ハーフミラーのうち、観察者からみて２番目に遠い位置に配置した観察対象の前面に配置するハーフミラーが所定の直線偏光成分は透過し、これと偏光軸が直交する直線偏光成分は反射する偏光分離素子であり、この偏光分離素子と観察者からみて最も遠い位置に配置した観察対象との間に、入射する光の直線偏光の偏光軸を９０°回転させる偏光変換素子を配置することを特徴とする請求項１に記載の表示装置。

【請求項１１】

前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域であり、前記複数の表示領域のうち、少なくとも１組の隣り合う表示領域から放射される映像光が互いに偏光軸が直交した直線偏光であり、前記１組の隣り合う表示領域のうち、観察者からみて近い距離にある表示領域の前面に配置する前記ハーフミラーが、前記１組の隣り合う表示領域のうち観察者からみて近い距離にある表示領域から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光成分は反射する偏光分離素子、或いは前記１組の隣り合う表示領域のうち観察者からみて近い距離にある表示領域から放射する直線偏光は反射し、これと偏光軸が直交する直線偏光成分は透過する偏光分離素子であることを特徴とする請求項１に記載の表示装置。

【請求項１２】

前記複数の観察対象が複数の２次元表示素子の表示面であり、前記複数の表示面のうち、少なくとも１組の隣り合う表示面から放射される映像光が互いに偏光軸が直交した直線偏光を放射するものであり、前記１組の隣り合う表示面のうち、観察者からみて近い距離にある表示面の前面に配置する前記ハーフミラーが、前記１組の隣り合う表示面のうち観察者からみて近い距離にある表示面から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光成分は反射する偏光分離素子、或いは前記１組の隣り合う表示面のうち観察者からみて近い距離にある表示面から放射する直線偏光は反射し、これと偏光軸が直交する直線偏光成分は透過する偏光分離素子であることを特徴とする請求項１に記載の表示装置。

【請求項１３】

観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置の表示方法であって、前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記複数の表示領域、もしくは前記複数の表示面には同じ表示対象を同時には表示せず、さらに遠くにあるものはその距離に対応する表示領域もしくは表示面に表示し、近くにあるものはその距離に対応する表示領域もしくは表示面に表示することを特徴とする表示方法。

【請求項１４】

観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置の表示方法であって、前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子に表示する映像は、異なる奥行きにわたり連続的に存在する表示対象については観察者から遠い奥行きにある部分はその奥行きに対応する表示領域もしくは表示面のみに表示し、観察者から近い奥行きにある部分はその奥行きに対応する表示領域もしくは表示面のみに表示し、異なる奥行きの中間位置に相当する部分はそれ以外の部分よりも暗く表示

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することを特徴とする表示方法。

【請求項１５】

観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置の表示方法であって、前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子に表示する映像は、奥行きの異なる位置にある表示対象が重なる場合、相対的に遠くにある表示対象のうち、相対的に近くにある表示対象によって遮蔽される部分は、前記相対的に遠くにある表示対象を表示する表示領域もしくは表示面において、前記相対的に近くにある表示対象によって遮蔽される領域に相当する部分の少なくとも一部を暗く表示することを特徴とする表示方法。

【請求項１６】

並列配置した複数の観察対象と、複数の反射鏡とを備え、前記複数の反射鏡のひとつは全反射ミラーであり、その他の反射鏡はハーフミラーであり、前記ハーフミラーは前記複数の観察対象の前面に配置し、前記全反射ミラーは前記ハーフミラーの前面側であって、前記複数の観察対象のうち、その両端に配置する観察対象の一方の観察対象を第１の観察者が観察する際に妨げとならず、さらに前記両端に配置する観察対象の他方の観察対象を第２の観察者が観察する際に妨げとならない形状および位置に配置し、第１の観察者からみて最も近い位置に配置した観察対象からの光は、第１の観察者からみて最も近い位置に配置した観察対象の前面に配置するハーフミラーを透過して観察され、第１の観察者からみて最も近い位置に配置した観察対象以外の観察対象からの光は、第１の観察者からみて最も近い位置に配置した観察対象の前面に配置するハーフミラーで反射して観察され、第２の観察者からみて最も近い位置に配置した観察対象からの光は、第２の観察者からみて最も近い位置に配置した観察対象の前面に配置するハーフミラーを透過して観察され、第２の観察者からみて最も近い位置に配置した観察対象以外の観察対象からの光は、第２の観察者からみて最も近い位置に配置した観察対象の前面に配置するハーフミラーで反射して観察されることを特徴とする表示装置。

【請求項１７】

前記複数の観察対象が同一平面上、或いは略同一平面上に配置されることを特徴とする請求項１６に記載の表示装置。

【請求項１８】

前記複数の反射鏡はその反射面が互いに平行であり、さらに、前記反射面は前記複数の観察対象が配置される平面に対して、平行に配置することを特徴とする請求項１６に記載の表示装置。

【請求項１９】

前記複数の観察対象が複数の２次元表示素子の表示面であり、前記複数の２次元表示素子はその構成部材の少なくともひとつが共通化されている、或いは前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域であることを特徴とする請求項１６に記載の表示装置。

【請求項２０】

前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であり、前記２次元表示素子は映像光として所定の偏光を放射するものであり、前記ハーフミラーの少なくとも一つが所定の偏光成分は反射し、これと偏光状態が異なる偏光成分は透過する偏光分離素子、あるいは、所定の偏光成分は透過し、これと偏光状態が異なる偏光成分は反射する偏光分離素子であることを特徴とする請求項１６に記載の表示装置。

【請求項２１】

請求項１に記載の表示装置と、前記表示装置を固定する筐体、もしくは板状部材と、前記表示装置を観察するための表示部を有し、

前記表示部が前記筐体、もしくは板状部材に設けられた開口部、あるいはその一部を遮光部材で遮蔽した部分であることを特徴とする機器。

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【請求項２２】
請求項１６に記載の表示装置と、前記表示装置を固定する筐体、もしくは板状部材と、前記表示装置を観察するための表示部を有し、
前記表示部が前記筐体、もしくは板状部材に設けられた２つの開口部、あるいはその一部を遮光部材で遮蔽した２つの部分であることを特徴とする機器。

【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、観察者からみて距離（奥行き）が異なる位置にある複数の観察対象を光学的に重ねて観察できる表示装置、及び奥行きを感じさせる表示方法、及びこれらを備える機器に関するものである。
【背景技術】
【０００２】
映像情報を表示する装置としては表示素子としてＣＲＴ(Cathod-Ray Tube)，プラズマディスプレイパネル，液晶表示素子，有機エレクトロルミネッセンス表示素子等を備える直視型の表示装置や、小型の表示素子が形成した光学画像をスクリーンに拡大投影するプロジェクション型の表示装置がある。
【０００３】
これらの表示装置はいずれも基本的には２次元の映像情報をもとに２次元像を表示するものである。ここでは以下，２次元像を表示する表示素子およびこれを備える表示装置のことをそれぞれ２次元表示素子及び２次元表示装置と呼ぶ。
【０００４】
これらの表示装置のうち、特に液晶表示素子を備える表示装置は薄型，軽量であることから大画面テレビ，パーソナルコンピューター用のモニター，携帯電話，ゲーム機、或いはパチンコやパチスロなどの遊技機等に幅広く利用されている。
【０００５】
ところで、従来から複数の２次元表示素子または２次元表示装置の表示面を観察者からみて奥行きの異なる位置（距離）に配置し、光学的に重ねて表示することで観察者に奥行き感や立体感を感知させる表示装置がある。このような表示装置は単に２次元像を表示する表示装置と比べると表現力が高く、より臨場感のある表示を実現できる。
【０００６】
このような表示装置の典型的な構造としては複数の２次元表示素子と、ハーフミラーを有し、ハーフミラーを透過して観察される２次元表示素子の表示面と，ハーフミラーで反射して観察される２次元表示素子の表示面を奥行きの異なる位置に配置する表示装置がある。図４３はこのような従来技術の一例を示すもので、２つの表示素子とハーフミラーを備える表示装置の概略断面図である。ここでは２次元表示素子として液晶表示素子を用い、観察者からみて奥行きが遠い位置に配置した表示素子（以下、遠距離用表示素子とも呼ぶ）からの映像光（以下、遠距離映像光とも呼ぶ）はハーフミラーを透過して観察され，観察者からみて奥行きが近い位置に配置した表示素子(以下、近距離用表示素子とも呼ぶ）からの映像光（以下、近距離映像光とも呼ぶ）はハーフミラーで反射して観察される場合を示す。この場合、観察者からみて奥行きの異なる位置に配置した２つの表示面に表示される映像は、ハーフミラーで光学的に合成され、重なった状態で観察される。
【０００７】
このような構造では異なる奥行き（距離）に配置する表示面が２つの場合，２つの２次元表示素子が必要となる。つまり，このような構造では異なる奥行きに配置する表示面の数と同じ数の２次元表示素子が必要となるため部品点数が増え、装置が大型化してしまうという欠点がある。特に２次元表示素子として液晶表示素子や有機エレクトロルミネッセンス表示素子などの薄型の表示素子を用いる場合にはその薄型という特徴は十分に活かすことができない。

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【０００８】
また、従来技術では遠距離映像光と近距離映像光の合成はハーフミラーを介して行うが、一般にハーフミラーは透過率Ｔ％と反射率Ｒ％の合計が最大で１００％となるものである。このため表示素子から放射する遠距離映像光と近距離映像光はそれぞれＲ％とＴ％の光が観察者には至らず損失光となり、観察者に届く映像光は表示素子から放射する光の半分以下に低減してしまうという問題があった。
【０００９】
特許文献１には観察者からみて異なる奥行き位置に配置した複数の反射型ホログラフィック拡散板と、各反射型ホログラフィック拡散板に２次元像を投影する複数のプロジェクタから構成される表示装置が開示されている。反射型ホログラフィック拡散板は設定された一定の方向、つまり対応するプロジェクタからの光は反射，散乱し、その他の方向から入射する光、例えば背面に配置した反射型ホログラフィック拡散板で反射，散乱した光は透過するものである。このため、奥行きの異なる位置に配置した複数の反射型ホログラフィック拡散板に投影される映像が重なった状態で観察される。
【００１０】
この場合、反射型ホログラフィック拡散板の透過率が１００％でなければ奥行きが遠い位置に配置する反射型ホログラフィック拡散板に投影される映像光は観察者に至るまでに損失が生じる。
【００１１】
また、複数の反射型ホログラフィック拡散板を観察者に観察される奥行きと同じ距離を隔てて並べる必要があるため、装置は奥行き方向に厚くなる。さらに複数の反射型ホログラフィック拡散板と同じ数のプロジェクタが必要となるため部品点数が増えて装置が大型になる。
【００１２】
尚、特許文献１、及び特許文献２には観察者に３次元立体像を感知させる表示方法が開示されている。この方法では観察者からみて奥行きの異なる複数の表示素子の表示面に形成される２次元像（映像）が、観察者の右眼と左眼とを結ぶ線上の一点からみた場合に重なるように表示する。さらに奥行きの異なる各表示面に表示される２次元像（映像）は、観察者からみた場合の輝度を一定に保ちつつ、表示対象の奥行き位置、つまり表示対象の観察者からの距離に応じた輝度の調整を施すことで観察者に３次元立体像が感知されるというものである。
【００１３】
この方法は立体視の生理的要因間の矛盾を抑制でき、なおかつ情報量を少なくできる新たな３次元表示方法として期待されるが、３次元立体像が良好に観察できる観察者の位置は限定される。つまり、観察者の視点が大きく変わると良好な３次元立体像は観察できなくなる。
【００１４】
【特許文献１】特開２００３－５７５９５号公報
【特許文献２】特開２０００－２１４４１３号公報
【特許文献３】国際公開番号：ＷＯ９５／２７９１９号
【発明の開示】
【発明が解決しようとする課題】
【００１５】
本発明が解決しようとする問題点は、観察者からみて奥行きの異なる位置（距離）に配置する複数の観察対象を光学的に重ねて表示する表示装置を実現する場合に部品点数が多くなり，装置が大型化する点にある。つまり、本発明が解決しようとする課題は観察者からみて奥行きの異なる位置（距離）に配置する複数の観察対象を光学的に重ねて表示する表示装置において，部品点数を削減し、装置を小型化、あるいは薄型化することにある。また、本発明が解決しようとする第２の問題は、観察者からみて奥行きの異なる位置（距離）に配置する２次元表示素子の表示面などの複数の観察対象を光学的に重ねて表示する

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装置において、２次元表示素子から放射する映像光が、観察者に到達する前にその一部が損失することにある。つまり、本発明が解決しようとする第２の課題は２次元表示素子から放射される映像光を効率よく観察者に到達させることでより明るい表示装置を実現することにある。

【００１６】

また、本発明が解決しようとする第３の課題は、観察者からみて奥行きの異なる位置（距離）に配置する２次元表示素子の表示面などの複数の観察対象を光学的に重ねて表示する装置において、視点が変化しても奥行き感を損なわない表示方法を実現することにある。本発明のその他の課題と新規な特徴については本明細書の記述及び添付図面を参照して明らかにする。

【課題を解決するための手段】

【００１７】

本発明は観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置であり、並列配置した複数の観察対象と、複数の反射鏡とを備える。前記複数の反射鏡のひとつは全反射ミラーであり、その他の反射鏡はハーフミラーである。前記ハーフミラーは観察者からみて最も遠い位置に配置した観察対象以外の観察対象の前面側に配置する。また、前記全反射ミラーは観察者からみて最も遠い位置に配置した観察対象からの光を前記ハーフミラーに向けて反射するように配置する。

【００１８】

さらに観察者からみて最も近い位置に配置した観察対象からの光は、観察者からみて最も近い位置に配置した観察対象の前面に配置したハーフミラーを透過して観察され、観察者からみて最も近い位置に配置した観察対象以外の観察対象からの光は、観察者からみて最も近い位置に配置した観察対象の前面に配置したハーフミラーで反射して観察されることを特徴とする。

【００１９】

また、前記複数の観察対象は同一平面上もしくは略同一平面上に配置されることを特徴とするものである。

【００２０】

この際、前記表示装置は前記複数の反射鏡の反射面が互いに略平行となるように配置し、さらに前記反射面は前記複数の観察対象が配置される略同一平面に対して、０°から４５°の角度をなすことを特徴とする。

【００２１】

また、前記表示装置は前記複数の観察対象が複数の２次元表示素子の表示面であり、該複数の２次元表示素子はその構成部材の少なくとも一つが共通化されていることを特徴とする。或いは前記表示装置は前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域であることを特徴とする。

【００２２】

また、前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面であって、前記２次元表示素子は映像光として所定の偏光を放射するものである。さらに前記ハーフミラーの少なくとも一つが所定の偏光成分は反射し、これと偏光状態が異なる偏光成分は透過する偏光分離素子、あるいは、所定の偏光成分は透過し、これと偏光状態が異なる偏光成分は反射する偏光分離素子であることを特徴とする。

【００２３】

また、この際、前記２次元表示素子から放射され、前記偏光分離素子に入射する光はその８０％以上が反射、もしくは透過することを特徴とする。

【００２４】

本発明の表示方法は、観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置の表示方法であって、前記複数の観察対象が単一の２次元表示素子の表示面における複数の異なる表示領域、もしくは複数の２次元表示素子の表示面

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である場合に以下の通りに表示することを特徴とする。
（１）異なる表示領域，或いは表示面には同時に同一の表示対象を表示しない。さらに遠くにあるものはその距離に対応する表示領域もしくは表示面に表示し、近くにあるものはその距離に対応する表示領域もしくは表示面に表示する。
（２）異なる奥行きに渡り連続的に存在する表示対象については観察者から遠い奥行き、つまり観察者から長い距離にある部分はその奥行き（距離）に対応する表示領域もしくは表示面のみに表示し、観察者から近い奥行き、つまり観察者から短い距離にある部分はその奥行き（距離）に対応する表示領域もしくは表示面のみに表示する。また、異なる奥行きの中間位置に相当する部分はそれぞれの表示領域もしくは表示面において、それ以外の部分よりも暗く表示する。この際，異なる奥行きの中間位置に相当する部分は異なる奥行きの中間に近づくに従い連続的に輝度が下がるように表示する。
（３）奥行きの異なる位置にある表示対象が重なる場合，相対的に遠くにある表示対象のうち、相対的に近くにある表示対象によって遮蔽される部分は、相対的に遠くにある表示対象を表示する表示領域もしくは表示面において、相対的に近くにある表示対象によって遮蔽される領域に相当する部分の少なくとも一部を暗く表示する。この際、遮蔽される部分はその遮蔽部分の周辺部から中央部に向かい連続的に表示を暗くする。

【００２５】

この他の手段については以下の記述で明らかとする。

【発明の効果】

【００２６】

本発明の表示装置は、同一平面上、または略同一平面上に並列配置した複数の観察対象を、観察者からみて奥行きの異なる位置にある複数の観察対象が光学的に重なった状態で観察できるものである。このため観察者が感知する奥行きよりも実際の奥行きが小さく、薄型の表示装置が実現できるという利点がある。

【００２７】

さらに、単一の２次元表示素子の表示面における複数の異なる表示領域を複数の観察対象とすることで、部品点数が少なく、低コストで薄型の表示装置を実現できるという利点がある。

【００２８】

また、前記複数の観察対象のうち、少なくとも一つの観察対象が所定の偏光を映像光として放射する２次元表示素子の表示面とし、この表示面の前面に配置するハーフミラーを所定の偏光成分は反射し、これと異なる偏光成分は透過する偏光分離素子，もしくは所定の偏光成分は透過し、これと異なる偏光成分は反射する偏光分離素子とすると、少なくともこの表示面から放射する映像光はほとんど損失することなく、観察者からの距離がこの表示面よりも遠い（長い）位置にある観察対象からの光と合成することができる。このため、ハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。

【００２９】

また，本発明の表示方式では観察者からみて奥行きが異なる表示面には同一の表示対象を同時に表示しないようにする。これにより奥行き感を感知できる視点の範度が広がり、視点が多少変化しても奥行き感のある表示を維持できるという利点がある。

【００３０】

また、本発明の表示装置を備える機器では、通常の２次元表示装置では表現できない奥行き感のある表示を、観察者が感知する奥行きよりも実際の奥行きが小さく、薄型の機器で実現できるという利点がある。

【発明を実施するための最良の形態】

【００３１】

本発明は観察者からみて奥行きの異なる位置にある複数の観察対象を光学的に重ねて表示する表示装置及び表示方法とこれを備える機器に関するものである。

【００３２】

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複数の観察対象はほぼ同一平面上に並列に配置する。これは観察者からみた表示装置の奥行き方向の厚さを薄くするために極めて有効な配置である。

【００３３】

観察対象はＣＲＴ、液晶表示素子、有機エレクトロルミネッセンス表示素子、プラズマディスプレイパネルなどの２次元像を表示する表示素子（以下、２次元表示素子）の表示面を用いることができる。或いは、観察対象としてスロットマシンなどで使用される外周面に複数の絵柄を配置したリールを回転させることで絵柄を切り替える表示素子の表示面などが考えられる。

【００３４】

観察対象は特に限定されるものではないが、装置の小型化のためには液晶表示素子、もしくは有機エレクトロルミネッセンス表示素子といった薄型の２次元表示素子の表示面を用いることが望ましい。

【００３５】

さらに、複数の観察対象は単一の２次元表示素子の表示面における複数の異なる表示領域とすることが部品点数を少なくするために望ましい。また、こうすることで観察対象は自ずと同一平面に配置されることになる。

【００３６】

ここでは以下、観察対象として液晶表示素子を用い、観察対象が単一の液晶表示素子の表示面における２つの異なる表示領域である場合を説明するが本発明はこれに限定されるものではない。

【００３７】

本発明の表示装置は複数の観察対象と複数の反射鏡を備える。反射鏡のひとつは少なくとも観察者からみて最も遠い位置に配置する観察対象からの光に対する反射率が高いミラー（以下，全反射ミラーとよぶ）とする。また、これ以外の反射鏡はハーフミラーとする。ここでは観察対象が２つの場合を説明するため、反射鏡は観察対象と同数の２つであり、一つの反射鏡はハーフミラー、もう一つの反射鏡は全反射ミラーである。

【００３８】

ハーフミラーは観察者からみて奥行きが近い、即ち観察者からの距離が短い位置にある観察対象と観察者との間に配置する。つまり、ハーフミラーは液晶表示素子の表示面のうち、奥行きが近い位置にある観察対象に対応する表示領域(以下，近距離表示領域と呼ぶ)の前面に配置する。

【００３９】

一方、全反射ミラーは観察者からみて奥行きが遠い、即ち観察者からの距離が長い位置にある観察対象からの光をハーフミラーに向けて反射する位置に配置する。つまり、全反射ミラーは液晶表示素子の表示面のうち、奥行きが遠い位置となる観察対象に対応する表示領域（以下，遠距離表示領域と呼ぶ）からの光をハーフミラーに向けて反射する位置に配置する。また、全反射ミラーは観察者が近距離表示領域を観察する際、妨げとならない形状とする。

【００４０】

ハーフミラーは液晶表示素子の近距離表示領域からの映像光（以下、近距離映像光と呼ぶ）と遠距離表示領域からの映像光（以下、遠距離映像光とよぶ）を合成する機能を担うものである。つまり、近距離映像光はハーフミラーを透過して観察者に観察され、遠距離映像光はハーフミラーで反射して観察される。

【００４１】

全反射ミラーは液晶表示素子の遠距離表示領域から放射する映像光をハーフミラーに向けて反射する機能を有するものである。このため、全反射ミラーは少なくとも遠距離映像光に対して反射率の高いミラーとすることが明るい映像を得るために重要である。

【００４２】

尚、液晶表示素子としてはバックライトを備え、バックライトからの光の透過光量を調整することで映像を表示する透過型の液晶表示素子を用いることができる。特に偏光板を

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備え、液晶層に入射する光の偏光状態を制御することで映像表示を行う液晶表示素子は比較的低い駆動電圧でコントラスト比の高い映像が得られることから望ましい。このような液晶表示素子から放射する映像光は直線偏光光となる。

【００４３】

このためハーフミラーとしては明るい映像光を得るために液晶表示素子の近距離表示領域から放射されハーフミラーに入射する直線偏光光は透過し、これと偏光軸が直交する直線偏光光は反射する偏光分離素子を用いることが望ましい。さらに遠距離表示領域とハーフミラーの間には遠距離表示領域から放射されハーフミラーに入射する映像光をハーフミラーが反射する偏光状態の光に変換する偏光変換素子を配置することが明るい映像を得るために望ましい。

【００４４】

ハーフミラーとして機能する偏光分離素子としては例えば特許文献３に開示されている複屈折反射型偏光フィルム、或いは、コレステリック液晶フィルムの表と裏に位相差フィルムを配置したもの、或いは屈折率の異なる誘電体を積層した誘電体多層膜を用いることができる。

【００４５】

また、偏光変換素子としてはこれに入射する直線偏光の偏光軸を９０°回転させる旋光素子や１／２波長板を用いることができる。

【００４６】

ハーフミラーと全反射ミラーは共に反射面が平面であり、互いの反射面が平行となるように配置することが望ましい。これはレンズなどの光学部材を付加したり、反射鏡の反射面を曲面にしなくても観察者に遠距離表示領域の映像が近距離表示領域の映像と相似な形状で観察されるようにするためである。尚、本発明はレンズなどの光学部材を付加したり、反射面の形状を任意の曲面形状にすることを排除するものではないが、部品点数を少なくし、より低コストな表示装置を実現するためには上記構成とすることが望ましい。

【００４７】

また、ハーフミラーと全反射ミラーは液晶表示素子の表示面に対しては平行、或いは傾きを有して配置する。ここでは以下、図面を参照してハーフミラーと全反射ミラーを液晶表示素子の表示面に対して４５°傾けて配置する場合を説明する。尚、液晶表示素子の表示面に対するハーフミラーと全反射ミラーの角度は用途によりそれぞれ好適な角度があるが、このことについては後述の実施例において詳細に説明する。

【００４８】

図２１は本発明の表示装置の一例を示す概略断面図であり、ハーフミラー２と全反射ミラー３を液晶表示素子１の表示面に対して４５°傾けて配置する場合を示す。

【００４９】

上記構成とすることで、液晶表示素子１の近距離表示領域１ｎから放射する映像光１１はハーフミラー２でほとんど反射されることなく透過して観察者２０に観察される。一方、液晶表示素子１の遠距離表示領域１ｆから放射する映像光１２は全反射ミラー３で反射した後、ハーフミラー２で反射して観察者２０に観察される。

【００５０】

この際、遠距離映像光１２は遠距離表示領域１ｆとハーフミラー２の間に配置した偏光変換素子４の作用によって、その大部分が偏光軸が９０°回転した直線偏光成分に変換されるため、ハーフミラー２でそのほとんどが反射して観察者２０に観察される。

【００５１】

つまり，ハーフミラー２として偏光分離素子を用い、さらに偏光変換素子を備えることで近距離映像光１１と遠距離映像光１２は共にほとんど損失することなく観察者２０に観察されるため映像光の損失がほとんどない明るい表示が得られる。

【００５２】

尚、遠距離表示領域１ｆは近距離表示領域１ｎと比べると、全反射ミラー３からハーフミラー２までの距離の分だけ観察者２０からの距離が遠くなる。このため、この表示装置

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では観察者２０からみて奥行きの異なる位置に配置した２つの２次元像を重ねた状態で表示することができる。

【００５３】

この際、観察者からみて奥行きの異なる観察対象は、実際には同一平面上に配置されているため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の表示装置が実現できる。

【００５４】

ところで、奥行きの異なる２次元像を重ねて表示する場合、表示方法を工夫することで立体感のある表示が可能となる。

【００５５】

そのひとつの方法は基本的には同一の表示対象を遠距離表示領域１ｆと近距離表示領域１ｎの両方に表示し、観察者の右眼と左眼とを結ぶ線上の一点からみた場合に各表示領域に表示する表示対象が重なるように表示するものである。

【００５６】

この際、遠距離表示領域１ｆと近距離表示領域１ｎに表示される２次元像は観察者からみた場合にその合計の輝度が表示対象の輝度と等しくなるように保った上で、表示対象のうち観察者からみて遠い奥行きにある部分は遠距離表示領域での輝度を高くし、近距離表示領域での輝度は低くする。また、表示対象のうち観察者から近い奥行きにある部分は近距離表示領域での輝度を高くし、遠距離表示領域での輝度は低くする。

【００５７】

このように、表示対象の観察者からみた奥行き位置、つまり、観察者からの距離に応じた輝度調整を行うことで観察者には３次元立体像が感知される。しかし、この方法は観察者の視点が変わり、遠距離表示領域１ｆと近距離表示領域１ｎに表示する表示対象の相対的な位置がずれると良好な３次元立体像は観察できなくなる。そこで、３次元立体像が良好に観察できる視点位置を観察者が容易に判別できるようにするための位置合わせの印を遠距離表示領域と近距離表示領域の両方に適宜表示する、或いは表示領域外で観察可能な領域、例えば表示領域の額縁部分に表示するようにするとよい。

【００５８】

位置合わせの印としては図８に例示するような十文字とし字の組み合わせや、図９に例示するような同心の円と中空の円など上下左右全方位に渡って位置合わせを確認できる印を用いればよいだろう。

【００５９】

尚、医療用や美術品の観察といった観察対象を正確に再現することが要求される用途ではなく、例えば、ゲーム機やパチンコなどの遊技機において表示装置の表現力を高める方法として奥行き感のある表示を実現する場合には以下の方法で映像を表示すると視点が多少変わっても奥行き感のある表示を維持することができるようになる。尚、ここでは複数の観察対象を単一の２次元表示素子の表示面における複数の異なる表示領域、あるいは複数の２次元表示素子の表示面とする場合を述べる。

【００６０】

（１）異なる表示領域、或いは表示面には同時に同一の表示対象を表示しない。さらに遠くにあるものはその距離に対応する表示面、もしくは表示領域（例えば遠距離表示領域）に表示し、近くにあるものはその距離に対応する表示面、もしくは表示領域（例えば近距離表示領域）に表示する。

（２）異なる奥行きに渡り連続的に存在する表示対象については観察者から遠い奥行き、つまり観察者から長い距離にある部分はその奥行き（距離）に対応する表示面もしくは表示領域（例えば遠距離表示領域）のみに表示し、観察者から近い奥行き、つまり観察者から短い距離にある部分はその奥行き（距離）に対応する表示面もしくは表示領域（例えば近距離表示領域）のみに表示する。また、異なる奥行きの中間位置に相当する部分は各表示面もしくは表示領域において、それ以外の部分よりも暗く表示する。この際、異なる奥行きの中間位置に相当する部分は異なる奥行きの中間に近づくに従い連続的に表示を暗く

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する、つまり連続的に輝度が下がるように表示することが不自然さを感じさせないために望ましい。
（３）奥行きの異なる位置にある表示対象が重なる場合、相対的に遠くにある表示対象のうち、相対的に近くにある表示対象によって遮蔽される部分は、相対的に遠くにある表示対象を表示する表示面もしくは表示領域において、相対的に近くにある表示対象によって遮蔽される領域に相当する部分の少なくとも一部を暗く表示する。この際、遮蔽される部分はその遮蔽部分の周辺部から中央部に向かい連続的に表示を暗くする、つまり連続的に輝度が下がるように表示することが不自然さを感じさせないために望ましい。
【００６１】
さらに、表示面もしくは表示領域に表示する映像は奥行き知覚の心理的要因を積極的に利用するとよい。例えば、近いものははっきりと表示し、遠いものはぼんやりと表示する大気遠近法や、遠くに向かう道の幅が徐々に狭くなっていくように見えることを利用する線遠近法、あるいは、きめを構成する要素の密度が遠くにいくほど高くなることを利用するきめの勾配や、陰影をつけることで奥行き感を表現する方法を利用することができる。
【００６２】
これらの心理的要因を利用した方法と、上記（１）（２）（３）に記載の方法を適宜用いることで視点が多少変化しても奥行き感のある表示を維持することができる表示装置を実現できる。
【００６３】
本発明の表示装置は、実際に奥行きが異なる観察対象を重ねて表示するため、奥行き知覚の生理的要因である眼のピント調節，輻輳，両眼視差などにより自然に奥行きを感知できる表示装置が実現できる。
【００６４】
また、本発明の表示装置では観察対象を同一平面に配置するため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく薄型の表示装置が実現できる。さらに観察対象を単一の２次元表示素子とすることで部品点数を少なくすることができる。
【００６５】
尚、本発明の表示装置の用途としてはゲーム機やパチンコなどの遊技機の他に，視力訓練用機器への適用が考えられる。これは，本発明の表示装置では映像を表示する位置を観察者からみて奥行き（距離）の異なる任意の位置に切り替えることができるためである。つまり，観察者からみて映像が表示される位置が切り替わると，観察者は映像の表示位置が変わるたびに目の焦点調節を行うため、目の焦点調節機能，即ち視力の訓練ができると考えらる。
【実施例１】
【００６６】
以下、本発明の実施例について図面を参照して説明する。図１と図２は本発明の表示装置の一実施例を示す概略断面図である。また、図３は同じく本発明の表示装置の一実施例を示す概略斜視図である。
【００６７】
この表示装置は観察者からみて奥行きの異なる２つの観察対象を光学的に重ねて表示する表示装置であり、表示素子１と、ハーフミラー２と、全反射ミラー３と、偏光変換素子４とを備える。尚、本発明の主体は光学系の構成にあるので、信号系，電気系，機構系、及びこれらを支える構造部材などの説明は省略する。
【００６８】
表示素子１は映像情報をもとに映像を表示するものであり、その表示面は観察者２０からみて奥行きの異なる位置に配置される２つの観察対象として機能するものである。このため、表示素子１の表示面は２つの観察対象に対応する２つの表示領域を有する。つまり、観察者からみて奥行きが近い位置となる観察対象に対応する表示領域１ｎ（以下、近距離表示領域１ｎと呼ぶ）と、観察者からみて奥行きが遠い位置となる観察対象に対応する表示領域１ｆ（以下、遠距離表示領域１ｆと呼ぶ）とを有する。

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【００６９】
表示素子１としては薄型，軽量であることから液晶表示素子や有機エレクトロルミネッセンス素子を用いることが表示装置全体の薄型化のために望ましい。また，後述するハーフミラー２による映像光の合成における損失をできるだけ小さくするために表示素子１としては映像光として偏光光を放射するものが望ましく、このような表示素子１としては液晶表示素子を用いることが好適である。ここでは以下，表示素子１として液晶表示素子を用いる場合を説明するので符号１を液晶表示素子に対しても使用する。
【００７０】
液晶表示素子はバックライトと、バックライトから放射される光の透過量を調節することで映像を表示する液晶表示パネルとから構成される。液晶表示素子としては例えばＴＮ（Twisted Nematic）方式，ＳＴＮ（Super Twisted Nematic）方式，ＥＣＢ(Electrical Controlled Birefringence）方式などを用いることができる。また、広視野角を特徴とするＩＰＳ（in Plane Switching）方式，ＶＡ(Vertical Alingned）方式などを用いることができる。これらの液晶表示素子は偏光板を備え、液晶層に入射する光の偏光状態を制御することで映像の表示を行うものであり，比較的低い駆動電圧でコントラスト比の高い映像が得られるものである。
【００７１】
次に図４を参照して液晶表示素子１について説明する。ここでは以下、液晶表示素子１としてＩＰＳ方式を用いる場合を説明するが，本発明はこれに限定されるものではない。
【００７２】
図４は液晶表示素子１の概略断面図である。液晶表示素子１は液晶表示パネル２００とその背面に配置したバックライト１００とから構成される。
【００７３】
バックライト１００は液晶表示パネル２００の表示領域を照明するもので，エッジライト方式（導光体方式），直下方式（反射板方式），面状光源方式などがある。バックライト１００はこれらの方式やその他の方式の中から用途や目的，表示領域の大きさに合わせて最適な方式を選べばよい。ここでは、エッジライト方式のバックライトについて説明するが、本発明はこれに限定されるものではない。
【００７４】
バックライト１００は，裏面に白色顔料によるドット印刷、或いは微細な凹凸形状やレンズ形状等の光の進行方向を変える手段を形成した透明な樹脂からなる導光体１０３と、導光体１０３の端面に配置した光源１０１と、導光体１０３の裏面側に配置した反射シート１０４と、導光体１０３の表面側に配置したプリズムシートや、拡散シートなどの光学フィルム１０５，１０６とを有している。
【００７５】
光源１０１としては冷陰極管や熱陰極管などの線状光源やＬＥＤなどの点状光源を使用することができる。ここでは以下、光源１０１として冷陰極管を使用する場合を説明するが本発明はこれに限定されるものではない。
【００７６】
光源１０１として冷陰極管を用いる場合は、光源からの光を導光体に効率よく入射させるため、光源を覆うようにランプカバー１０２を配置すると良い。
【００７７】
この構成において、光源１０１から出射した光は直接、或いはランプカバー１０２で反射した後、導光体１０３に入射する。導光体１０３に入射した光は全反射しながら導光体１０３内を伝播するが，導光体１０３の裏面に施された、光の進行方向を変える手段に至った光は、その進行方向が変わり，導光体１０３表面側から出射する。導光体１０３から出射した光は、プリズムシートや拡散シートなどの光学フィルムにより出射角度の分布や、面内での輝度分布が調整された後、液晶表示パネル２００に照射される。
【００７８】
液晶表示パネル２００は，平坦かつ透明で光学的に等方なガラス，あるいはプラスチッ

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タからなる第１の透明基板２０１および第２の透明基板２０２とを有する。透明基板201には、カラーフィルタや、ポリイミド系高分子からなる配向膜（いずれも不図示）が積層されている。第２の透明基板２０２には、配向膜，画素を形成する電極，信号電極，薄膜トランジスタ等のスイッチング素子（いずれも不図示）が形成されている。

【００７９】

図５は本実施例の液晶表示パネル２００の１画素の構成を示す概略正面図である。液晶表示パネル２００の１画素は透明基板２０２上に形成した共通電極２００３及び走査信号電極２００４と、これらの上層に図示しないゲート絶縁膜を介して形成した映像信号電極２００１及び画素電極２００２と、非晶質もしくは多結晶Ｓｉ膜等により形成したスイッチング素子としてのＴＦＴ（Thin Film Transistor）２００６を有する。

【００８０】

また、画素電極２００２は共通電極２００３と一部重なり合い、保持容量を形成する。共通電極２００３、及び画素電極２００２は一画素を４つの領域に分割しており、互いに略一定の間隙を保ちながら，ジクザク型になっている。また、液晶表示素子の表示面における表示領域分割方向に対する共通電極２００３、および画素電極２００２のジグザグの傾き角度γは約±１０°である。さらにこれらの上層には保護層が形成され、その上に配向膜が形成される。

【００８１】

２枚の透明基板２０１，２０２は配向膜形成面を向かい合わせ、図示しないスペーサーにより一定の間隙を設けた状態で枠状のシール材で周囲を接着することで内部に空間が形成される。この空間に誘電異方性が正のネマチック液晶を封入し、封止することで液晶層２０３が設けられる。

【００８２】

液晶層２０３は２枚の透明基板２０１，２０２上に形成された配向膜に施される配向処理により、その液晶分子長軸の配向方向が規定される。液晶層２０３の液晶配向方向は，２枚の透明基板２０１，２０４間で捩じれのない、いわゆるホモジニアス配向とする。

【００８３】

透明基板２０１の前面と透明基板２０２の背面にはそれぞれ偏光板２０４及び２０５を配置する。

【００８４】

図６は偏光板２０４及び偏光板２０５の直線偏光の透過軸と液晶層２０３の液晶分子長軸の配向方向の一例を示す図である。ここでは以下、図示の通り、液晶層の配向方向203aは表示領域分割方向と平行とし、偏光板２０４の直線偏光の透過軸２０４ａは液晶層203の配向方向２０３ａと平行とし，偏光板２０５の直線偏光の透過軸２０５ａは液晶層203の配向方向２０３ａと直交する場合を説明する。

【００８５】

尚、偏光板２０４，２０５の直線偏光の透過軸は図６に例示した方向に対して共に90°回転していても良い。

【００８６】

偏光板２０４および偏光板２０５としては、例えば延伸したポリビニルアルコールにヨウ素を吸着させることにより偏光機能を付与した膜の両面に、トリアセチルセルロースの保護層を施したものを用いることができる。なお、偏光板２０４および偏光板２０５は、それぞれ透明基板２０１及び透明基板２０２に、透明な接着剤により接着される。

【００８７】

バックライト１００からの光は偏光板２０５を透過した後、液晶層２０３を通過して偏光板２０４に入射する。この際、映像情報発生部（不図示）から伝えられる映像情報に対応した電圧を共通電極および画素電極に印加することで液晶層２０３を通過する光の偏光状態を変えて偏光板２０４を透過する光の量を制御することができる。これにより、偏光板２０４を透過する直線偏光からなる所望の映像光を形成することができる。

【００８８】

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尚、液晶表示素子１は１つの連続した表示面を便宜上、近距離表示領域１ｎと遠距離表示領域１ｆに分割することで２つの観察対象を実現する。これにより、単一の表示素子で２つの異なる奥行きに配置した観察対象を実現できるため、部品点数が減る。また、２つの観察対象は同一平面上に配置されることになるので、観察者からみて奥行き方向の長さが小さく、薄型の表示装置が実現できるという利点がある。

【００８９】

本実施例では、ハーフミラー２は液晶表示素子１の近距離表示領域１ｎからの映像光１１（以下、近距離映像光１１と呼ぶ）と遠距離表示領域１ｆからの映像光１２（以下、遠距離映像光１２とよぶ）を合成する機能を有するものである。また、全反射ミラー３は液晶表示素子１の遠距離表示領域１ｆから放射する映像光１２をハーフミラー２に向けて反射する機能を有するものである。このため、全反射ミラー３は少なくともこれに入射する遠距離映像光１１に対して反射率が高いミラーとすることが明るい映像を得るために望ましい。

【００９０】

ここでは、ハーフミラー２と全反射ミラー３は共に反射面が平面であり、互いに平行となるように配置する場合を説明する。これはレンズなどの光学部材を新たに付加する、あるいはハーフミラーや全反射ミラーの反射面を曲面にする、あるいは遠距離表示領域や近距離表示領域の形状を変形させる、などしなくても観察者に遠距離表示領域の映像と近距離表示領域の映像を相似な形状で観察できるようにするためである。尚、本発明はレンズなどの光学部材を付加したり、ハーフミラーや全反射ミラーの反射面を任意の曲面形状にすることを排除するものではないが、部品点数を少なくし、より低コストな表示装置を実現するためには上記構成とすることが望ましい。

【００９１】

ハーフミラー２と全反射ミラー３は液晶表示素子１の表示面に対して平行、或いは傾きを有して配置する。ここでは以下、ハーフミラー２及び全反射ミラー３を液晶表示素子１の表示面に対して平行に配置する場合を説明する。

【００９２】

この場合、ハーフミラー２は液晶表示素子１の近距離表示領域１ｎの前面に配置する。ここでは特にハーフミラー２を液晶表示素子１の表示面に密着して配置する場合について述べる。ハーフミラー２の大きさは近距離表示領域１ｎを覆うのに必要最低限の大きさであれば良く、高い位置精度で組み立てられる場合には近距離表示領域と同じ大きさにすれば部材面積が必要最小限となり低コスト化につながる。ただし、ハーフミラー２の大きさは合わせずれを考慮して、近距離表示領域１ｎの大きさよりもやや大きくすることが現実的である。

【００９３】

全反射ミラー３は液晶表示素子１の前面側であって、想定する観察者の方向に応じて適切な距離だけ液晶表示素子１の表示面から離れた位置に配置する。

【００９４】

以下、全反射ミラー３の配置位置について図２及び図３を参照して説明する。ここでは、観察者２０が液晶表示素子１の表示面に垂直な方向に対し、表示領域分割方向と平行で、なおかつ近距離表示領域１ｎ側の方位（図では右側方向）へ、所定の角度（以下、観察角度とも呼ぶ）傾いた方向から観察する場合を想定する。

【００９５】

この場合、全反射ミラー３は観察者２０からみて近距離表示領域１ｎを遮らず、なおかつ遠距離表示領域１ｆと近距離表示領域１ｎがハーフミラー２を介して重なって見える位置に配置する。

【００９６】

ハーフミラー２を液晶表示素子１の表示面上に密着して配置する場合は、ハーフミラー２の反射面は液晶表示素子１の表示面に極めて近い位置に存在する。そこで、ハーフミラー２の反射面と液晶表示素子１の表示面とが同じ平面に存在すると仮定し、ハーフミラー

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２の反射面から全反射ミラー３の反射面までの最短距離をＨ、観察角度をθ、遠距離表示領域１ｆの表示領域分割方向における幅をＷ１、遠距離表示領域１ｆと近距離表示領域１ｎのすき間の距離をＷ０とする。この場合、距離Ｈが数式（数１）を満足していると、観察者２０は遠距離表示領域１ｆの映像をハーフミラー２を介して観察することができるようになる。

【００９７】

（数１）

$$H = (W0 + W1) / 2 / \tan\theta \quad \cdots (1)$$

例えば、Ｗ０＋Ｗ１＝１００㎜，θ＝３５°とすると、Ｈ＝約７１．４㎜とすれば、観察者２０は遠距離表示領域１ｆの映像をハーフミラー２を介して観察することができるようになる。

【００９８】

尚、実際には液晶表示素子１の表示面とハーフミラー２の反射面は完全に同一の平面にあるわけではない。このため、ハーフミラー２の反射面と液晶表示素子１の表示面との間にある有限の距離を考慮すると、遠距離表示領域１ｆの映像をハーフミラー２を介して観察できる場合、距離Ｈは数式（数２）を満足する。

【００９９】

（数２）

$$H \geq (W0 + W1) / 2 / \tan\theta \quad \cdots (2)$$

この際、全反射ミラー３の近距離表示領域１ｎ側の端部（図中、右側の端部）の位置は想定される観察者が近距離表示領域１ｎを観察する際、妨げとならない位置とする。また、全反射ミラー３はその反射面の大きさが少なくとも遠距離表示領域１ｆ以上の大きさであればよく、高い合わせ精度で組み立てられる場合には遠距離表示領域１ｆと同じ大きさにすれば部材面積が必要最小限に小さくなり低コスト化につながなる。ただし、全反射ミラー３の反射面の大きさは合わせずれの大きさを考慮して、遠距離表示領域１ｆよりもやや大きくすることが現実的である。

【０１００】

近距離映像光１１はハーフミラー２を透過して観察者２０に観察される。また、遠距離映像光１２はハーフミラー２で反射して観察者２０に観察される。このため観察者が明るい映像を得るにはハーフミラー２はこれに入射する近距離映像光１１に対しては透過率が高く、遠距離映像光１２に対しては反射率が高いことが望ましい。

【０１０１】

そこで、本発明ではハーフミラー２として入射する光を透過と反射で偏光状態が異なる光に分離する偏光分離素子を用いる。偏光分離素子は言い換えると２方向から入射する偏光状態の異なる光を透過と反射により一方向に合成する機能を有するものである。

【０１０２】

ここでは液晶表示素子１が映像光として直線偏光を放射することから、ハーフミラー２として液晶表示素子１から放射する直線偏光成分は透過し、これと偏光軸が直交する直線偏光成分は反射する偏光分離素子を用いる。

【０１０３】

この際、偏光分離素子を用いることでより明るい映像を得るために、偏光分離素子は所定の直線偏光に対する透過率と、これと偏光軸が直交する直線偏光に対する反射率の和が１００％よりも大きい必要がある。また、ハーフミラーでの映像光の損失を完全に無くすために偏光分離素子は所定の直線偏光に対する透過率と、これと偏光軸が直交する直線偏光に対する反射率の和が２００％となることが望ましい。

【０１０４】

このため、偏光分離素子の所定の直線偏光に対する透過率と、これと偏光軸が直交する直線偏光に対する反射率の和をＴＲ％とすると、ハーフミラー２としては１００％＜ＴＲ％≦２００％となる偏光分離素子を用いる必要がある。

【０１０５】

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尚、偏光分離素子は、偏光分離素子でない通常のハーフミラーと比べると高価であるため、費用対効果を考慮すると、ハーフミラー２としては１６０％＜ＴＲ％≦２００％となる偏光分離素子を用いることが望ましい。この場合、近距離映像光１１と遠距離映像光１２の明るさを同程度にするために、偏光分離素子の所定の直線偏光に対する透過率と、これと偏光軸が直交する直線偏光に対する反射率は共に８０％以上で同程度の値であることが望ましい。

【０１０６】

尚、以下の説明ではハーフミラー２として偏光分離素子を用いる場合を説明するため、偏光分離素子に対してもハーフミラー２と同じ符号２を用いる。

【０１０７】

偏光分離素子２は液晶表示素子１から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光は反射するものを用いる。

【０１０８】

このような偏光分離素子２としては例えば特許文献３に開示されている異なる複屈折性を有する高分子フィルムを複数層積層した複屈折反射型偏光フィルム、もしくはコレステリック液晶フィルムの表と裏に位相差フィルムを配置したもの、もしくは屈折率の異なる誘電体を積層した誘電体多層膜、もしくは金属ワイヤーグリッドによる偏光フィルターを用いることができる。

【０１０９】

複屈折反射型偏光フィルムの場合、これに入射する光のうち所定の直線偏光成分は透過し、これと偏光軸が直交する直線偏光成分は反射するフィルムが３Ｍ社（米国）からDBEFという商品名で市販されており、これを偏光分離素子２として使用することができる。この際、マット処理等のように映像がぼやけるような処理がなされていないものを使用することが鮮明な映像を得るために重要である。

【０１１０】

偏光分離素子２としてコレステリック液晶フィルムの表と裏に位相差フィルムを配置したものを使用する場合、コレステリック液晶フィルムの裏側、すなわち液晶表示素子１側に配置する位相差フィルムは液晶表示素子１から放射する映像光がコレステリック液晶フィルムを透過する楕円偏光（円偏光を含む）に変換するものを用いる。一方、コレステリック液晶フィルムの表側、すなわち観察者側に配置する位相差フィルムは、遠距離表示領域１ｆから放射し、全反射ミラー３で反射した後、偏光分離素子２に入射する映像光をコレステリック液晶フィルムで反射する楕円偏光（円偏光）に変換するものを用いる。

【０１１１】

コレステリック液晶は、ヘリカルな分子配列に基づく特異な光学特性を示すもので、ヘリカル軸に対してやや傾いた角度で入射した光が、コレステリック螺旋の回転方向に応じて、一方の回転方向の楕円偏光は反射し、他方は透過するという選択反射を示すものである。選択反射の波長域は、分子配列のピッチによって決まるので、可視波長域全域で選択反射が起こるようにするためには、ピッチの異なる複数のコレステリック液晶を積層して用いることが必要である。或いは、可視波長域全域で選択反射を得るために、Asia Display 95 Digest, p735, The Institute of Television Engineers of Japan (ITE) & The Society for Information Display (SID) に記載されているようなピッチを連続的に変化させたコレステリック液晶を用いてもよい。

【０１１２】

誘電体多層膜による偏光分離素子は透明基材上に屈折率の異なる誘電体薄膜を積層するもので、プリズムタイプと平板タイプがある。

【０１１３】

金属ワイヤーグリッドによる偏光フィルターは透明基材上に千数百オングストロームのピッチで、銀，アルミニウム，クロムなどの導電性の金属線状パターンを形成したもので，透明基材を平板とすれば平板タイプの偏光分離素子を実現できる。

【０１１４】

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尚、偏光分離素子２として、複屈折反射型偏光フィルムや、コレステリック液晶フィルムのように、フィルム状の部材を用いる場合は以下の点に注意することが望ましい。

【０１１５】

すなわちフィルム状の偏光分離素子２は、そのままでは平坦性が低いため単に液晶表示素子１の前面に配置しただけではフィルムのゆがみにより映像がゆがむ場合がある。そこで、偏光分離素子２としてフィルム状の部材を使用する場合は、透明な粘着剤を介して、ガラス板あるいはプラスチック板等のように剛性が高く、平坦、かつ透明で光学的に等方な透明基材に粘着固定し、歪みがないようにすることが望ましい。あるいは偏光分離素子２を平坦な状態で固定するために新たな透明基材を用いるのではなく、液晶表示素子１の表示面上に偏光分離素子２を透明な粘着剤を介して粘着固定するようにしてもよい。

【０１１６】

遠距離表示領域１ｆから放射する映像光が全反射ミラー３を介して偏光分離素子２に至る光路中には偏光変換素子を配置する。偏光変換素子は遠距離表示領域１ｆから放射され偏光分離素子２に入射する映像光を偏光分離素子２が反射する偏光状態の光に変換するものである。

【０１１７】

ここでは、偏光変換素子４を遠距離表示領域１ｆの前面に密着して配置する場合を説明する。この場合、偏光変換素子４は遠距離表示領域１ｆから放射する直線偏光を、その偏光軸が９０°回転した直線偏光に変換するものである。つまり、偏光変換素子４としてはこれに入射する直線偏光の偏光軸を９０°回転させる旋光子や１／２波長板を用いればよい。この場合、偏光変換素子４の大きさは観察者２０からみて遠距離表示領域１ｆが覆われるのに必要最低限の大きさであれば良い。偏光変換素子４が液晶表示素子１の表示面と平行に配置され、高い位置精度で組み立てられる場合には遠距離表示領域１ｆと同じ大きさにすれば部材面積が必要最小限となり低コスト化につながる。ただし、偏光変換素子４の大きさは合わせずれを考慮して、遠距離表示領域１ｆの大きさよりもやや大きくすることが現実的である。

【０１１８】

偏光変換素子４としては配向処理された２枚の透明基板の間に液晶層を封入し、液晶の分子長軸を２枚の透明基板間で９０°捩じった状態の液晶セルを用いることができる。この場合、偏光変換素子を実現する液晶セルは遠距離映像光１２に対してウエーブガイドの条件を満足するように構成される。ウエーブガイドの条件は、例えば、Ｊ．Ｐｈｙｓ．Ｄ：Ａｐｐｌ．Ｐｈｙｓ．Ｖｏｌ．８（１９７５）の１５７５～１５８４頁のＣ．Ｈ．ＧｏｏｃｈとＨ．Ａ．Ｔａｒｒｙによる論文に記載されている。

【０１１９】

ウエーブガイドの条件は、異常光モードと常光モードでは変わらないので、偏光変換素子４として使用する液晶セルの液晶表示素子側における液晶分子長軸の配向方向は、液晶表示素子１の偏光板２０４の直線偏光の透過軸に平行であっても垂直であってもどちらでもよい。

【０１２０】

偏光変換素子としてはこの他に１／２波長板や、位相差フィルムの積層による捩じれ構造体を用いることができる。

【０１２１】

１／２波長板としては、可視波長域において高い透過率を有する、一軸延伸した高分子のフィルム、例えばポリビニルアルコール，ポリカーボネート，ポリサルフォン，ポリスチレン，ポリアリレート，或いはノルボルネン系の樹脂などからなる位相差フィルムを用いることができる。この他にも雲母や水晶または分子長軸を一方向に揃えて配向した液晶層等を用いることができる。

【０１２２】

尚、一般的には１／２波長板を構成する材質の屈折率の波長依存性（以下、波長分散）により、一種類の位相差板で可視波長の広い波長範囲に渡って１／２波長板として機能す

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る位相差板を構成することは困難である。そこで波長分散の異なる少なくとも２種類の位相差板をその光学軸が交差するように貼り合わせることで広い波長域で１／２波長板として機能するよう構成したものを使用してもよい。或いは、波長が短くなるほど複屈折が大きくなる、いわゆる逆分散と呼ばれる性質を有する高分子フィルムを用いてもよい。位相差フィルムの積層による捩じれ構造体は、例えば１／２波長の位相差を有する位相差フィルムを複数枚その光学軸を連続的にずらしながら積層することで実現される。位相差フィルムとしては上記１／２波長板に使用する高分子フィルムを使用することができる。尚、ここで例示した偏光変換素子は光が垂直に入射する際に最も有効に機能するものである。従って、本実施例のようにハーフミラー（偏光分離素子）２及び全反射ミラー３を液晶表示素子１の表示面に対して平行に配置して、観察角度θが０°と成らない場合は考慮が必要である。

【０１２３】

つまり、偏光変換素子として上記旋光子や一軸延伸した位相差フィルムからなる１／２波長板や捩じれ構造体を使用する場合は、図７に例示する通り、偏光変換素子４を液晶表示素子の表示面に対して、想定する観察角度θと同じ角度θだけ傾けて配置することが望ましい。ここで、図７は本発明の表示装置の一実施例を示す概略断面図である。

【０１２４】

この場合、遠距離表示領域１ｆから放射される遠距離映像光１２は偏光変換素子４に垂直に入射するため上記旋光子及び一軸延伸した位相差フィルムからなる１／２波長板や捩じれ構造体により実現する偏光変換素子４は最も有効に機能するようになる。さらに偏光変換素子４を液晶表示素子１の表示面に対して角度θだけ傾けて配置する場合は、偏光変換素子４を液晶表示素子１の表示面に平行に配置する場合に比べて、偏光変換素子４の必要最低限の大きさを$\cos\theta$倍だけ小さくすることができる。

【０１２５】

尚、本発明は図１から図３に例示する通り、偏光変換素子を液晶表示素子１の表示面に対して平行に配置する場合を除外するものではない。偏光変換素子として上記旋光子及び一軸延伸した位相差フィルムからなる１／２波長板や捩じれ構造体を使用する場合であっても観察角度θが小さければ偏光変換素子は有効に機能する。

【０１２６】

しかし、この場合は観察角度θを大きくすると偏光変換素子４の機能が低下して遠距離映像光１２のハーフミラー（偏光分離素子）２での反射率が低下し、観察者２０に観察される遠距離映像光の明るさが低下する。従って、この場合には光が斜めに入射しても有効に機能する偏光変換素子を用いるようにするとよい。つまり、偏光変換素子として光の入射角度θに対して有効に機能するものを用いれば良い。このような偏光変換素子は例えば１／２波長板であれば２軸異方性の位相差フィルムを用いることで実現できる。

【０１２７】

尚、偏光変換素子４を液晶表示素子１の表示面に対して平行に配置する場合は、偏光変換素子４を液晶表示素子１の表示面上に透明な粘着材などにより接着固定すれば余分な保持部材が不要になり部品点数を減らすことができる。

【０１２８】

全反射ミラー３は液晶表示素子１の遠距離表示領域１ｆから放射する遠距離映像光１２をハーフミラー２に向けて反射する機能を有するものである。このため、全反射ミラー３は少なくとも遠距離映像光１２に対して反射率の高いミラーとすることが明るい映像を得るために重要である。

【０１２９】

全反射ミラー３としてはガラスやプラスチックなどの光学的に等方で透明な平坦な基板に銀やアルミニウムなどの反射率の高い金属膜により反射面を形成したものや、誘電体多層膜により反射面を形成したものを用いることができる。

【０１３０】

或いは全反射ミラー３に入射する遠距離映像光１２に対応した偏光成分の光を反射する

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偏光反射ミラーであってもよい。偏光反射ミラーとしてはハーフミラー２と同様な偏光分離素子を用いることができる。

【０１３１】

次に本表示装置の動作について説明する。上記構成とすることで、液晶表示素子１の近距離表示領域１ｎから放射される近距離映像光１１はハーフミラー（偏光分離素子）２でほとんど反射されることなく透過して観察者２０に観察される。一方、液晶表示素子１の遠距離表示領域１ｆから放射する遠距離映像光１２は偏光変換素子４を通過する際、偏光軸が９０度回転した直線偏光となり、全反射ミラー３で反射した後、ハーフミラー（偏光分離素子）２でそのほとんどが反射して観察者２０に観察される。

【０１３２】

つまり、ハーフミラー２として偏光分離素子を用いることで近距離映像光１１と遠距離映像光１２は共にほとんど損失することなく観察者２０に観察されるため明るい表示が得られる。この際，遠距離表示領域１ｆは近距離表示領域１ｎと比べると、遠距離表示領域１ｆから全反射ミラー３までの距離と全反射ミラー３からハーフミラー２までの距離の分だけ観察者２０からみた距離が遠くなる。このため、観察者２０からみて奥行きの異なる位置に配置した２つの２次元像が重なった状態で観察されることになる。

【０１３３】

本発明の表示装置では特に観察者からみて奥行きの異なる位置にある観察対象は、実際には同一平面上に配置しているため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さく，薄型の表示装置が実現できる。さらに観察対象を単一の表示素子とすることで部品点数を少なくすることができる。

【０１３４】

尚、部品点数を減らすためには複数の観察対象は単一の液晶表示素子の表示面とすることが望ましいが、複数の観察対象を並列に配置した複数の液晶表示素子の表示面で実現するようにしても良い。この場合は，部品点数を少しでも減らすために、並列配置した複数の液晶表示素子は、それを構成する部材、例えば、バックライトや筐体、或いはバックライトを構成する光源，導光体，反射シート，光学フィルムなどの部材の一部を共通化することが望ましい。

【０１３５】

尚、本実施例では液晶表示素子１が，表示領域分割方向と平行もしくは直交する方向に偏光軸を有する直線偏光を映像光として放射する場合を述べた。これは以下の理由による。一般に反射面に斜めに入射して反射する光は反射面に対してｓ偏光成分とｐ偏光成分とで位相差を生じる。このため、反射面に対してｓ偏光あるいはｐ偏光となる直線偏光以外の光が反射面に斜めに入射すると反射の前後でその偏光状態は変化する。

【０１３６】

本表示装置では液晶表示素子１から放射する遠距離映像光１２は全反射ミラー３に斜めに入射するが、液晶表示素子１が表示領域分割方向と平行もしくは直交する方向に偏光軸を有する直線偏光を映像光として放射するため，遠距離映像光１２は全反射ミラー３に対してｐ偏光またはｓ偏光として入射する。この場合、遠距離映像光１２は全反射ミラー３での反射の際、偏光状態が変化しないので、ハーフミラー（偏光分離素子）２において効率良く反射されて明るい映像を得ることができる。

【０１３７】

一方、もしも液晶表示素子１が表示領域分割方向と平行もしくは直交する方向に偏光軸を有する直線偏光以外の偏光を映像光として放射するとすると、遠距離映像光は全反射ミラーでの反射の前後でその偏光状態が変わってしまう。このためハーフミラー（偏光分離素子）２において、効率良く映像光を反射させるためには新たに映像光の偏光状態を制御する部材を追加する必要が生じてしまう。

【０１３８】

つまり、本実施例の表示装置のように液晶表示素子１が表示領域分割方向と平行もしくは直交する方向に偏光軸を有する直線偏光を映像光として放射するようにすることで、よ

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り明るい映像をより少ない部材で実現することができる。

【０１３９】

尚、液晶表示素子１の表示面の形状は一般に矩形であるため、遠距離表示領域１ｆと近距離表示領域１ｎが同じ大きさの矩形であれば表示領域を有効に利用できる。ただし、本表示装置では遠距離表示領域１ｆと近距離表示領域１ｎが重なって観察されるが、観察者２０からみて遠距離表示領域１ｆは遠くにあるため、遠距離表示領域１ｆと近距離表示領域１ｎの実際の大きさが同じである場合には観察者２０には遠距離表示領域１ｆが近距離表示領域１ｎよりも小さく観察される。この状態は遠距離表示領域１ｆの周囲を光吸収部材により黒くするなどして不要な光が観察されないようにすれば用途によっては許容されると考えられる。

【０１４０】

尚、観察者からみた遠距離表示領域１ｆと近距離表示領域１ｎの大きさが過不足なく同じに見えるようにするには観察者の視点を固定したうえで以下の通りとすると良い。

【０１４１】

ここで、図２，図３に示す通り、遠距離表示領域１ｆの表示領域分割方向における幅をＷ１、これと直行する方向の幅をＷ３、近距離表示領域１ｎの表示領域分割方向における幅をＷ２、これと直行する方向の幅をＷ４とする。さらに観察者２０から近距離表示領域１ｎの中央部までの距離をＬ１、観察者２０からみた近距離表示領域１ｎから遠距離表示領域１ｆまでの距離をＬ２とする。

【０１４２】

この場合、液晶表示素子１での実際の遠距離表示領域１ｆと近距離表示領域１ｎの大きさの比、すなわち、Ｗ１／Ｗ２及びＷ３／Ｗ４が数式（数３）を満足すると観察者からみて遠距離表示領域１ｆと近距離表示領域１ｎが同じ大きさに見える。

【０１４３】

（数３）

$$W1/W2=W3/W4=(L1+L2)/L1=L2/L1+1 \quad \cdots (3)$$

尚、ハーフミラー２を液晶表示素子１の表示面上に密着配置する場合，ハーフミラー２の反射面は液晶表示素子１の表示面に極めて近い位置に存在する。そこで、ハーフミラー２の反射面と液晶表示素子１の表示面とが同じ平面に存在すると仮定し、ハーフミラー２の反射面から全反射ミラー３の反射面までの最短距離をＨ、観察角度をθとすると、Ｌ２は数式（数４）で表される。

【０１４４】

（数４）

$$L2=2H/\cos\theta \quad \cdots (4)$$

例えば、Ｌ１＝５００㎜，θ＝３５°，Ｈ＝７１．４㎜の場合は、数式（数３）及び（数４）からＷ１／Ｗ２およびＷ３／Ｗ４の値は約１．３５となり，遠距離表示領域は近距離表示領域に対して３５％程度その幅を大きくすると、観察者からみた各表示領域の大きさは等しく見える。

【０１４５】

尚、観察者からみた遠距離表示領域１ｆの大きさが近距離表示領域１ｎの大きさよりも大きくなると、遠近感が損なわれる場合がある。また、実際の遠距離表示領域１ｆの大きさを近距離表示領域１ｎの大きさよりも小さくすると液晶表示素子１の表示面に無駄な領域が生じてしまう。そこで，遠近感を損なうことがなく、さらに液晶表示素子１の表示面にできる不要な領域を小さくするためにＷ１／Ｗ２及びＷ３／Ｗ４は数式（数５）を満足するように設定することが望ましい。

【０１４６】

（数５）

$$1 \leqq W1/W2=W3/W4 \leqq L2/L1+1 \quad \cdots (5)$$

尚、観察者からみて奥行きの異なる位置にある表示領域の映像を重ねて表示する場合、表示方法を工夫することで立体感のある表示が可能となる。

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【０１４７】
そのひとつの方法は奥行きの異なる位置にある表示領域に表示される映像は基本的には同一の表示対象とし、観察者の右眼と左眼とを結ぶ線上の一点からみた場合に重なるように表示するものである。この際、遠距離表示領域と近距離表示領域に表示される２次元像（映像）は観察者からみた場合の合計の輝度が表示対象の輝度と等しくなるように保った上で、観察者から遠い奥行きにあるものは遠距離表示領域の輝度を高くし、近距離表示領域の輝度は低くする。また、観察者から近い奥行きにあるものは近距離表示領域の輝度を高くし、遠距離表示領域の輝度は低くする。
【０１４８】
このように表示対象の奥行き位置に応じた輝度調整をすることで観察者には３次元立体像が感知される。しかし、この方法は観察者の視点が変わると良好な３次元立体像が観察できなくなる。そこで、３次元立体像が良好に観察できる視点位置を観察者が容易に判別できるようにするための位置合わせの印を遠距離表示領域と近距離表示領域の両方に適宜表示する、或いは表示領域外で観察可能な領域、例えば表示領域の額縁部分に表示するようにするとよい。
【０１４９】
位置合わせの印としては図８に例示するように遠距離表示領域もしくはその額縁部分に表示する十文字と、近距離表示領域もしくはその額縁部分であって、上記十文字が表示される位置に対応する位置に表示するＬ字を４つ組み合わせた図形を用いることができる。あるいは図９に例示するように遠距離表示領域もしくはその額縁部分に表示する円と、近距離表示領域もしくはその額縁部分であって、上記円が表示される位置に対応する位置に表示する上記円と同心の中空円を用いることができる。尚、位置合わせの印はこれらに限定されるものではなく、上下左右全方位に渡り位置合わせができる印であればよい。
【０１５０】
尚、医療用や美術品の観察といった観察対象を正確に再現することが要求される用途ではなく、例えば、ゲーム機やパチンコなどの遊技機において表示装置の表現力を高める方法として奥行き感のある表示を実現する場合には以下の方法で各表示領域の映像を作成すると多少視点が変わっても奥行き感のある表示を維持することができるようになる。
【０１５１】
（１）観察者からみて奥行きが異なる位置にある表示領域には同時に同一の表示対象を表示しない。つまり、遠くにあるもの（表示対象）は遠距離表示領域に表示し、近くにあるものは近距離表示領域に表示する。この際、遠くにあるものは小さく表示し、近くにあるものは大きく表示するとより大きな遠近感が得られる。
（２）観察者からみて異なる奥行きに渡り連続的に存在する表示対象は観察者から遠い奥行きにある部分は遠距離表示領域のみに表示し、観察者から近い奥行きにある部分は近距離表示領域のみに表示する。また、異なる奥行きの中間位置に相当する部分は各表示領域において、それ以外の部分よりも暗く表示する。この際、異なる奥行きの中間位置に相当する部分は異なる奥行きの中間に近づくに従い連続的に表示を暗くする、つまり連続的に輝度が下がるように表示することが不自然さを感じさせないために望ましい。
（３）奥行きの異なる位置にある表示対象が重なる場合、遠くにある表示対象のうち、近くにある表示対象によって遮蔽される部分は、遠距離表示領域において、近くにある表示対象によって遮蔽される領域に相当する部分の少なくとも一部を暗く表示する。この際、遮蔽される部分はその遮蔽部分の周辺部から中央部に向かい連続的に表示を暗くする、つまり連続的に輝度が下がるように表示することが不自然さを感じさせないために望ましい。さらに、各表示領域に表示する映像は奥行き知覚の心理的要因を積極的に利用するとよい。例えば、近いものははっきりと表示し、遠いものはぼんやりと表示する大気遠近法や、遠くに向かう道の幅が徐々に狭くなっていくように見えることを利用する線遠近法、あるいは、きめを構成する要素の密度が遠くにいくほど高くなることを利用するきめの勾配や、陰影をつけることで奥行き感を表現する方法を利用するとよい。
【０１５２】

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図１０は液晶表示素子１の表示面における表示例を示す図である。このように近距離表示領域１ｎには近くに存在する表示対象（ここでは木および道）をより明るく、より大きく表示し、表示対象が遠ざかるにつれて徐々に暗く表示するようにする。また、道は遠ざかるにつれてその幅が連続的に狭くなるように表示する。

【０１５３】

一方、遠距離表示領域１ｆには遠くに存在する表示対象をより明るく、より小さく表示し、表示対象が近づくにつれて徐々に暗く表示するようにする。また、遠距離表示領域１ｆと近距離表示領域１ｎには同じ表示対象を同時に表示しないようにする。

【０１５４】

図１１は液晶表示素子１に図１０に例示する映像を表示した場合に観察者に観察される映像を模擬的に示す図である。このように観察者には２つの異なる奥行きの中間に位置する対象がやや暗く表示されるが、視点が多少ずれても奥行き感のある映像が損なわれることを抑制できる。

【０１５５】

図１２から図１４は第１の表示対象がまっすぐ伸びる道であり、第１の表示対象の上方であって、なおかつ遠方にある第２の表示対象が、徐々に近づいてくる場合の液晶表示素子１の表示例である。

【０１５６】

図１２に例示する通り、第２の表示対象１ｏはこれが遠くにある場合は遠距離表示領域１ｆのみに小さく表示し、近づくにつれて第２の表示対象１ｏをだんだん大きく表示するようにする。

【０１５７】

また、図１３に例示する通り、第２の表示対象１ｏがさらに近づくと、第２の表示対象１ｏを表示する領域を遠距離表示領域１ｆから近距離表示領域１ｎに切り替える。

【０１５８】

このとき、移動する表示対象に対しては２つの異なる奥行きの中間に相当する位置に存在する場合に暗く表示しなくても奥行き感はあまり損なわれないようである。

【０１５９】

ここで、視点が多少ずれても奥行き感や遠近感を損なわないために重要なのはひとつの表示対象を同時に２つの異なる奥行きに位置に相当する表示領域に表示しないことである。つまり、ひとつの表示対象を遠距離表示領域と近距離表示領域の両方に同時に表示しないことである。

【０１６０】

また、図１４に例示する通り、近距離表示領域１ｎに表示する第２の表示対象１ｏと遠距離表示領域１ｆに表示する第１の表示対象が重なるときには、遠くにある第１の表示対象のうち、近くにある第２の表示対象１ｏにより遮蔽される部分（以下、遮蔽部１ｓとよぶ）は表示を暗くする。この際、観察者から見た遮蔽部１ｓの大きさは多少視点がずれても違和感が生じないようにするために、第２の表示対象１ｏに遮蔽される部分の大きさよりも小さくする、或いはその遮蔽部１ｓの周辺部から遮蔽部１ｓの中央部に向かい連続的に表示を暗くする、つまり連続的に輝度を低くしていくことが望ましい。

【０１６１】

これらの方法を用いることで本表示装置は視点が多少変化しても奥行き感のある表示を維持することができる。また、本表示装置は、観察者からみて実際に奥行きが異なる位置にある観察対象を重ねて表示するため、奥行き知覚の生理的要因である眼のピント調節，輻輳，両眼視差などにより奥行きを感知できる表示装置が実現できる。

【実施例２】

【０１６２】

次に本発明の表示装置の他の実施例について図１５を参照して説明する。図１５は本発明の表示装置の一例を示す概略断面図である。

【０１６３】

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本実施例は（実施例１）で図１から図３を参照して説明した表示装置において、偏光変換素子の構造とその配置位置を変えてたこと以外は基本的に同じであるため同じ部分には同じ符号を付け詳細な説明は省略する。

【０１６４】

本実施例では偏光変換素子４ｂを全反射ミラー３の反射面を覆うように配置する。また、全反射ミラー３としてはガラスやプラスチックなどの平坦で、なおかつ光学的に等方な透明基板に銀やアルミニウムなどの反射率の高い金属膜を形成したものを用いる。

【０１６５】

本発明における偏光変換素子４ｂは遠距離表示領域１ｆから放射され、ハーフミラー（偏光分離素子）２に入射する遠距離映像光１２をハーフミラー（偏光分離素子）２において高い反射率で反射する光に変換するものである。つまり、偏光変換素子４ｂは遠距離表示領域１ｆから放射する遠距離映像光１２を、その偏光軸が９０°回転した直線偏光に変換するものである。

【０１６６】

このような偏光変換素子４ｂとしては１／４波長板を用いることができる。１／４波長板としては、可視波長域において高い透過率を有する、延伸した高分子のフィルム、例えばポリビニルアルコール，ポリカーボネート，ポリサルフォン，ポリスチレン，ポリアリレート，或いはノルボルネン系の樹脂等からなる位相差フィルムを用いることができる。

【０１６７】

尚、一般的に１／４波長板を構成する材質の屈折率の波長依存性（波長分散）により、一種類の位相差フィルムで可視波長の広い波長範囲に渡って１／４波長板として機能する位相差フィルムを構成することは困難である。

【０１６８】

そこで，波長分散の異なる少なくとも２種類の位相差フィルムをその光学軸が交差するように貼り合わせることで広い波長域で１／４波長板として機能するよう構成したもの，あるいは、１／４波長板として機能する位相差フィルムと１／２波長板として機能する位相差フィルムをその光学軸が交差するように貼り合わせることで広い波長域で１／４波長板として機能するよう構成したものを使用するとよい。

【０１６９】

或いは、波長が短くなるほど複屈折が大きくなる、いわゆる逆分散と呼ばれる性質を有する高分子フィルムからなる位相差フィルムを用いてもよい。

【０１７０】

尚、遠距離表示領域１ｆから放射する遠距離映像光１２は偏光変換素子４ｂに対して観察角度θと同じ角度で入射する。このため観察角度θを大きく設定すると、偏光変換素子１ｂとして一軸異方性の位相差フィルムで実現する１／４波長板を用いる場合にはその機能が低下して，遠距離映像光１２のハーフミラー２での反射率が低下して表示が暗くなってしまう。

【０１７１】

従って、観察角度θを大きく設定する場合には光が斜めに入射しても有効に機能する偏光変換素子を用いるようにすることが望ましい。このような偏光変換素子は２軸異方性の位相差フィルムを用いることで実現できる。

【０１７２】

尚、偏光変換素子４ｂは全反射ミラー３に直接、透明な粘着材などにより接着固定すれば余分な保持部材が不要になり部品点数を減らすことができる。

【０１７３】

本実施例においても，（実施例１）と同様に観察対象が同一平面に配置されるため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく薄型の表示装置が実現できる。さらに観察対象を単一の２次元表示素子とすることで部品点数を少なくすることができる。また，遠距離映像光１２と近距離映像光１１はほとんど損失することなくハーフミラー（偏光分離素子）２において合成され観察者に観察されるため明るい映像を得るこ

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とができる。

【実施例３】

【０１７４】

次に本発明の表示装置の他の実施例について図１６から図１８を参照して説明する。本実施例は（実施例１）或いは（実施例２）において、偏光変換素子を無くし、液晶表示素子１の偏光板に一部変更を加えたこと以外は基本的に上記実施例と同じ構成であるため同じ部分には同じ符号を付け詳細な説明は省略する。

【０１７５】

図１６は本発明の表示装置の一例を示す概略断面図である。図示の通り、この表示装置では遠距離映像光１２の偏光状態を変える偏光変換素子を配置しない。その代わりに、液晶表示素子１を構成する偏光板の直線偏光の透過軸を遠距離表示領域１ｆと近距離表示領域１ｎとで異ならせている。

【０１７６】

図１７はこの表示装置を構成する液晶表示素子１の概略断面図である。液晶表示素子１は液晶表示パネル２００とその背面に配置したバックライト１００とから構成される。液晶表示パネル２００を構成する透明基板２０１の前面と透明基板２０２の背面にはそれぞれ偏光板を配置するが、ここでは近距離表示領域１ｎ及び遠距離表示領域１ｆに対応する領域でそれぞれ直線偏光の透過軸が異なる偏光板を配置する。

【０１７７】

透明基板２０１の前面であって遠距離表示領域１ｆに相当する領域には偏光板２０４Ａを配置し、近距離表示領域１ｎに相当する領域には偏光板２０４Ｂを配置する。また、透明基板２０２の背面であって遠距離表示領域１ｆに相当する領域には偏光板２０５Ａを配置し、近距離表示領域１ｎに相当する領域には偏光板２０５Ｂを配置する。

【０１７８】

図１８は偏光板２０４Ａ，２０４Ｂ及び偏光板２０５Ａ，２０５Ｂの直線偏光の透過軸と液晶層２０３の液晶分子長軸の配向方向の一例を示す図である。図示の通り、液晶層２０３の配向方向２０３ａは表示領域分割方向と平行にする。また、偏光板２０４Ａの直線偏光の透過軸２０４Ａａは液晶層２０３の配向方向２０３ａと直交させ、偏光板204Ｂの直線偏光の透過軸２０４Ｂａは液晶層２０３の配向方向２０３ａと平行とする。また、偏光板２０５Ａの直線偏光の透過軸２０５Ａａは液晶層２０３の配向方向２０３ａと平行とし、偏光板２０５Ｂの直線偏光の透過軸２０５Ｂａは液晶層２０３の配向方向２０３ａと直交させる。

【０１７９】

上記構成とすることで遠距離表示領域１ｆから放射される遠距離映像光１２と近距離表示領域１ｎから放射される近距離映像光１１は互い偏光軸が直交した直線偏光となる。

【０１８０】

この場合、近距離表示領域１ｎから放射する近距離映像光１１はハーフミラー（偏光分離素子）２でほとんど損失することなく透過して観察者２０に観察される。また、遠距離表示領域１ｆから放射する遠距離映像光１２は全反射ミラー３に対して斜めに入射するが、遠距離映像光１２は全反射ミラー３の反射面に対してｓ偏光となる直線偏光であるため、全反射ミラー３での反射の際、偏光状態を維持したままハーフミラー（偏光分離素子）２に至る。

【０１８１】

このため遠距離映像光１２はハーフミラー（偏光分離素子）２でほとんど損失なく反射されて観察者２０に観察される。

【０１８２】

つまり、本表示装置では偏光変換素子を備えなくても、近距離映像光１１と遠距離映像光１２はハーフミラー（偏光分離素子）２においてほとんど損失なく合成され、観察者２０に観察されるため明るい映像を表示することができる。

【０１８３】

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尚、全反射ミラー３に入射する遠距離映像光は全反射ミラー３の反射面に対して、ｓ偏光またはｐ偏光であれば全反射ミラーでの反射の際、その偏光状態は維持される。このため、偏光板の直線偏光の透過軸は図１８に例示する方向に対して全ての偏光板の透過軸を９０度回転させて配置してもよい。

【０１８４】

ただし、一般にｓ偏光はｐ偏光よりも反射率が高くしやすいのでより、図１８に例示する構成にすることで反射率がより高い全反射ミラー３が実現できることになる。

【０１８５】

尚、本実施例では液晶表示素子１の表面に偏光軸が異なる２枚の偏光板を配置するため、偏光板を高い精度で配置しなければ２枚の偏光板の間に隙間ができてしまう。もし、２枚の偏光板の間に隙間ができると、バックライト１００からの光がこの隙間を通して漏れてしまい画質を劣化させる場合がある。

【０１８６】

このため、偏光板２０４Ａと２０４Ｂの間、或いは偏光板２０５Ａと２０５Ｂの間に相当する位置には光漏れを防ぐための遮光部材を配置することが望ましい。

【０１８７】

遮光部材は２枚の偏光板の間の光漏れを防ぐものであれば良い。従って、偏光板204Ａと２０４Ｂの間、或いは偏光板２０５Ａと２０５Ｂの間に、遮光性のある部材、例えば金属箔や黒色の顔料や染料を含有する樹脂フィルムを遮光部材として配置することで光漏れを防止するようにしても良い。尚、遮光部材として金属箔を用いる場合は少なくとも観察者側の表面を不要な光を反射をしないように黒色にするとよい。

【０１８８】

或いは、図１７に例示する通り、透明基板２０１もしくは透明基板２０２において、偏光板２０４Ａと２０４Ｂの間、或いは偏光板２０５Ａと２０５Ｂの間に相当する位置にクロムなどの金属膜や黒い顔料や染料を混入した樹脂膜を設けることで遮光部材２１０を実現するようにしてもよい。

【０１８９】

本実施例においても、（実施例１）と同様に観察対象が同一平面に配置されるため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく薄型の表示装置が実現できる。さらに観察対象を単一の２次元表示素子とすることで部品点数を少なくすることができる。

【０１９０】

本実施例では特に上記実施例のように偏光分離素子を設ける必要がないので部品点数をより少なくすることができる。

【０１９１】

尚、（実施例１）から（実施例３）で説明した表示装置はいずれも液晶表示素子１の表示面に対して垂直な方向から所定の角度（観察角度θ）傾いた状態で観察するものである。このため液晶表示素子１としては、斜め方向から観察してもコントラスト比の低下が少ない液晶表示素子１を用いることが望ましい。このような液晶表示素子としては上記実施例で説明したＩＰＳ方式、或いはＶＡ方式が望ましく、ＯＣＢ方式や視野角を拡大するための位相差フィルムを備えるＴＮ方式を用いてもよい。

【０１９２】

また、観察者は液晶表示素子１を斜め方向から観察することになるため、遠距離表示領域１ｆおよび近距離表示領域１ｎの実際の形状が長方形の場合には、観察者には表示領域が台形にみえることになる。

【０１９３】

表示装置の用途によっては、観察者にみえる表示領域が長方形であることが望ましい場合がある。この場合は、遠距離表示領域１ｆおよび近距離表示領域１ｎの実際の形状を観察者からみて遠い方の辺が長い台形にするなどして、観察者には長方形に見えるように補正するとよい。

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【０１９４】
また、より少ない消費電力で、より明るい表示を実現するために、液晶表示素子１を構成するバックライト１００から放射する光を観察者の方向、すなわち観察角度θだけ傾いた方向へより多く放射するように指向性を持たせることが望ましい。
【０１９５】
バックライト１００から放射される光の指向性は導光体１０３の裏面に形成する微細な凹凸形状やレンズ形状等の光の進行方向を変える微細な構造の形状、或いは導光体１０３上に配置する光学フィルム１０５、例えばプリズムシートのプリズムの頂角を変えることで制御することができる。
【実施例４】
【０１９６】
次に本発明の表示装置の他の実施例について図１９を参照して説明する。本実施例は（実施例３）で説明した表示装置において，ハーフミラー２と全反射ミラー３の配置方法等を変更したものである。このため、（実施例３）で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。
【０１９７】
図１９は本発明の表示装置の一例を示す概略断面図である。本実施例の表示装置ではハーフミラー（偏光分離素子）２と全反射ミラー３を液晶表示素子１の表示面に対して45°傾けた状態で配置する。
【０１９８】
この場合、観察者２０からみて近距離表示領域１ｎが全てハーフミラー２で覆われるようにするには液晶表示素子１の表示領域分割方向と直交する方向（図では紙面に垂直な方向）でのハーフミラー２の幅は、同じ方向における近距離表示領域１ｎの幅と同じ、あるいは組み立て時の位置ずれ等を考慮して近距離表示領域１ｎの幅よりもやや大きくする。また、これと直交する方向におけるハーフミラー２の幅は近距離表示領域１ｎの表示領域分割方向における幅の√２倍、あるい組み立て時の位置ずれ等を考慮して近距離表示領域１ｎの表示領域分割方向における幅の√２倍よりもやや大きくする。
【０１９９】
全反射ミラー３は遠距離表示領域１ｆから放射される遠距離映像光１２をその領域が欠けることなくハーフミラー２に向けて反射できる大きさにする。このため、液晶表示素子１の表示領域分割方向と直交する方向（図では紙面に垂直な方向）における全反射ミラー３の幅は、同じ方向における遠距離表示領域１ｆの幅と同じ、あるいは組み立て時の位置ずれ等を考慮して遠距離表示領域１ｆの幅よりもやや大きくする。また、これと直交する方向における全反射ミラー３の幅は遠距離表示領域１ｆの表示領域分割方向における幅の√２倍、あるいは位置ずれ等を考慮して遠距離表示領域１ｆの表示領域分割方向における幅の√２倍よりもやや大きくする。
【０２００】
ハーフミラー２としては上記実施例と同様、偏光分離素子を用いる。偏光分離素子として例えば特許文献３に開示されている異なる複屈折性を有する高分子フィルムを複数層積層した複屈折反射型偏光フィルム、コレステリック液晶フィルムの表と裏に位相差フィルムを配置したもの、屈折率の異なる誘電体を積層した誘電体多層膜、或いは金属ワイヤーグリッドによる偏光フィルターを用いることができる。
【０２０１】
尚、偏光分離素子として、複屈折反射型偏光フィルムや、コレステリック液晶フィルムのように，フィルム状の部材を用いる場合は以下の点に注意することが望ましい。
【０２０２】
フィルム状の偏光分離素子はそのままでは平坦性を保つことが難しく歪みにより映像を乱す場合がある。このため、偏光分離素子としてフィルム状の素子を使用する場合は、透明な粘着剤を介して、ガラス板あるいはプラスチック板等の平坦で、なおかつ光学的に等方な透明基材に接着固定し，歪まないようにすることが望ましい。

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【０２０３】
偏光分離素子として誘電体多層膜を用いる場合は平板タイプだけでなく、プリズムタイプを用いることができる。プリズムタイプの偏光分離素子は断面形状が直角２等辺三角形である三角柱状のプリズムの斜面に誘電体多層膜による偏光分離面を形成し、別の３角柱状のプリズムを貼り合わせたものである。プリズムタイプの偏光分離素子は高価であるが、高い光学性能が得られるため、映像光の損失が極めて少なく、明るい映像を実現できる。本表示装置では上記実施例と同様に、液晶表示素子１の近距離表示領域１ｎから放射する近距離映像光１１はハーフミラー（偏光分離素子）２でほとんど反射されることなく透過して観察者２０に観察される。一方、液晶表示素子１の遠距離表示領域１ｆから放射する遠距離映像光１２は全反射ミラー３で反射した後、ハーフミラー２でそのほとんどが反射して観察者２０に観察される。つまり、近距離映像光１１と遠距離映像光１２は共にほとんど損失することなく観察者２０に観察されるため明るい表示が得られる。

【０２０４】
また、遠距離表示領域１ｆは近距離表示領域１ｎと比べると、全反射ミラー３からハーフミラー２までの距離の分だけ観察者２０からの距離が遠くなる。このため、観察者２０からみて奥行きの異なる位置にある２つの表示領域の２次元像（映像）を重ねた状態で表示することができる。

【０２０５】
この際、観察者からみて奥行きの異なる位置にある観察対象（表示領域）は、実際には同一平面上に配置されているため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さい、薄型の表示装置が実現できる。

【０２０６】
尚、（実施例３）と（実施例４）を比べた場合、（実施例３）の表示装置では観察者は液晶表示素子の表示面を所定の観察角度θだけ傾いた状態で観察することになるが、（実施例４）の表示装置では液晶表示素子１の表示面を垂直方向、つまり、真正面から観察することになる。このため(実施例４)の表示装置では液晶表示素子の表示領域の形状は何ら補正しなくてもそのままの形状で観察者に観察される。また、液晶表示素子としてＩＰＳ方式やＶＡ方式などの広視野角な方式ではなく、ＴＮ方式などの比較的視野角の狭い方式を用いてもよい。

【０２０７】
ところで、本発明の表示装置において、表示素子の表示面を正面方向から観察する構成にするには（実施例４）で説明した表示装置のようにハーフミラーと全反射ミラーの反射面を液晶表示素子の表示面に対して傾けて配置するとよい。このとき、ハーフミラーと全反射ミラーの液晶表示素子の表示面に対する傾きの角度は４５°に限定されるものではない。図２０は本発明の表示装置の一例を示す概略断面図である。この表示装置は（実施例４）で説明した表示装置において、全反射ミラー３とハーフミラー（偏光分離素子）２の配置を変更したものである。

【０２０８】
ハーフミラー２の反射面は液晶表示素子１の表示面に対して、角度βだけ傾けて配置する。また、全反射ミラー３は観察者が近距離表示領域を観察する際に妨げとならず、その反射面がハーフミラー２の反射面に対して平行で、さらに遠距離表示領域１ｆから放射する遠距離映像光１２をハーフミラー２に向けて反射できる位置に配置する。

【０２０９】
この場合、ハーフミラー２の傾斜角度βが０°よりも大きければ、原理的には表示素子の表示面を正面方向から観察する表示装置を実現できる。ただし、角度βがちいさすぎる、または大きすぎる場合には表示装置の光学系の厚みの大部分を占める液晶表示素子の表示面から、ハーフミラーもしくは全反射ミラーの観察者側の端部までの距離が長くなり装置は大型化してしまう。

【０２１０】
このため、表示素子の表示面を正面方向から観察する表示装置を実現する場合には角度

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βの大きさは２０°～４５°とすることが望ましい。

【０２１１】

尚、表示素子の表示面を正面方向から観察するという制限をなくせば、（実施例１）から（実施例３）で説明した表示装置のようにハーフミラーを表示素子の表示面と平行、つまり、角度βが０°となるように配置しても薄型の表示装置を実現することができる。

【０２１２】

表示装置の光学系の厚さの大部分を占める液晶表示素子の表示面からハーフミラーもしくは全反射ミラーの観察者側の端部までの距離は、（実施例４）の表示装置のようにハーフミラーの傾き角度βが４５°の場合には、遠距離表示領域の表示領域分割方向における幅以上の距離が必要となる。

【０２１３】

これに対し、（実施例３）の表示装置では観察角度θを３０°よりも大きくすれば、液晶表示素子の表示面から全反射ミラー３までの距離が遠距離表示領域の表示領域分割方向における幅よりも短くできる。

【０２１４】

つまり、（実施例１）から（実施例３）の表示装置ようにハーフミラーと全反射ミラーを液晶表示素子の表示面と平行に配置する、即ち、ハーフミラーの傾き角度βを０°すると、観察角度θを３０°以上にすればより薄型の表示装置が実現できることになる。

【０２１５】

従って、本発明の表示装置ではハーフミラーの傾き角度βを０°～４５°の範囲から選択することが望ましい。

【０２１６】

このように本発明の表示装置ではハーフミラーと全反射ミラーの液晶表示素子の表示面に対する傾き角度を変えることで、それぞれ特徴の異なる表示装置が実現できる。このため、ハーフミラーと全反射ミラーの液晶表示素子の表示面に対する傾き角度は、表示装置の用途に合わせ、適当な構成を選択するようにすればよい。

【実施例５】

【０２１７】

次に本発明の表示装置の他の実施例について図２１を参照して説明する。本実施例は（実施例１）で図１を参照して説明した表示装置において、ハーフミラー２と全反射ミラー３の配置方法などを変えたものである。このため（実施例１）と同じ部分には同じ符号を付け詳細な説明は省略する。

【０２１８】

図２１は本発明の表示装置の一例を示す概略断面図である。本表示装置ではハーフミラー（偏光分離素子）２と全反射ミラー３を液晶表示素子１の表示面に対して４５°傾けた状態で配置する。つまり、ハーフミラー（偏光分離素子）２と全反射ミラー３に関しては（実施例４）で説明した表示装置と同じである。

【０２１９】

本実施例の表示装置が（実施例１）の表示装置と異なる特徴は観察者２０に観察される遠距離映像光１２は偏光変換素子４に対して垂直に入射していることである。

【０２２０】

ここで、偏光変換素子４は遠距離表示領域１ｆから放射する遠距離映像光１２を、その偏光軸が９０°回転した直線偏光に変換するものである。偏光変換素子４としては上記と同様、配向処理された２枚の透明基板の間に液晶層を封入し、液晶の分子長軸を２枚の透明基板間で９０°捩じった液晶セルを用いることができる。或いは１／２波長板として機能する位相差フィルム、または位相差フィルムの積層による捩じれ構造体を用いることができる。これらの偏光変換素子はいずれも光が垂直に入射する際に最も有効に機能するものである。本実施例の表示装置では遠距離表示領域１ｆから放射する遠距離映像光１２は偏光変換素子４に垂直に入射するので、偏光変換素子４を通過する遠距離映像光１２は高い効率で偏光軸が９０度回転した直線偏光に変換される。このためハーフミラー（偏光分

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離素子）２に入射する遠距離映像光１２は高い反射率で反射されて観察者２０に向かうため、より明るい映像を得ることができる。

【０２２１】

図２２は本発明の表示装置の一例を示す概略断面図である。この表示装置は図２１を参照して説明した表示装置において、偏光変換素子４の位置を液晶表示素子１と全反射ミラー３との間から、全反射ミラー３とハーフミラー（偏光分離素子）２の間に変更したものである。

【０２２２】

この場合は偏光変換素子４を液晶表示素子１の表示面に対して垂直に配置することで、遠距離表示領域１ｆから放射する遠距離映像光１２は全反射ミラー３で反射した後、偏光変換素子４に垂直に入射することになる。このため偏光変換素子４を通過する遠距離映像光１２は高い効率で偏光軸が９０度回転した直線偏光に変換される。従って、ハーフミラー（偏光分離素子）２に入射する遠距離映像光１２は高い反射率で反射され、観察者２０に向かうためより明るい映像を得ることができる。

【実施例６】

【０２２３】

次に本発明の表示装置の他の実施例について図２３を参照して説明する。本実施例は（実施例２）で図１５を参照して説明した表示装置において、ハーフミラー（偏光分離素子）２を液晶表示素子１の表示面の全面に配置し、２つの方向から観察するように構成したものである。このため、（実施例２）で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０２２４】

図２３は本発明の表示装置の一例を示す概略断面図である。この表示装置は二人の観察者２０Ａ，２０Ｂがそれぞれ異なる方向から表示装置を観察するように構成したもので、観察者２０Ａからみて奥行きが近い位置、つまり距離が短い位置にある表示領域が、観察者２０Ｂに対しては奥行きが遠い位置、つまり距離が長い位置にある表示領域となるものである。このため、液晶表示素子１の２つの表示領域をここでは表示領域１Ａ、及び表示領域１Ｂと呼ぶ。

【０２２５】

ハーフミラー（偏光分離素子）２は表示領域１Ａおよび表示領域１Ｂを完全に覆うように配置する。

【０２２６】

表示領域１Ａと表示領域１Ｂの形状は同じ形状とすることで、観察者２０Ａと観察者２０Ｂに同じ条件で映像が観察されるようになる。

【０２２７】

全反射ミラー３は表示領域１Ａから放射される映像光のうち、観察者２０Ａの方向へ向かう映像光１３をハーフミラー（偏光分離素子）２の表示領域１Ｂの前面に相当する領域に向けて反射し、表示領域１Ｂから放射される映像光のうち、観察者２０Ｂの方向へ向かう映像光１５をハーフミラー（偏光分離素子）２の表示領域１Ａの前面に相当する領域に向けて反射するものである。

【０２２８】

さらに、全反射ミラー３の形状と位置は観察者２０Ａから観察した際には表示領域１Ｂを通ることがなく、観察者２０Ｂから観察した際には表示領域１Ａを通ることがないものとする。

【０２２９】

偏光変換素子４ｂは全反射ミラー３の反射面と同じ形状とすれば良く、透明な接着剤などにより全反射ミラー３に貼り付ければよい。

【０２３０】

例えば、表示領域１Ａおよび表示領域１Ｂが表示領域分割方向に平行な方向の幅がＷ１，これと直交する方向の幅がＷ３の長方形であれば、全反射ミラー３及び偏光変換素子

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４ｂは表示領域分割方向に平行な方向の幅がＷ１、これと直交する方向の幅がＷ３の長方形とすればよい。ただし、位置ずれなどを考慮して、全反射ミラー３及び偏光変換素子４の大きさは観察者２０Ａから観察した際には表示領域１Ｂを通ることがなく、観察者20Ｂから観察した際には表示領域１Ａを通ることがない程度にやや大きくすることが現実的である。このとき全反射ミラー３の中心位置は表示領域１Ａと表示領域１Ｂとの間の中心位置１ｃの直上部と一致させるとよい。

【０２３１】

観察者２０Ａは液晶表示素子１の表示面を液晶表示素子１の表示面に垂直な方向に対し、表示領域分割方向と平行で、なおかつ表示領域１Ｂ側の方位（図では右側方向）へ、所定の角度（観察角度）θだけ傾いた方向から観察する。この場合、観察者２０Ｂは液晶表示素子１の表示面に垂直な方向に対し、表示領域分割方向と平行で、なおかつ表示領域１Ａ側の方位（図では左側方向）へ、所定の角度（観察角度）θだけ傾いた方向から観察することになる。観察者２０Ａに対する観察角度と観察者２０Ｂに対する観察角度は方位が異なるため，ここでは便宜上、観察者２０Ｂに対する観察角度はマイナスの符号をつけて－θと表記する。

【０２３２】

ここで、ハーフミラー（偏光分離素子）２の反射面と液晶表示素子１の表示面とが同じ平面に存在すると仮定し、ハーフミラー（偏光分離素子）２の反射面から全反射ミラー３の反射面までの最短距離をＨ、観察者２０Ａに対する観察角度をθ、表示領域１Ａと表示領域１Ｂのすき間の距離をＷ０とすると距離Ｈが上記数式（数１）を満足すれば、観察者２０Ａは表示領域１Ａの映像をハーフミラー（偏光分離素子）２を介して観察することができるようになる。また、観察者２０Ｂは表示領域１Ｂの映像をハーフミラー（偏光分離素子）２を介して観察することができるようになる。

【０２３３】

例えば、Ｗ０＋Ｗ１＝１００㎜，θ＝３５°とすると，Ｈ＝約７１．４㎜となるが、実際にはハーフミラー（偏光分離素子）２の反射面と液晶表示素子１の表示面は完全に同じ平面に存在するわけではないので、この位置のずれの分だけ距離Ｈはやや大きめにするとよい。

【０２３４】

本表示装置では表示領域１Ｂから放射する映像光のうち、観察角度θと平行な方向に放射する映像光１４はハーフミラー（偏光分離素子）２でほとんど反射されることなく透過して観察者２０Ａに観察される。一方、表示領域１Ａから放射する映像光のうち、観察角度θと平行な方向に放射する映像光１３は全反射ミラー３で反射してハーフミラー（偏光分離素子）２の表示領域１Ｂの前面に相当する領域に向かう。

【０２３５】

映像光１３は全反射ミラー３で反射してハーフミラー（偏光分離素子）２に向かう際、偏光変換素子４ｂを通過する。偏光変換素子４ｂは液晶表示素子１から放射し、全反射ミラー３で反射してハーフミラー（偏光分離素子）２に向かう映像光を、その偏光軸が90°回転した直線偏光に変換するものである。従って、表示領域１Ａから放射する映像光１３は全反射ミラー３で反射して、ハーフミラー（偏光分離素子）２に向かう際、偏光変換素子４ｂの作用により偏光軸が９０°回転した直線偏光に変換される。このため映像光１３はハーフミラー（偏光変換素子）２でその大部分が反射して観察者２０Ａに観察される。

【０２３６】

この際、表示領域１Ａは表示領域１Ｂと比べると，おおよそ表示領域１Ａから全反射ミラー３までの距離と全反射ミラー３からハーフミラー２までの距離の分だけ観察者２０Ａからの距離が遠くなる。このため，この表示装置では観察者２０Ａからみて奥行きの異なる位置にある２つの表示領域の２次元像（映像）を重ねた状態で表示することができる。

【０２３７】

一方、表示領域１Ａから放射する映像光のうち、観察角度－θと平行な方向に放射する映像光１６はハーフミラー（偏光分離素子）２でほとんど反射されることなく透過して観

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察者２０Ｂに観察される。また、表示領域１Ｂから放射する映像光のうち、観察角度－θと平行な方向に放射する映像光１５は全反射ミラー３で反射してハーフミラー（偏光分離素子）２の表示領域１Ａの前面に相当する領域に向かう。

【０２３８】

映像光１５は全反射ミラー３で反射してハーフミラー（偏光分離素子）２に向かう際、偏光変換素子４ｂの作用により偏光軸が９０°回転した直線偏光に変換される。このためハーフミラー（偏光分離素子）２に向かう映像光１５はその大部分が反射して観察者20Ｂに観察される。

【０２３９】

この際、表示領域１Ｂは表示領域１Ａと比べると、おおよそ表示領域１Ｂから全反射ミラー３までの距離と全反射ミラー３からハーフミラー（偏光分離素子）２までの距離の分だけ観察者２０Ｂからの距離が遠くなる。このため、この表示装置では観察者２０Ｂからみて奥行きの異なる位置にある２つの表示領域の２次元像（映像）を重ねた状態で表示することができる。

【０２４０】

本表示装置では観察者２０Ａに対しては、表示領域１Ａが距離の遠い位置に配置された観察対象となり、表示領域１Ｂが距離の近い位置に配置された観察対象となる。一方、観察者２０Ｂに対しては、表示領域１Ｂが距離の遠い位置に配置された観察対象となり、表示領域１Ａが距離の近い位置に配置された観察対象となる。

【０２４１】

つまり、液晶表示素子の一つの表示領域の映像が、この表示領域から近い位置の観察者に対しては、奥行きが近い位置、つまり距離が短い位置にある映像となり、この表示領域から遠い位置の観察者に対しては奥行きの遠い位置、つまり距離の長い位置にある映像となる。

【０２４２】

この表示装置は二人の異なる位置にいる観察者に対して、奥行きが異なる２つの２次元像（映像）を観察者の位置に応じた順序で重ねた状態で同時に表示することができる。このため、より臨場感の高い対戦型のゲーム機などの表示装置として好適な表示装置が実現できる。

【０２４３】

また、この表示装置では二人の異なる位置にいる観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面である。このため、部品点数が少なく、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の表示装置が実現できる。

【０２４４】

尚、偏光分離素子からなるハーフミラー２を用いることで表示領域１Ａおよび表示領域１Ｂから放射される映像光は共にほとんど損失することなく観察者２０Ａと観察者２０Ｂに観察されるため明るい表示が得られる。

【０２４５】

ここでは偏光変換素子４ｂを全反射ミラー３に貼り付ける場合を説明したが、偏光変換素子４ｂはハーフミラー（偏光分離素子）２に貼り付けても機能する。ただし、この場合は偏光変換素子を、表示領域１Ａおよび表示領域１Ｂを覆うハーフミラー（偏光変換素子）２と同じ大きさにする必要があるため、その面積は偏光変換素子を全反射ミラーに貼り付ける場合の倍以上となってしまう。

【０２４６】

あるいは偏光変換素子として（実施例１）で説明した１／２波長板や、旋光子を用いることができる。この場合、偏光変換素子はハーフミラー（偏光分離素子）２の表面のうち、液晶表示素子１の表示領域１Ａ、あるいは表示領域１Ｂのいずれか一方の前面に相当する領域に配置すればよい。

【実施例７】

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【０２４７】
次に本発明の表示装置の他の実施例について図２４を参照して説明する。この表示装置は（実施例３）で図１６を参照して説明した表示装置において、遠距離表示領域１Ｆの前面に新たにハーフミラーを配置して、２つの異なる方向から表示装置を観察するように構成したものである。このため（実施例３）で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０２４８】
図２４は本発明の表示装置の一例を示す概略断面図である。この表示装置は二人の観察者２０Ａ，２０Ｂがそれぞれ異なる方向から表示装置を観察するように構成したもので、観察者２０Ａからみて奥行きが近い位置、つまり距離が短い位置にある表示領域が、観察者２０Ｂに対しては奥行きが遠い位置、つまり距離が長い位置にある表示領域となるものである。このため、液晶表示素子１の２つの表示領域をここでは表示領域１Ａ、及び表示領域１Ｂと呼ぶ。

【０２４９】
表示領域１Ａと表示領域１Ｂの前面にはそれぞれ偏光分離素子からなるハーフミラー２Ａとハーフミラー２Ｂが配置される。

【０２５０】
図２５はハーフミラー２Ａ及びハーフミラー２Ｂと、液晶表示素子１を構成する偏光板の直線偏光の透過軸と、液晶層における液晶分子長軸の配向方向の一例を示す説明図である。図示の通り、液晶層２０３の配向方向２０３ａは表示領域分割方向と平行とする。また、偏光板２０４Ａの直線偏光の透過軸２０４Ａａは液晶層２０３の配向方向２０３ａと直交させ、偏光板２０４Ｂの直線偏光の透過軸２０４Ｂａは液晶層２０３の配向方向203aと平行とする。また、偏光板２０５Ａの直線偏光の透過軸２０５Ａａは液晶層２０３の配向方向２０３ａと平行とし、偏光板２０５Ｂの直線偏光の透過軸２０５Ｂａは液晶層203の配向方向２０３ａと直交させる。

【０２５１】
また、ハーフミラー２Ａの直線偏光の透過軸２Ａａは偏光板２０４Ａの直線偏光の透過軸２０４Ａａと平行とし、ハーフミラー２Ｂの直線偏光の透過軸２Ｂａは偏光板２０４Ｂの直線偏光の透過軸２０４Ｂａと平行とする。

【０２５２】
上記構成とすることで表示領域１Ａから放射される映像光と表示領域１Ｂから放射される映像光は互い偏光軸が直交した直線偏光となる。また、表示領域１Ａ及び表示領域１Ｂから放射される映像光はそれぞれハーフミラー２Ａ及びハーフミラー２Ｂをほとんど損失することなく透過する。

【０２５３】
全反射ミラー３や表示領域１Ａと表示領域１Ｂの形状については（実施例６）で説明した表示装置と同じ思想を適用する。つまり、全反射ミラー３は表示領域１Ａから放射する映像光のうち、観察者２０Ａの方向へ向けて放射する映像光１３をハーフミラー２Ｂに向けて反射し、表示領域１Ｂから放射される映像光のうち、観察者２０Ｂの方向へ向けて放射する映像光１５をハーフミラー２Ａに向けて反射するものである。さらに、全反射ミラー３の形状と位置は観察者２０Ａから観察した際には表示領域１Ｂを遮ることがなく、観察者２０Ｂから観察した際には表示領域１Ａを遮ることがないものとする。また、表示領域１Ａと表示領域１Ｂの形状は同一の形状とすることで、観察者２０Ａと観察者２０Ｂには同じ条件で映像が観察されるようになる。

【０２５４】
尚、ハーフミラー２Ａおよびハーフミラー２Ｂの形状はそれぞれ表示領域１Ａと表示領域１Ｂを欠くことなく覆うことができる形状とする。つまり、ハーフミラー２Ａおよびハーフミラー２Ｂの形状はそれぞれ表示領域１Ａと表示領域１Ｂと同じ形状、或いは位置ずれなどを考慮して表示領域１Ａ及び表示領域１Ｂよりもやや大きな形状とする。

【０２５５】

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ここで、（実施例６）で説明した表示装置と同様に、観察者２０Ａは液晶表示素子１をその表示面に垂直な方向に対して観察角度θだけ傾いた方向から観察し、観察者２０Ｂは液晶表示素子１をその表示面に垂直な方向に対して観察角度－θだけ傾いた方向から観察する場合を想定する。

【０２５６】

この場合、表示領域１Ｂから放射する映像光のうち、観察角度θと平行な方向に放射する映像光１４はハーフミラー（偏光分離素子）２Ｂを透過して観察者２０Ａに観察される。一方、表示領域１Ａから放射する映像光のうち、観察角度θと平行な方向に放射する映像光１３はハーフミラー（偏光分離素子）２Ａを透過して、全反射ミラー３で反射してハーフミラー（偏光分離素子）２Ｂに向かう。映像光１３は全反射ミラー３での反射の際、その偏光状態が維持されるため、ハーフミラー（偏光分離素子）２Ｂでその大部分が反射されて観察者２０Ａに観察される。

【０２５７】

この際、表示領域１Ａは表示領域１Ｂに対して、おおよそ表示領域１Ａから全反射ミラー３までの距離と全反射ミラー３からハーフミラー（偏光分離素子）２Ｂまでの距離の分だけ観察者２０Ａからの距離が遠くなる。このため、観察者２０Ａには奥行きの異なる位置にある２つの表示領域に表示される２次元像（映像）が重った状態で観察される。

【０２５８】

一方、表示領域１Ａから放射する映像光のうち、観察角度－θと平行な方向に放射する映像光１６はハーフミラー（偏光分離素子）２Ａを透過して観察者２０Ｂに観察される。また、表示領域１Ｂから放射する映像光のうち、観察角度－θと平行な方向に放射する映像光１５はハーフミラー（偏光分離素子）２Ｂを透過して、全反射ミラー３で反射してハーフミラー（偏光分離素子）２Ａに向かう。映像光１５は全反射ミラー３での反射の際、その偏光状態が維持されるため、ハーフミラー（偏光分離素子）２Ａでその大部分が反射されて観察者２０Ｂに観察される。

【０２５９】

この際、表示領域１Ｂは表示領域１Ａと比べると、おおよそ表示領域１Ｂから全反射ミラー３までの距離と全反射ミラー３からハーフミラー（偏光分離素子）２Ａまでの距離の分だけ観察者２０Ｂからの距離が遠くなる。このため、観察者２０Ａには奥行きの異なる位置にある２つの表示領域に表示される２次元像（映像）が重った状態で観察される。

【０２６０】

つまり、この表示装置では観察者２０Ａに対しては、表示領域１Ａが距離の遠い位置にある観察対象となり、表示領域１Ｂが距離の近い位置にある観察対象となる。一方、観察者２０Ｂに対しては、表示領域１Ｂが距離の遠い位置にある観察対象となり、表示領域１Ａが距離の近い位置にある観察対象となる。

【０２６１】

この表示装置は二人の異なる位置にいる観察者に対して、奥行きが異なる２つの２次元像（映像）を観察者の位置に応じた順序で重ねた状態で同時に表示することができる。このため、より臨場感の高い対戦型のゲーム機などの表示装置として好適な表示装置が実現できる。

【０２６２】

また、この表示装置では二人の異なる位置にいる観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面である。このため、部品点数が少なく、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の表示装置が実現できる。

【０２６３】

尚、ハーフミラー２Ａおよびハーフミラー２Ｂとして偏光分離素子を用いることで表示領域１Ａおよび表示領域１Ｂから放射される映像光は共にほとんど損失することなく観察者２０Ａと観察者２０Ｂに観察されるため明るい表示が得られる。

【０２６４】

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本表示装置では特に（実施例６）で説明した表示装置と異なり、偏光変換素子を必要としないため部材を減らすことができる。また、偏光変換素子の性能に起因する映像の明るさ低下の懸念がない。

【実施例８】

【０２６５】

次に本発明の表示装置の他の実施例について説明する。ここで説明する表示装置は（実施例３）で図１６を参照して説明した表示装置において、液晶表示素子１を小型化し、液晶表示素子１の遠距離表示領域１ｆに相当する部分に別の表示素子を配置したものである。このため上記実施例で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０２６６】

図２６は本発明の表示装置の一例を示す概略斜視図である。この表示装置は観察対象として液晶表示素子１のほかにスロットマシンなどで使用される外周面に複数の絵柄を配置したリールを回転させることで絵柄を切り替える表示素子（以下、リール表示素子とよぶ）５を配置したものである。

【０２６７】

リール表示素子５は図示しない照明装置によって照明されるリールの外周面に配置した絵柄が表示面となる。リール表示素子５の表示面は観察者２０からみて奥行きが遠い位置、つまり距離が長い位置に配置する観察対象であり、液晶表示素子１の表示面は観察者２０からみて奥行きが近い位置、つまり、距離が短い位置に配置する観察対象となる。

【０２６８】

この場合、液晶表示素子１から放射する映像光１７はハーフミラー（偏光分離素子）２をほとんど損失することなく透過して観察者２０に観察される。また、リール表示素子５から放射する映像光１８は全反射ミラー３で反射してハーフミラー（偏光分離素子）２に至る。リール表示素子５から放射する映像光は一般に無偏光であるため、ハーフミラー（偏光分離素子）２に入射する映像光１８はその約半分がハーフミラー（偏光分離素子）２で反射して観察者２０に観察される。

【０２６９】

つまり、本表示装置ではリール表示素子５からの映像光１８はハーフミラー２においてその約半分が損失するが、液晶表示素子１からの映像光１７はハーフミラーとして偏光分離素子を用いることでほとんど損失することなく観察者２０に観察されるため明るい映像を表示することができる。

【０２７０】

この場合、リール表示素子５の表示面は液晶表示素子１の表示面と比べると、おおよそリール表示素子５の表示面から全反射ミラー３までの距離と全反射ミラー３からハーフミラー（偏光分離素子）２までの距離の分だけ観察者２０からの距離が遠くなる。このため、観察者２０には奥行きの異なる位置にある２つの表示面が重なった状態で観察される。

【０２７１】

つまり、本表示装置では、リール表示素子５の表示面の手前に液晶表示素子１の表示面の映像が浮かんでみえることになる。

【０２７２】

このような表示はパチンコやスロットマシンなどの遊技機において、演出効果を高めるために極めて有効である。

【０２７３】

なお、このような表示はリール表示素子の前面に液晶表示パネルを配置することで実現することが可能である。この場合、リール表示素子の表示面からの光は液晶表示パネルを透過する必要があるが、液晶表示パネルの透過率は通常１０％に満たないため、９０％以上の光が損失することになる。

【０２７４】

これに対し、本実施例の表示装置ではリール表示素子の表示面からの光はハーフミラー

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で約５０％損失するが、液晶表示パネルを透過する必要がないのでより明るい映像を得ることができる。

【０２７５】

さらに本発明の表示装置では観察者からみて２つの異なる奥行き（距離）にある観察対象がほぼ同一平面上に配置されるため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく、薄型の表示装置が実現できる。

【実施例９】

【０２７６】

次に本発明の表示装置の他の実施例について説明する。ここで説明する表示装置は（実施例３）で図１６を参照して説明した表示装置において、液晶表示素子１を小型化し、液晶表示素子１の近距離表示領域１ｎに相当する部分に別の表示素子を配置したものである。このため上記実施例で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０２７７】

図２７は本発明の表示装置の一例を示す概略斜視図である。この表示装置は観察対象として液晶表示素子１のほかにスロットマシンなどで使用されるリール表示素子５を配置したものである。

【０２７８】

リール表示素子５の表示面は観察者２０からみて奥行きが近い位置、つまり距離が短い位置に配置する観察対象であり、液晶表示素子１の表示面は観察者２０からみて奥行きが遠い位置、つまり、距離が長い位置に配置する観察対象となる。

【０２７９】

また、リール表示素子５の観察者２０側の表示面上には偏光分離素子からなるハーフミラー２を配置する。

【０２８０】

この場合、リール表示素子５の表示面から放射する映像光１７は非偏光であるため、その約５０％がハーフミラー（偏光分離素子）２を透過して観察者２０に観察される。また、液晶表示素子１から放射する映像光１８は全反射ミラー３で反射してハーフミラー（偏光分離素子）２に至る。

【０２８１】

液晶表示素子１から放射される映像光は直線偏光であり、ハーフミラー（偏光分離素子）２に入射する映像光１８はほとんど損失することなく、その大部分が反射して観察者２０に観察される。

【０２８２】

つまり、本表示装置ではリール表示素子５からの映像光１７はハーフミラー（偏光分離素子）２においてその約半分が損失するが、液晶表示素子１からの映像光１８はハーフミラーとして偏光分離素子を用いることでほとんど損失することなく観察者２０に観察されるため明るい映像を表示することができる。

【０２８３】

この際、液晶表示素子１の表示面はリール表示素子５の表示面と比べると、液晶表示素子１の表示面から全反射ミラー３までの距離と全反射ミラー３からハーフミラー（偏光分離素子）２までの距離の分だけ観察者２０からの距離が遠くなる。このため、観察者２０には奥行きの異なる位置にある２つの表示面が重なった状態で観察される。

【０２８４】

つまり，本表示装置では、リール表示素子５の表示面の背面に液晶表示素子１の表示面の映像がみえることになる。

【０２８５】

このような表示はパチンコやスロットマシンなどの遊技機において、演出効果を高めるのに有効である。

【実施例１０】

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【０２８６】
次に本発明の表示装置の他の実施例について説明する。ここで説明する表示装置は（実施例４）で図１９を参照して説明した表示装置において、液晶表示素子１を小型化し、液晶表示素子１の遠距離表示領域１ｆに相当する部分に別の表示素子を配置したものである。このため上記実施例で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０２８７】
図２８は本発明の表示装置の一例を示す概略断面図である。この表示装置は観察対象として液晶表示素子１のほかにスロットマシンなどで使用される外周面に複数の絵柄を配置したリールを回転させることで絵柄を切り替える表示素子（以下、リール表示素子とよぶ）５を配置したものである。

【０２８８】
リール表示素子５は図示しない照明装置によって照明されるリールの外周面に配置した絵柄が表示面となる。リール表示素子５の表示面は観察者２０からみて奥行きが遠い位置、つまり距離が長い位置に配置する観察対象であり、液晶表示素子１の表示面は観察者２０からみて奥行きが近い位置、つまり、距離が短い位置に配置する観察対象となる。

【０２８９】
この場合、液晶表示素子１から放射する映像光１７はハーフミラー（偏光分離素子）２をほとんど損失することなく透過して観察者２０に観察される。また、リール表示素子５から放射する映像光１８は全反射ミラー３で反射してハーフミラー（偏光分離素子）２に至る。

【０２９０】
リール表示素子５から放射する映像光は一般に無偏光であるため、ハーフミラー（偏光分離素子）２に入射する映像光１８はその約半分がハーフミラー（偏光分離素子）２で反射して観察者２０に観察される。

【０２９１】
つまり、本表示装置ではリール表示素子５からの映像光１８はハーフミラー２においてその約半分が損失するが、液晶表示素子１からの映像光１７はハーフミラーとして偏光分離素子を用いることでほとんど損失することなく観察者２０に観察されるため明るい映像を表示することができる。

【０２９２】
この場合、リール表示素子５の表示面は液晶表示素子１の表示面と比べると、おおよそ全反射ミラー３からハーフミラー２までの距離の分だけ観察者２０からの距離が遠くなる。このため、観察者２０には奥行きの異なる位置にある２つの表示面が重なった状態で観察される。

【０２９３】
つまり、本表示装置では、リール表示素子５の表示面の手前に液晶表示素子１の表示面の映像が浮かんでみえることになる。

【０２９４】
このような表示はパチンコやスロットマシンなどの遊技機において、演出効果を高めるために極めて有効である。

【０２９５】
なお、このような表示はリール表示素子の前面に液晶表示パネルを配置することで実現することが可能である。この場合、リール表示素子の表示面からの光は液晶表示パネルを透過する必要があるが、液晶表示パネルの透過率は通常１０％に満たないため，９０％以上の光が損失することになる。

【０２９６】
これに対し、本実施例の表示装置ではリール表示素子の表示面からの光はハーフミラーで約５０％損失するが、液晶表示パネルを透過する必要がないのでより明るい映像を得ることができる。

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【０２９７】
さらに本発明の表示装置では観察者からみて２つの異なる奥行き（距離）にある観察対象がほぼ同一平面上に配置されるため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく、薄型の表示装置が実現できる。
【実施例１１】
【０２９８】
次に本発明の表示装置の他の実施例について説明する。ここで説明する表示装置は（実施例１）で図１から図３を参照して説明した表示装置において、液晶表示素子１の表示領域を３つの表示領域に分割し、新たに別のハーフミラーを配置したものである。このため上記実施例で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。
【０２９９】
図２９は本発明の表示装置の一例を示す概略断面図である。この表示装置は液晶表示素子１の表示面を３つの表示領域に分割したもので、これらの表示領域は観察者２０からみて３つの奥行き（距離）が異なる位置にある観察対象に相当するものである。このため、ここでは観察者からの奥行きが最も遠い位置、つまり、観察者からみて最も距離が長い位置にある観察対象に相当する表示領域を遠距離表示領域１ｆと呼び、観察者からの奥行きが最も近い位置、つまり、観察者からみて最も距離が短い位置にある観察対象に相当する表示領域を近距離表示領域１ｎと呼び、観察者からの奥行きが中間の位置、つまり、観察者からみた距離が中間となる位置にある観察対象に相当する表示領域を中距離表示領域１ｍと呼ぶ。
【０３００】
また、液晶表示素子１の遠距離表示領域１ｆの前面には偏光変換素子４を配置し、中距離表示領域１ｍの前面には偏光分離素子からなるハーフミラー２を配置し、近距離表示領域１ｎの前面にはハーフミラー６を配置する。
【０３０１】
液晶表示素子１の３つの表示領域１ｆ，１ｍ，１ｎは観察者２０からみて３つの異なる奥行き（距離）にある観察対象に相当するものである。このため本表示装置では観察者からみて奥行きが異なる位置にある観察対象と同じ数の３つの反射鏡，すなわち全反射ミラー３，ハーフミラー（偏光分離素子）２，ハーフミラー６の３つの反射鏡を備える。
【０３０２】
全反射ミラー３は液晶表示素子１の遠距離表示領域１ｆから放射する映像光１９ｆをハーフミラー（偏光分離素子）２に向けて反射する機能を有するものであり，さらに中距離表示領域１ｍから放射する映像光１９ｍをハーフミラー６に向けて反射する機能を有するものである。
【０３０３】
全反射ミラー３としてはガラスやプラスチックなどからなる平坦で、光学的に等方な透明基板に銀やアルミニウムなどの反射率の高い金属膜により反射面を形成したものや、誘電体多層膜により反射面を形成したものを用いる。ここでは全反射ミラー３はこれに入射する映像光１９ｆ及び映像光１９ｍに対して反射率が高いものを用いることが明るい映像を得るために望ましい。
【０３０４】
全反射ミラー３は観察者２０からみて近距離表示領域１ｎを遮らず，なおかつ遠距離表示領域１ｆと中距離映像表示領域１ｍと近距離表示領域１ｎとがハーフミラー６を介して重なって見える位置に配置する。
【０３０５】
また，全反射ミラー３はその反射面の大きさが少なくとも液晶表示素子１の遠距離表示領域１ｆから中距離映像表示領域１ｍまでの領域の大きさ以上の大きさであればよく、高い合わせ精度で組み立てられる場合には遠距離表示領域１ｆから中距離映像表示領域１ｍまでの領域と同じ大きさにすれば部材面積を小さくできる。ただし、全反射ミラー３の反射面の大きさは合わせずれの大きさを考慮して、遠距離表示領域１ｆから中距離映像表示

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領域１ｍまでの領域よりもやや大きくすることが現実的である。

【０３０６】

本表示装置では、ハーフミラー（偏光分離素子）２は液晶表示素子１の中距離表示領域１ｍからの映像光１９ｍ（以下、中距離映像光１９ｍと呼ぶ）と遠距離表示領域１ｆからの映像光１９ｆ（以下、遠距離映像光１９ｆとよぶ）を合成する機能を有するものである。また、ハーフミラー６は中距離映像光１９ｍ及び遠距離映像光１９ｆを、近距離表示領域１ｎからの映像光１９ｎ（以下、近距離映像光１９ｎとよぶ）と合成する機能を有するものである。

【０３０７】

液晶表示素子１は映像光として直線偏光を放射することから、ハーフミラー（偏光分離素子）２は液晶表示素子１から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光は反射する偏光分離素子を用いることが明るい映像を得るために望ましい。

【０３０８】

一方、ハーフミラー６としては、異なる２方向から入射する光をその偏光状態によらず透過、あるいは反射することで一方向に合成する機能を有するものを用いる。このようなハーフミラーとしてはガラスやプラスチックなどの透明で平坦な基板に銀やアルミニウムなどの反射率の高い金属薄膜により、入射する光の一部が透過し、一部が反射するような反射面を形成したものや、誘電体多層膜によって入射する光の半分程度が透過し、半分程度が反射する反射面を形成したものを用いることができる。

【０３０９】

遠距離表示領域１ｆの前面には偏光変換素子４を配置する。偏光変換素子は遠距離表示領域１ｆから放射される映像光１９ｆを、その偏光軸が９０°回転した直線偏光に変換するものである。つまり、偏光変換素子４としてはこれに入射する光の直線偏光の偏光軸を９０°回転させる旋光子や１／２波長板を用いればよい。

【０３１０】

この場合、偏光変換素子４の大きさは観察者２０からみて遠距離表示領域１ｆが覆われるのに必要最低限の大きさであれば良い。偏光変換素子４が液晶表示素子１の表示面と平行に配置され、高い位置精度で組み立てられる場合には遠距離表示領域１ｆと同じ大きさにすれば部材面積が必要最小限となり低コスト化につながる。ただし、偏光変換素子４の大きさは合わせずれを考慮して、遠距離表示領域１ｆの大きさよりもやや大きくすることが現実的である。

【０３１１】

偏光変換素子４としては上記実施例と同様、配向処理された２枚の透明基板の間に液晶層を封入し、液晶の分子長軸を２枚の透明基板間で９０°捩じった液晶セルや位相差フィルムからなる１／２波長板や、位相差フィルムを積層することで実現する捩じれ構造体を用いることができる。尚、これらの偏光変換素子は光が垂直に入射する際に最も有効に機能するものである。従って、偏光変換素子４は遠距離映像光１９ｆが垂直に入射するように液晶表示素子１の表示面に対して傾けて配置するようにしてもよい。

【０３１２】

本表示装置では液晶表示素子１の遠距離表示領域１ｆから放射する映像光１９ｆは偏光変換素子４を通過する際、偏光軸が９０度回転した直線偏光となり、全反射ミラー３で反射した後、ハーフミラー（偏光分離素子）２でほとんど損失することなく反射して、再び全反射ミラー３に向かう。

【０３１３】

また、中距離表示領域１ｍから放射する映像光１９ｍはハーフミラー（偏光分離素子）２でほとんど反射することなく透過して全反射ミラー３へ向かう。

【０３１４】

つまり、遠距離表示領域１ｆの前面に偏光変換素子４を配置し、ハーフミラー２として偏光分離素子を用いることで遠距離映像光１９ｆと中距離映像光１９ｍは共にほとんど損失することなく合成されて全反射ミラー３へ向かう。

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【０３１５】
全反射ミラー３へ向かった遠距離映像光１９ｆと中距離映像光１９ｍは全反射ミラー３で反射して、ハーフミラー６へ向かい、さらにハーフミラー６でその一部が反射して観察者２０に観察される。
【０３１６】
一方、近距離表示領域１ｎから放射する映像光１９ｎはその一部がハーフミラー６を透過して観察者２０に観察される。
【０３１７】
この際、中距離表示領域１ｍは近距離表示領域１ｎと比べると、おおよそ中距離表示領域１から全反射ミラー３までの距離と全反射ミラー３からハーフミラー６までの距離の分だけ観察者２０からみた距離が遠くなる。また、遠距離表示領域１ｆは中距離表示領域１ｍと比べると、おおよそ遠距離表示領域１ｆから全反射ミラー３までの距離と全反射ミラー３からハーフミラー（偏光分離素子）２までの距離の分だけ観察者２０からみた距離が遠くなる。
【０３１８】
このため、観察者２０からみて奥行きの異なる３つの位置にある表示領域に表示される２次元像（映像）が重なった状態で観察される。つまり、本表示装置は観察者からみて奥行きが異なる位置にある３つの観察対象を重ねた状態で表示することができる。従って、観察者により深い奥行き感を感知させることができる表示装置を実現できる。
【０３１９】
また、本表示装置は観察者からみて奥行きの異なる位置にある複数の観察対象が、実際には同一平面上に配置しているため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さく、薄型の表示装置が実現できる。
【０３２０】
特に本実施例では３つの観察対象を単一の表示素子の表示面で実現しているので部品点数を少なくすることができる。
【０３２１】
また、ハーフミラー２として偏光分離素子を用いることで遠距離映像光１９ｆと中距離映像光１９ｍはほとんど損失なく合成されるためハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。
【０３２２】
尚、本発明の表示装置は奥行きの異なる位置にある観察対象が４つ以上であってもよい。この場合、液晶表示素子１の表示領域を４つ以上に分割し、観察対象、つまり分割した表示領域と同じ数の反射鏡を配置する。この際、反射鏡の１つは全反射ミラーとし、液晶表示素子の前面であって、その表示面から一定の距離だけ離れた位置に表示面と平行に配置する。
【０３２３】
また、残りの反射鏡はハーフミラーとし、観察者からみて最も奥行きの遠い位置、つまり、観察者からみて最も距離が長い位置に配置する観察対象に相当する表示領域を除く表示領域の前面に表示面と平行となるように配置する。
【０３２４】
より明るい映像を得たい場合には、観察者からみて最も距離が長い位置に配置する観察対象に相当する表示領域とは別の表示領域の前面に配置するハーフミラーのひとつを偏光分離素子とする。
【０３２５】
偏光分離素子は液晶表示素子から放射する直線偏光は反射し、これと偏光軸が直交する直線偏光は透過するものとし、この偏光分離素子が前面に配置される表示領域とこの偏光分離素子の間には偏光変換素子を配置する。
【０３２６】
この場合、偏光分離素子が前面に配置された表示領域から放射する映像光と、この表示

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領域よりも観察者からみて奥行きが遠い位置にある観察対象に相当する表示領域からの映像光は偏光分離素子でほとんど損失することなく合成される。このため、ハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。

【０３２７】

この他の構成でより明るい映像を得るには観察者からみて最も奥行きの遠い位置、つまり、観察者からみて最も距離が長い位置にある観察対象に相当する表示領域の前面に偏光変換素子を配置する。さらに、観察者からみて２番目に奥行きの遠い位置、つまり、観察者からみて２番目に距離が長い位置にある観察対象に相当する表示領域の前面に配置するハーフミラーを偏光分離素子とする。この偏光分離素子は液晶表示素子から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光は反射するものとする。

【０３２８】

この場合、観察者からみて最も奥行きの遠い位置にある観察対象に相当する表示領域から放射される映像光と、観察者からみて２番目に奥行きの遠い位置にある観察対象に相当する表示領域から放射される映像光は共に偏光分離素子においてほとんど損失することなく合成される。このため、ハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。

【０３２９】

尚、液晶表示素子の各表示領域に配置するハーフミラーは、ハーフミラーとして偏光分離素子を用いないものに関しては隣り合う表示領域の前面に配置するハーフミラーどうしを一体化してもよい。この場合、ハーフミラー一つの面積は大きくなるが数は少なくなる。つまり、本発明の表示装置では観察者からみて奥行きの異なる位置にある観察対象と同じ数の反射鏡を配置するが、複数のハーフミラーを一体化することで見かけ上，反射鏡の数は減らすことができる。このため，反射鏡の数は部品点数を少なくするという観点からは観察対象の数と同じ数以下で、なおかつ２枚以上とすることが現実的である。

【実施例１２】

【０３３０】

次に本発明の表示装置の他の実施例について説明する。ここで説明する表示装置は（実施例５）で図２１を参照して説明した表示装置において、液晶表示素子１の表示領域を３つの表示領域に分割し、新たに別のハーフミラーを配置したものである。このため上記実施例で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０３３１】

図３０は本発明の表示装置の一例を示す概略断面図である。この表示装置は液晶表示素子１の表示面を便宜上３つの表示領域に分割したもので、これらの表示領域は観察者２０からみて奥行き（距離）の異なる３つの位置にある観察対象に相当するものである。このため、ここでは観察者からの奥行きが最も遠い位置、つまり、観察者からみて最も距離が長い位置にある観察対象に相当する表示領域を遠距離表示領域１ｆと呼び、観察者からの奥行きが最も近い位置，つまり、観察者からみて最も距離が短い位置にある観察対象に相当する表示領域を近距離表示領域１ｎと呼び、観察者からの奥行きが中間の位置、つまり、観察者からみた距離が中間となる位置にある観察対象に相当する表示領域を中距離表示領域１ｍと呼ぶ。

【０３３２】

液晶表示素子１の遠距離表示領域１ｆの前面には全反射ミラー３を液晶表示素子１の表示面に対して４５°傾けた状態で配置する。また、中距離表示領域１ｍの前面にはハーフミラー（偏光分離素子）２を、近距離表示領域１ｎの前面にはハーフミラー６を液晶表示素子１の表示面に対して４５°傾けた状態で配置する。さらに、液晶表示素子１の遠距離表示領域１ｆの前面にはこれを覆うように偏光変換素子４を配置する。

【０３３３】

液晶表示素子１の３つの表示領域１ｆ，１ｍ，１ｎは観察者２０からみて奥行き（距離）の異なる３つの位置にある観察対象に相当するものである。このため本表示装置では奥行

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きの異なる観察対象と同数の３つの反射鏡、すなわち全反射ミラー３，ハーフミラー（偏光分離素子）２，ハーフミラー６の３つの反射鏡を備える。

【０３３４】

全反射ミラー３は液晶表示素子１の遠距離表示領域１ｆから放射する映像光１９ｆをハーフミラー（偏光分離素子）２に向けて反射する機能を有するものである。全反射ミラー３としてはガラスやプラスチックなどの平坦で光学的に等方な透明基板に銀やアルミニウムなどの反射率の高い金属膜により反射面を形成したものや、誘電体多層膜により反射面を形成したものを用いる。ここでは全反射ミラー３はこれに入射する映像光１９ｆに対して反射率が高いものを用いることが明るい映像を得るために望ましい。

【０３３５】

ハーフミラー２は液晶表示素子１の中距離表示領域１ｍからの映像光１９ｍ（以下、中距離映像光１９ｍと呼ぶ）と遠距離表示領域１ｆからの映像光１９ｆ（以下、遠距離映像光１９ｆとよぶ）を合成する機能を有するものである。また、ハーフミラー６は中距離映像光１９ｍ及び遠距離映像光１９ｆを、近距離表示領域１ｎからの映像光１９ｎ（以下、近距離映像光１９ｎとよぶ）と合成する機能を有するものである。

【０３３６】

液晶表示素子１は映像光として直線偏光を放射する。ここでは液晶表示素子１の遠距離表示領域１ｆの前面にこれを覆うように偏光変換素子４を配置する。また、ハーフミラー２としては液晶表示素子１から放射する直線偏光は反射し、これと偏光軸が直交する直線偏光は透過する偏光分離素子を用いる。

【０３３７】

ハーフミラー６としては、異なる２方向から入射する光をその偏光状態によらず透過、あるいは反射することで一方向に合成する機能を有するものを用いる。このようなハーフミラーとしてはガラスやプラスチックなどの透明で平坦な基板に銀やアルミニウムなどの反射率の高い金属薄膜によって入射する光の一部が透過し、一部が反射するような反射面を形成したものや、誘電体多層膜によって入射する光の半分程度が透過し、半分程度が反射する反射面を形成したものを用いることができる。

【０３３８】

偏光変換素子４は液晶表示素子１の表示面から放射される映像光をその偏光軸が９０°回転した直線偏光に変換するものである。

【０３３９】

偏光変換素子４としては配向処理された２枚の透明基板の間に液晶層を封入し、液晶の分子長軸を２枚の透明基板間で９０°捩じった液晶セルや位相差フィルムからなる１／２波長板や、位相差フィルムを積層することで実現する捩じれ構造体を用いることができる。尚、これらの偏光変換素子は光が垂直に入射する際に最も有効に機能するものである。このため、偏光変換素子４は液晶表示素子１の表示面に対して平行に配置して、液晶表示素子１から放射する遠距離映像光１９ｆが垂直に入射するようにする。

【０３４０】

偏光変換素子４の大きさは遠距離表示領域１ｆが覆われるのに必要最低限の大きさであれば良く、高い位置精度で組み立てられる場合には遠距離表示領域１ｆと同じ大きさにすれば部材面積が必要最小限となる。ただし、偏光変換素子の大きさは合わせずれを考慮して、遠距離表示領域１ｆの大きさよりもやや大きくすることが現実的である。

【０３４１】

本実施例の表示装置では液晶表示素子１の遠距離表示領域１ｆから放射する遠距離映像光１９ｆは偏光変換素子４を通過する際、偏光軸が９０度回転した直線偏光となり、全反射ミラー３で反射した後、ハーフミラー（偏光分離素子）２でほとんど反射することなく大部分が透過して、ハーフミラー６に向かう。

【０３４２】

また、中距離表示領域１ｍから放射する中距離映像光１９ｍはハーフミラー（偏光分離素子）２をほとんど透過することなく、その大部分が反射してハーフミラー６へ向かう。

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【０３４３】
つまり、遠距離表示領域１ｆの前面に偏光変換素子を配置し、ハーフミラー２として偏光分離素子を用いることで遠距離映像光１９ｆと中距離映像光１９ｍは共にほとんど損失することなく合成されてハーフミラー６へ向かう。
【０３４４】
ハーフミラー６へ向かった遠距離映像光１９ｆと中距離映像光１９ｍはハーフミラー６でその一部が反射して観察者２０に観察される。
【０３４５】
一方、近距離表示領域１ｎから放射する近距離映像光１９ｎはその一部がハーフミラー６を透過して観察者２０に観察される。
【０３４６】
この際、中距離表示領域１ｍは近距離表示領域１ｎと比べると、ハーフミラー（偏光分離素子）２からハーフミラー６までの距離の分だけ観察者２０からみた距離が遠くなる。また、遠距離表示領域１ｆは中距離表示領域１ｍと比べると、全反射ミラー３からハーフミラー（偏光分離素子）２までの距離の分だけ観察者２０からみた距離が遠くなる。
【０３４７】
このため、観察者２０からみて奥行きの異なる３つの位置にある表示領域に表示される２次元像（映像）が重なった状態で観察される。つまり、本表示装置は観察者からみて奥行きが異なる位置にある３つの観察対象を重ねた状態で表示することができる。従って、観察者により深い奥行き感を感知させることができる表示装置を実現できる。
【０３４８】
尚、本実施例の表示装置では特に液晶表示素子の表示面を垂直方向から、つまり正面方向から観察できる。このため観察者は液晶表示素子の表示面に表示される映像をそのままの形状で観察することができる。
【０３４９】
また、本表示装置は観察者からみて奥行きの異なる位置にある観察対象は、実際には同一平面上に配置しているため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さく、薄型の表示装置が実現できる。
【０３５０】
特に本実施例では３つの観察対象を単一の表示素子の表示面で実現しているので部品点数を少なくすることができる。
【０３５１】
また、ハーフミラー２として偏光分離素子を用いることで遠距離映像光１９ｆと中距離映像光１９ｍはほとんど損失なく合成されるためハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。
【０３５２】
尚、もしも、液晶表示素子１の中距離表示領域１ｍの前面にこれを覆うように偏光変換素子４を配置する場合には、ハーフミラー２としては液晶表示素子１から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光は反射する偏光分離素子を用いることが明るい映像を得るために望ましいことは本発明のこれまでの説明から明らかだろう。
【０３５３】
尚、本発明の表示装置ではハーフミラー等の反射鏡を液晶表示素子の表示面に対して傾けて配置する場合にも、観察者からみて奥行きの異なる位置にある観察対象を４つ以上としてもよい。
【０３５４】
ここでは以下、液晶表示素子１の表示領域を４つ以上に分割し、表示領域の分割数と同じ数の反射鏡を各表示領域の前面に液晶表示素子の表示面に対して４５°傾けた状態で配置する場合について説明する。
【０３５５】
この場合、反射鏡は観察者からみて最も奥行きの遠い位置、つまり、観察者からみて最

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も距離が長い位置にある観察対象に相当する表示領域の前面に配置するものを除きハーフミラーとする。また、観察者からみて最も奥行きの遠い位置にある観察対象に相当する表示領域の前面に配置する反射鏡は全反射ミラーもしくは少なくともこれに入射する映像光の反射率が高いミラーとする。

【０３５６】

より明るい映像を得たい場合には、観察者からみて最も距離が長い位置にある観察対象に相当する表示領域とは別の表示領域の前面に配置するハーフミラーのひとつを偏光分離素子とする。

【０３５７】

偏光分離素子は液晶表示素子から放射する直線偏光は透過し、これと偏光軸が直交する直線偏光は反射するものとし、この偏光分離素子が前面に配置される表示領域とこの偏光分離素子の間に偏光変換素子を配置する。

【０３５８】

この場合、偏光分離素子が前面に配置された表示領域からの映像光と、この表示領域よりも観察者からみた距離が長い位置にある観察対象に相当する表示領域からの映像光は偏光分離素子ではほとんど損失することなく合成される。このため、ハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。

【０３５９】

この他の構成でより明るい映像を得るには、観察者からみて最も奥行きの遠い位置、つまり、観察者からみて最も距離が長い位置にある観察対象に相当する表示領域の前面に偏光変換素子を配置する。さらに、観察者からみて２番目に奥行きの遠い位置、つまり、観察者からみて２番目に距離が長い位置にある観察対象に相当する表示領域の前面に配置するハーフミラーを液晶表示素子から放射する直線偏光は反射し、これと偏光軸が直交する直線偏光は透過する偏光分離素子とする。

【０３６０】

この場合、観察者からみて最も奥行きの遠い位置にある観察対象に相当する表示領域から放射される映像光と、観察者からみて２番目に奥行きの遠い位置にある観察対象に相当する表示領域から放射される映像光は共にほとんど損失することなく合成される。このため、ハーフミラーに偏光分離素子を用いない場合に比べて、映像光の損失が少なく、より明るい表示装置を実現することができる。

【実施例１３】

【０３６１】

次に本発明の表示装置を備える機器の実施例について図面を参照して説明する。ここでは以下、代表的な遊技機であるパチンコ遊技機を例にあげて説明する。

【０３６２】

図３１は本発明の表示装置を備えるパチンコ遊戯機の概略正面図である。このパチンコ遊技機３００は筐体に額縁状の前面枠３７０が開閉可能に取り付けられており、前面枠３７０の開口部には板状の遊戯板３２０が取り付けられている。また、前面枠３７０の前面には遊戯板３２０の前面を覆うように透明なガラス板や樹脂板で構成される透明板360が開閉可能に取り付けられる。

【０３６３】

前面枠３７０の下方には遊戯用の球（以下、パチンコ玉とよぶ）を受ける受け皿３４０や、パチンコ玉の発射操作を制御する操作ハンドル３５０などが取り付けられている。

【０３６４】

遊戯板３２０の前面にはパチンコ玉の入賞口３３０や、ガイドレール，釘などが取り付けられる。また、遊戯板３２０はパチンコ玉が入賞口に入った場合などに変動表示が観察できる表示部３１０を備える。

【０３６５】

次に本発明の主体である表示部３１０およびその近傍の構成について説明する。図３２

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は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。

【０３６６】

このパチンコ遊技機は遊戯板３２０に対して（実施例１）で説明した表示装置を適用したものであり、上記実施例と同じ部分については同じ符号を付け、詳細な説明は省略する。遊戯板３２０は表示部３１０に対応する位置に開口部３１１を有する。遊戯板３２０の背面側であって、開口部３１１を通して観察できる位置にはハーフミラー２と偏光変換素子４を備える液晶表示素子１を配置する。また、開口部３１１よりも上側の遊戯板３２０の背面には全反射ミラー３を備える。

【０３６７】

観察者２０は開口部３１１を通して、液晶表示素子１からの放射する映像光を観察することになる。このため、開口部３１１の大きさと近距離表示領域１ｎの大きさはほぼ同じ大きさとし、観察者２０が開口部３１１を介して、液晶表示素子１の近距離表示領域１ｎを観察できるように構成する。

【０３６８】

また、遊戯板３２０の背面側であって、開口部３１１を通して観察者が観察できる部分には少なくともその表面を黒色化した遮光部材３２１を適宜配置することが外部からの光によって、表示に悪影響がでないようにするために望ましい。

【０３６９】

この場合、観察者２０は表示部３１０をやや下方から見上げるように観察することになるため、表示部３１０、つまり、開口部３１１は遊戯板の上の方に設けることが望ましい。また、必要に応じて遊戯板３２０の開口部３１１には透明なガラス板や樹脂板からなる保護板を備えてもよい。

【０３７０】

本遊技機では表示部３１０に観察者２０からみて奥行きの異なる位置にある２つの２次元像（映像）を重ねた映像を表示できる。つまり、奥行き感がある映像や、立体感のある映像など、通常の２次元映像では表現できない、極めて表現力の高い映像を表示することができる。

【０３７１】

このため本遊技機では他の遊技機に対して差別化された斬新な演出ができる遊技機を実現できる。

【０３７２】

また、本遊技機では観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面であるため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の遊技機を実現できる。

【実施例１４】

【０３７３】

次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここで説明する機器は（実施例１３）で図３１を参照して説明したパチンコ遊戯機において、遊技機に備える表示装置の構成を変えたものである。このため、上記実施例と同じ部分には同じ符号を付け詳細な説明は省略する。また、ここでは特に本発明の主体である表示部３１０およびその近傍の構成について説明する。

【０３７４】

図３３は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。

【０３７５】

このパチンコ遊技機は遊戯板３２０に対して（実施例８）で説明した表示装置を適用したものであり、上記実施例と同じ部分については同じ符号を付け、詳細な説明は省略する。遊戯板３２０は表示部３１０に対応する位置に開口部３１１を有する。遊戯板３２０の背面側であって、開口部３１１を通して観察できる位置にはハーフミラー２を備える液晶表示素子１を配置する。また、開口部３１１よりも上側の遊戯板３２０の背面には全反射

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ミラー３を備える。

【０３７６】

観察者２０は開口部３１１を通して、リール表示素子５及び液晶表示素子１から放射する映像光を観察することになる。このため、開口部３１１の大きさと液晶表示素子１の表示面の大きさはほぼ同じ大きさとし、観察者２０が開口部３１１を介して、液晶表示素子１の表示面を直接、観察できるように構成する。

【０３７７】

また、遊戯板３２０の背面側であって、開口部３１１を通して観察者が観察できる部分には少なくともその表面を黒色化した遮光部材３２１を適宜配置することが外部からの光によって、表示に悪影響がでないようにするために望ましい。

【０３７８】

この場合、観察者２０は表示部３１０をやや下方から見上げるように観察することになるため、表示部３１０、つまり、開口部３１１は遊戯板の上の方に設けることが望ましい。また、必要に応じて遊戯板３２０の開口部３１１には透明なガラス板や樹脂板からなる保護板を備えてもよい。

【０３７９】

本遊技機では表示部３１０に観察者２０からみて奥行きの異なる位置にある２つの２次元像を重ねた映像を表示できる。つまり、観察者２０にはリール表示素子５の絵柄の手前に液晶表示素子１の映像が浮かんでみえることになる。このような映像表示は遊技機において、演出効果を高めるために極めて有効である。

【０３８０】

このため本遊技機では他の遊技機に対して差別化された斬新な演出ができる遊技機を実現できる。

【０３８１】

また、本遊技機では観察者からみて奥行き（距離）の異なる２つの位置にある観察対象は実際には同一平面に配置しているため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく、薄型の表示装置が実現できる。

【実施例１５】

【０３８２】

次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここで説明する機器は（実施例１３）で図３１を参照して説明したパチンコ遊戯機において、遊技機に備える表示装置の構成を変えたものである。このため、上記実施例と同じ部分には同じ符号を付け詳細な説明は省略する。また、ここでは特に本発明の主体である表示部３１０およびその近傍の構成について説明する。

【０３８３】

図３４は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。このパチンコ遊技機は遊戯板３２０に対して（実施例５）で図２１を参照して説明した表示装置を適用したものであり、上記実施例と同じ部分については同じ符号を付け、詳細な説明は省略する。

【０３８４】

遊戯板３２０は表示部３１０に対応する位置に開口部３１１を有する。遊戯板３２０の背面側であって、開口部３１１を通して観察できる位置には遊戯板３２０に対して４５°傾けて配置されたハーフミラー２と、液晶表示素子１を配置する。また、開口部３１１よりも上側の遊戯板３２０の背面側にはその反射面がハーフミラー２と平行になるように配置した全反射ミラー３を備える。

【０３８５】

観察者２０は開口部３１１を通して、液晶表示素子１から放射する映像光を観察することになる。このため、開口部３１１の大きさと液晶表示素子１の近距離表示領域１ｎの大きさはほぼ同じ大きさとし、観察者２０が開口部３１１を介して、液晶表示素子１の近距離表示領域１ｎを直接、観察できるように構成する。

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【０３８６】
また、遊戯板３２０の背面側であって、開口部３１１を通して観察者が観察できる部分には少なくともその表面を黒色化した遮光部材３２１を適宜配置することが外部からの光によって、表示に悪影響がでないようにするために望ましい。
【０３８７】
この場合、観察者２０は表示部３１０を垂直方向から、つまり、真正面から観察することになるので、表示部３１０、つまり、遊戯板の開口部３１１は遊戯板３２０の中央部に設けることが望ましい。また、必要に応じて遊戯板３２０の開口部３１１には透明なガラス板や樹脂板からなる保護板を備えてもよい。
【０３８８】
本遊技機では表示部３１０に観察者２０からみて奥行きの異なる位置にある２つの２次元像（映像）を重ねた映像を表示できる。つまり、奥行き感がある映像や、立体感のある映像など、通常の２次元映像では表現できない、極めて表現力の高い映像を表示することができる。
【０３８９】
このため本遊技機では他の遊技機に対して差別化された斬新な演出ができる遊技機を実現できる。
【０３９０】
また、本遊技機では観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面であるため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の遊技機を実現できる。
【実施例１６】
【０３９１】
次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここで説明する機器は（実施例１３）で図３１を参照して説明した遊戯機において、遊技機に備える表示装置の構成を変えたものであるため、上記実施例と同じ部分には同じ符号を付け詳細な説明は省略する。また、ここでは特に本発明の主体である表示部３１０およびその近傍の構成について説明する。
【０３９２】
図３５は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。
【０３９３】
このパチンコ遊技機は遊戯板３２０に対して（実施例１０）で図２８を参照して説明した表示装置を適用したものであり、上記実施例と同じ部分に関しては同じ符号を付け、詳細な説明は省略する。
【０３９４】
遊戯板３２０は表示部３１０に対応する位置に開口部３１１を有する。遊戯板３２０の背面側であって、開口部３１１を通して観察できる位置には遊戯板３２０に対して４５°傾けて配置するハーフミラー２を備え、さらにその奥に液晶表示素子１を配置する。また、開口部３１１よりも上側の遊戯板３２０の背面側にはその反射面がハーフミラー２と平行になるように全反射ミラー３を備え、さらにその奥にその表示面が液晶表示素子１の表示面と略平行となる位置にリール表示素子５を配置する。
【０３９５】
観察者２０は開口部３１１を通して、リール表示素子５及び液晶表示素子１から放射する映像光を観察することになる。このため、開口部３１１の大きさと液晶表示素子１の表示領域の大きさはほぼ同じ大きさとし、観察者２０が開口部３１１を介して、液晶表示素子１の表示面を直接、観察できるように構成する。
【０３９６】
また、遊戯板３２０の背面側であって、開口部３１１を通して観察者が観察できる部分には少なくともその表面を黒色化した遮光部材３２１を適宜配置することが外部からの光

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によって、表示に悪影響がでないようにするために望ましい。

【０３９７】

特に本実施例ではリール表示素子５からの光の一部はハーフミラー２を透過する為、このハーフミラー２を透過した光が迷光となって画質劣化の原因にならないように遮光部材によって吸収するようにすると良い。

【０３９８】

この場合、観察者２０は表示部３１０を垂直方向から、つまり、真正面から観察することになるので、表示部３１０、つまり、開口部３１１は遊戯板３２０の中央部に設けることが望ましい。また、必要に応じて遊戯板３２０の開口部３１１には透明なガラス板や樹脂板からなる保護板を備えてもよい。

【０３９９】

本遊技機では表示部３１０に、リール表示素子５の表示面と、その手前に浮かんでみえる液晶表示素子１の映像が観察できる。このような表示はパチンコやスロットマシンなどの遊技機において、演出効果を高めるために極めて有効である。

【０４００】

このため本遊技機では他の遊技機に対して差別化された斬新な演出ができる遊技機を実現できる。

【０４０１】

また、本遊技機では観察者からみて奥行き（距離）の異なる位置にある２つの観察対象は、実際には略同一平面上に配置しているため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく、薄型の遊技機が実現できる。

【実施例１７】

【０４０２】

次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここでは以下、代表的な遊技機であるパチンコ遊技機を例にあげて説明する。

【０４０３】

図３６は本発明の表示装置を備えるパチンコ遊戯機の概略正面図である。このパチンコ遊技機３００は筐体に額縁状の前面枠３７０が開閉可能に取り付けられており、前面枠３７０の開口部には板状の遊戯板３２０が取り付けられている。また、前面枠３７０の前面には遊戯板３２０の前面を覆うように透明なガラス板や樹脂板で構成される透明板360が開閉可能に取り付けられる。この際、透明板３６０と遊戯板３２０の間には遊戯板320の上に取り付けられる構造物が透明板３６０と接触しないように一定の間隔が設けられる。

【０４０４】

また、前面枠３７０の下方にはパチンコ玉を受ける受け皿３４０や、パチンコ玉の発射操作を制御する操作ハンドル３５０などが取り付けられている。

【０４０５】

遊戯板３２０の前面にはパチンコ玉の入賞口３３０や、ガイドレール，釘などが取り付けられる。また、遊戯板３２０はパチンコ玉が入賞口に入った場合などに変動表示が観察できる表示部３１０を備える。また、表示部３１０の上部に相当する位置には、遮光手段３６５が配置され、その表面側には必要に応じて装飾絵柄やロゴなどが印字される。

【０４０６】

次に本発明の主体である表示部３１０およびその近傍の構成について説明する。図３７は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。

【０４０７】

このパチンコ遊技機は遊戯板３２０に対して（実施例１）で説明した表示装置を適用したものであり、上記実施例と同じ部分に関しては同じ符号を付け、詳細な説明は省略する。この遊技機は遊戯板３２０に液晶表示素子１の表示面と同じ、もしくはそれよりもやや大きな開口部３１１を有し、ハーフミラー２と偏光変換素子４を備える液晶表示素子１をその開口部３１１、或いはそれよりもやや奥に配置する。透明板３６０の背面には、液晶

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表示素子１から所定の距離、つまり本発明の表示装置を実現できる距離だけ離れた位置に全反射ミラー３を備える。

【０４０８】

また、透明板３６０には観察者２０が液晶表示素子１の近距離表示領域１ｎを観察するのに妨げとならず、なおかつ、観察者２０から全反射ミラー３や遠距離表示領域１ｆを見えないようにする位置に遮光手段３６５を備える。

【０４０９】

遮光手段３６５は観察者から見て透明板３６０の表側、もしくは裏側、あるいは透明板の内部に配置すれば良い。遮光手段３６５は顔料や染料を含む樹脂板や金属板、あるいは、遮光性の塗料を透明板３６０に塗布することで実現すれば良い。この際、遊技機のデザインを損なわないようにするために遮光手段３６５の観察者側の面には装飾絵柄やロゴなどを配置するとよい。

【０４１０】

観察者２０は遮光手段３６５より下の部分で液晶表示素子１からの放射する映像光を観察することになる。このため、遮光手段３６５の下の部分が表示部３１０に相当することになる。

【０４１１】

この場合、観察者２０は表示部３１０をやや下方から見上げるように観察することになるため、表示部３１０、つまり、開口部３１１は遊戯板３２０の上の方に設けることが望ましい。また、必要に応じて遊戯板３２０の開口部３１１には透明なガラス板や樹脂板からなる保護板を備えてもよい。保護板を備える場合は、保護板での光の反射で表示部310から観察される映像が悪影響を受けないために、表面反射を抑える反射防止処理を施すことが望ましい。

【０４１２】

本遊技機では表示部３１０に観察者２０からみて奥行きの異なる位置にある２つの２次元像を重ねた映像を表示できる。つまり、奥行き感がある映像や、立体感のある映像など、通常の２次元映像では表現できない、極めて表現力の高い映像を表示することができる。このような表示は遊技機の演出効果を高めるのに極めて有効である。

【０４１３】

尚、本実施例ではパチンコ玉が全反射ミラー３と液晶表示素子１の間を通過できるように構成することができる。この場合、全反射ミラー３と液晶表示素子１の間を通過するパチンコ玉は表示部３１０において観察されることになる。例えば、パチンコ玉が液晶表示素子１の遠距離表示領域１ｆの前面から近距離表示領域１ｎの前面に移動すると、観察者には表示部３１０において、パチンコ玉が遠くから近くに移動するように見える。このため、本遊技機では従来の遊技機ではできなかった斬新な演出ができる遊技機を実現できる。また、本遊技機では観察者からみて奥行きの異なる位置にある観察対象が、実際には単一の表示素子の表示面であるため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の遊技機を実現できる。

【０４１４】

特に本実施例では全反射ミラー３を遊技機の透明板３６０に配置することで、遊戯板３２０と透明板３６０の間にある空間を効率よく利用できるためより薄型の遊技機を実現できる。

【実施例１８】

【０４１５】

次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここで説明する機器は（実施例１７）で図３６を参照して説明したパチンコ遊戯機において、遊技機に備える表示装置の構成を変えたものである。このため、上記実施例と同じ部分には同じ符号を付け詳細な説明は省略する。また、ここでは特に本発明の主体である表示部３１０およびその近傍の構成について説明する。

【０４１６】

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図３８は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。

【０４１７】

このパチンコ遊技機は遊戯板３２０に対して（実施例５）で図２１を参照して説明した表示装置を適用したものであり，上記実施例と同じ部分については同じ符号を付け、詳細な説明は省略する。

【０４１８】

この遊技機は遊戯板３２０に液晶表示素子１の表示領域と同じ、もしくはそれよりもやや大きな開口部を有し、偏光変換素子４を備える液晶表示素子１をその開口部の奥に配置する。

【０４１９】

液晶表示素子１と透明板３６０の間にはハーフミラー２と、全反射ミラー３を液晶表示素子１の表示面に対して４５°傾けて配置する。また、液晶表示素子１の表示面は遊戯板３２０に対してほぼ平行に配置する。

【０４２０】

また、透明板３６０には観察者２０が液晶表示素子１の近距離表示領域１ｎを観察するのに妨げとならず、観察者２０から全反射ミラー３が見えないようにする位置に遮光手段３６５を備える。

【０４２１】

遮光手段３６５は観察者から見て透明板３６０の表側、もしくは裏側、あるいは透明板の内部に配置すれば良い。遮光手段３６５は顔料や染料を含む樹脂板や金属板、あるいは、遮光性の塗料を透明板３６０に塗布することで実現すれば良い。この際、遊技機のデザインを損なわないようにするために遮光手段３６５の観察者側の面には装飾絵柄やロゴなどを配置するとよい。

【０４２２】

観察者２０は遮光手段３６５より下の部分で液晶表示素子１からの放射する映像光を観察することになる。このため、遮光手段３６５の下の部分が表示部３１０に相当することになる。

【０４２３】

この場合、観察者２０は表示部３１０を垂直方向から、つまり，真正面から観察することになるので、表示部３１０は遊戯板の中央部に設けることが望ましい。

【０４２４】

また、遊戯板３２０の開口部の周りには外部から液晶表示素子１に不要な光が入射して表示に悪影響が生じないようにするために、遮光部材３２１を設けると良い。この遮光部材３２１はパチンコ玉が表示部３１０に進入しないようにするための隔壁と兼用しても良い。本遊技機では表示部３１０に観察者２０からみて奥行きの異なる位置にある２つの２次元像を重ねた映像を表示できる。つまり、奥行き感がある映像や、立体感のある映像など、通常の２次元映像では表現できない、極めて表現力の高い映像を表示することができる。このため、本遊技機では従来の遊技機ではできなかった斬新な演出ができる遊技機を実現できる。

【０４２５】

また、本遊技機では観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面であるため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型の遊技機を実現できる。特に本実施例では全反射ミラー３やハーフミラー（偏光分離素子）２を遊技機の透明板３６０と遊戯板３２０の間にある空間も利用して配置するため、より薄型の遊技機を実現できる。

【実施例１９】

【０４２６】

次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここで説明する機器は（実施例１７）で図３６を参照して説明したパチンコ遊戯機において

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、遊技機に備える表示装置の構成を変えたものである。このため、上記実施例と同じ部分には同じ符号を付け詳細な説明は省略する。また、ここでは特に本発明の主体である表示部３１０およびその近傍の構成について説明する。

【０４２７】

図３９は本発明の表示装置を備える遊戯機の表示部３１０およびその近傍の概略断面図である。

【０４２８】

このパチンコ遊技機は遊戯板３２０に対して（実施例１０）で図２８を参照して説明した表示装置を適用したものであり、上記実施例と同じ部分については同じ符号を付け、詳細な説明は省略する。

【０４２９】

この遊技機は遊戯板３２０に液晶表示素子１の表示面とリール表示素子５の表示面を足した大きさと同程度の開口部を有し、液晶表示素子１とリール表示素子５をその開口部の奥に配置する。

【０４３０】

液晶表示素子１と透明板３６０の間にはハーフミラー（偏光分離素子）２を液晶表示素子１の表示面に対して４５°傾けて配置する。また、リール表示素子５と透明板３６０の間には全反射ミラー３をハーフミラー２と平行に配置する。また、液晶表示素子１の表示面は遊戯板３２０に対してほぼ平行となるように配置する。

【０４３１】

透明板３６０には観察者２０が液晶表示素子１の表示領域を観察するのに妨げとならず、全反射ミラー３が観察者２０に見えないようにする位置に遮光手段３６５を備える。

【０４３２】

遮光手段３６５は観察者から見て透明板３６０の表側、もしくは裏側、あるいは透明板の内部に配置すれば良い。遮光手段３６５は顔料や染料を含む樹脂板や金属板、あるいは、遮光性の塗料を透明板３６０に塗布することで実現すれば良い。この際、遊技機のデザインを損なわないようにするために遮光手段３６５の観察者側の面には装飾絵柄やロゴなどを配置するとよい。

【０４３３】

観察者２０は遮光手段３６５より下の部分で液晶表示素子１とリール表示素子５から放射する映像光を観察することになる。このため、遮光手段３６５の下の部分が表示部310に相当することになる。

【０４３４】

この場合、観察者２０は表示部３１０を垂直方向から、つまり、真正面から観察することになるので、表示部３１０は遊戯板の中央部に設けることが望ましい。また、遊戯板３２０の開口部の周りには外部から液晶表示素子１に不要な光が入射して表示に悪影響が生じないようにするために遮光部材３２１を設けると良い。この遮光部材３２１はパチンコ玉が表示部３１０に進入しないようにするための隔壁と兼用しても良い。

【０４３５】

本遊技機では表示部３１０に観察者２０からみて奥行きの異なる位置にある２つの２次元像を重ねた映像を表示できる。つまり、観察者２０にはリール表示素子５の絵柄の手前に液晶表示素子１の映像が浮かんでみえることになる。このような表示はパチンコやスロットマシンなどの遊技機において、演出効果を高めるために極めて有効である。

【０４３６】

このため本遊技機では他の遊技機に対して差別化された斬新な演出ができる遊技機を実現できる。

【０４３７】

また、本遊技機では観察者からみて奥行き（距離）の異なる位置にある観察対象が略同一平面上に配置されるため、観察者に感知される奥行きよりも実際の奥行き方向の長さが小さく、薄型の表示装置が実現できる。特に本遊技機では全反射ミラー３やハーフミラー

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（偏光分離素子）２を遊技機の透明板３６０と遊戯板３２０の間にある空間も利用して配置するため、より薄型の遊技機を実現できる。

【実施例２０】

【０４３８】

次に本発明の表示装置を備える機器の他の実施例について図面を参照して説明する。ここでは以下、テーブル状のゲーム機を例にあげて説明する。

【０４３９】

図４０は本発明の表示装置を備えるゲーム機の概略斜視図である。このゲーム機５００は筐体５３０内に本発明の表示装置５１０を備え、側面にはゲームの動作を操作するための操作部５２０が取り付けられている。筐体５３０の上面部には開口部５３１が設けられ、観察者２０はこの開口部５３１を通して表示装置の映像を観察する。

【０４４０】

このゲーム機５００に備えられる表示装置５１０は（実施例１）で図１から図３を参照して説明した表示装置であり、観察者２０は表示装置を構成する液晶表示素子１を斜め方向から観察することになる。

【０４４１】

本ゲーム機のようなテーブル状のゲーム機では観察者２０は斜め方向から表示装置を観察することになる。このため、（実施例１）で説明した表示装置は本ゲーム機の表示装置５１０として好適である。

【０４４２】

尚、筐体５３０の内部には少なくともその表面を黒色化した遮光部材を適宜配置することが外部からの光によって、表示に悪影響がでないようにするために望ましい。

【０４４３】

また、筐体内部に埃などが進入することを防ぐために筐体の開口部５３１には透明なガラス板や樹脂板からなる保護板を備えるとよい。

【０４４４】

本ゲーム機では観察者２０からみて奥行きの異なる位置にある２つの２次元像を重ねた映像を表示できる。つまり、奥行き感がある映像や、立体感のある映像など、通常の２次元映像では表現できない、極めて表現力の高い映像を表示することができる。このため本ゲーム機では斬新な演出ができるゲーム機を実現することができる。

【０４４５】

また、本ゲーム機では観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面であるため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型のゲーム機を実現できる。

【実施例２１】

【０４４６】

次に本発明の表示装置を備える他の機器の実施例について図面を参照して説明する。ここでは以下、テーブル状の対面型のゲーム機を例にあげて説明する。

【０４４７】

図４１は本発明の表示装置を備えるゲーム機の概略斜視図である。このゲーム機６００は筐体６３０内に本発明の表示装置６１０を備え、筐体の対向する側面の外側にはそれぞれゲームの動作を操作するための操作部６２０Ａ，６２０Ｂが取り付けられている。筐体６３０の上面部には２つの開口部６３１Ａ，６３１Ｂが設けられ、観察者２０Ａと観察者２０Ｂはそれぞれ開口部６３１Ａと開口部６３１Ｂを通して表示装置６１０の映像を観察する。

【０４４８】

ゲーム機６００に備えられる表示装置６１０は（実施例６）で図２３を参照して説明した表示装置、或いは（実施例７）で図２４を参照して説明した表示装置であり、表示装置６１０は二つの異なる方向、つまり二人の対面する観察者に対して、奥行きが異なる位置にある２つの２次元像を重ねた映像を同時に表示することができる。また、このとき、２

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人の観察者は表示装置を構成する液晶表示素子１を斜め方向から観察することになる。

【０４４９】

本ゲーム機のようなテーブル状のゲーム機では観察者２０Ａと観察者２０Ｂはともに斜め方向から表示装置を観察することになる。このため、（実施例６）と（実施例７）で説明した表示装置は本ゲーム機の表示装置６１０として好適である。

【０４５０】

尚、筐体６３０の内部には少なくともその表面を黒色化した遮光部材を適宜配置することが外部からの光によって、表示に悪影響がでないようにするために望ましい。

【０４５１】

また、筐体内部に埃などが進入することを防ぐために筐体の開口部６３１Ａ及び開口部６３１Ｂには透明なガラス板や樹脂板からなる保護板を備えるとよい。

【０４５２】

本ゲーム機では観察者２０Ａと観察者２０Ｂは共に観察者からみて奥行きの異なる位置にある２つの２次元像を重ねた映像を表示できる。つまり、奥行き感がある映像や、立体感のある映像など、通常の２次元映像では表現できない、極めて表現力の高い映像を表示することができる。このため本ゲーム機では斬新な演出ができるゲーム機を実現することができる。

【０４５３】

特に本ゲーム機では、液晶表示素子の同じ表示領域の映像が、この表示領域から近い位置の観察者に対しては、奥行きが近い位置，つまり距離が短い位置にある映像となり、この表示領域から遠い位置の観察者に対しては奥行きの遠い位置、つまり距離が長い位置にある映像となる。

【０４５４】

つまり，本ゲーム機では二人の異なる位置にいる観察者に対して、同じ２つの２次元像を観察者の位置に応じた順序で重ねた状態で表示することができる。このため、より臨場感の高い表示ができるゲーム機を実現できる。このようなゲーム機は対戦型のゲーム機に好適である。

【０４５５】

また、本ゲームでは観察者からみて奥行きの異なる位置にある観察対象は、実際には単一の表示素子の表示面であるため、観察者に感知される奥行きよりも実際の奥行き方向の厚みが小さい薄型のゲーム機を実現できる。

【実施例２２】

【０４５６】

次に本発明の表示装置の他の実施例について説明する。ここで説明する表示装置は（実施例１２）で図３０を参照して説明した表示装置において、液晶表示素子１の３つの表示領域のうち近距離表示領域に相当する部分をなくし、その部分に観察者から表示装置の外部を観察できる開口部７を設けたものである。

【０４５７】

このため上記実施例で説明した表示装置と同じ部分には同じ符号を付け詳細な説明は省略する。

【０４５８】

図４２は本発明の表示装置の一例を示す概略断面図である。この表示装置は液晶表示素子１の２つの表示領域と、表示装置の外部を観察対象とするものである。液晶表示素子１の２つの表示領域は観察者２０からみて奥行き（距離）の異なる位置にある２つの観察対象に相当するものである。ここでは液晶表示素子１の表示領域のうち、観察者２０からみて奥行きが遠い位置，つまり、観察者２０からみて距離が長い位置にある観察対象に相当する表示領域を遠距離表示領域１ｆと呼び、観察者からみて奥行きが近い位置、つまり、観察者からみて距離が短い位置にある観察対象に相当する表示領域を中距離表示領域１ｍと呼ぶ。

【０４５９】

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また、表示装置の外部の観察対象８（以下、外部観察対象と呼ぶ）は表示装置の用途に応じた任意の位置に存在し、観察者２０からみた奥行き、つまり観察者２０からの距離は任意に定めることができる。

【０４６０】

例えば、外部観察対象８が液晶表示素子１の表示面と略同一平面、あるいはこれに近い位置にあれば、外部観察対象８は観察者からの奥行きが最も近い位置、つまり、観察者からみて最も距離が短い位置にある観察対象となる。

【０４６１】

また、外部観察対象８が外部観察対象８からハーフミラー６までの距離が、液晶表示素子１の遠距離表示領域１ｆから全反射ミラー３までの距離と、全反射ミラー３からハーフミラー６までの距離との合計の距離よりも長くなる位置にあれば、外部観察対象８は観察者２０からの奥行きが最も遠い位置、つまり、観察者からみて最も距離が長い位置にある観察対象となる。

【０４６２】

つまり、外部観察対象８は観察者２０からみた奥行き方向の位置が、最も近い位置から最も遠い位置まで任意の位置とすることができる。

【０４６３】

本実施例の表示装置では液晶表示素子１の遠距離表示領域１ｆから放射する映像光19ｆは偏光変換素子４を通過する際、偏光軸が９０度回転した直線偏光となり、全反射ミラー３で反射した後、ハーフミラー（偏光分離素子）２をほとんど反射することなく大部分が透過して、ハーフミラー６に向かう。

【０４６４】

また、中距離表示領域１ｍから放射する映像光１９ｍはハーフミラー（偏光分離素子）２をほとんど透過することなく、その大部分が反射してハーフミラー６へ向かう。

【０４６５】

つまり、遠距離表示領域１ｆの前面に偏光変換素子４を配置し、ハーフミラー２として偏光分離素子を用いることで遠距離映像光１９ｆと中距離映像光１９ｍは共にほとんど損失することなく合成されてハーフミラー６へ向かうため明るい映像光が得られる。

【０４６６】

ハーフミラー６へ向かった遠距離映像光１９ｆと中距離映像光１９ｍはハーフミラー６でその一部が反射して観察者２０に観察される。

【０４６７】

一方、外部観察対象８から放射する映像光１９ｅは開口部７を通過して、その一部がハーフミラー６を透過して観察者２０に観察される。

【０４６８】

このため、観察者２０からみて奥行きの異なる位置にある２つの表示領域に表示される２次元像（映像）と、外部観察対象８が重なった状態で観察者２０に観察される。

【０４６９】

つまり、本表示装置は観察者からみて奥行きが異なる位置にある２つの観察対象と、任意の奥行き位置にある外部観察対象を重ねた状態で表示することができる。

【０４７０】

このため様々な用途への展開が考えられる。例えば、外部観察対象を遠方の物体や風景とすれいば、表示装置の大きさに制限されない大きな奥行き感を感知させる表示装置が実現できる。

【０４７１】

あるいは、外部観察対象８と、液晶表示素子１に表示される電子化された映像情報を照合することで真贋判定を行うといった用途に使用することができる。

【０４７２】

あるいは、外部観察対象８を自動車の外部の風景とし、車外の風景と、液晶表示素子１の映像を重ねて表示することで自動車のさまざまな情報を表示する装置としても使用する

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ことができる。
【産業上の利用可能性】
【０４７３】
本発明の表示装置では観察者からみて奥行き（距離）の異なる位置にある複数の観察対象を光学的に重ねた状態で観察できるので、観察者に奥行き感、あるいは３次元立体像が感知される表示装置を実現できる。
【０４７４】
このため、臨場感や高い表現力が望まれるゲーム機やパチンコなどの遊技機の表示装置として好適である。
【０４７５】
或いは、医療用や美術品の観察といった観察対象をより正確に再現することが要求される表示装置にも適用できる。
【０４７６】
また、本発明の表示装置では観察者からみて奥行き（距離）の異なる位置にある観察対象を交互に切り替えて表示することができるため、観察者の目の焦点調節機能を訓練するといった用途にも適用できる。
【０４７７】
また、本発明の表示装置では観察対象の少なくともひとつを表示装置外部の物体や風景とすることができる。この場合、表示装置外部の観察対象と、表示素子に表示される電子化された映像情報を照合することで真贋判定を行うといった用途にも適用できる。
【０４７８】
あるいは、外部の観察対象を自動車の外部の風景とし、車外の風景と、表示素子の映像を重ねて表示することで自動車のさまざまな情報を表示する装置としても使用することができる。
【図面の簡単な説明】
【０４７９】
【図１】本発明の表示装置を説明するための概略断面図である。（実施例１）
【図２】本発明の表示装置を説明するための概略断面図である。（実施例１）
【図３】本発明の表示装置を説明するための概略斜視図である。（実施例１）
【図４】本発明の表示装置に係る液晶表示素子の概略断面図である。（実施例１）
【図５】本発明の表示装置に係る液晶表示パネルの画素の構成を示す正面図である。（実施例１）
【図６】本発明の表示装置に係る部材の直線偏光の透過軸と液晶層の配向方向の一例を示す説明図である。（実施例１）
【図７】本発明の表示装置を説明するための概略断面図である。
【図８】本発明の表示装置に係る視点の位置合わせの印の一例を示す説明図である。
【図９】本発明の表示装置に係る視点の位置合わせの印の一例を示す説明図である。
【図１０】本発明の表示装置に係る表示素子の表示面における表示の一例を示す説明図である。
【図１１】本発明の表示装置において観察者に観察される映像を模擬的に示す説明図である。
【図１２】本発明の表示装置に係る表示素子の表示面における表示の一例を示す説明図である。
【図１３】本発明の表示装置に係る表示素子の表示面における表示の一例を示す説明図である。
【図１４】本発明の表示装置に係る表示素子の表示面における表示の一例を示す説明図である。
【図１５】本発明の表示装置を説明するための概略断面図である。（実施例２）
【図１６】本発明の表示装置を説明するための概略断面図である。（実施例３）
【図１７】本発明の表示装置に係る液晶表示素子の概略断面図である。（実施例３）

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【図１８】本発明の表示装置に係る部材の直線偏光の透過軸と液晶層の配向方向の一例を示す説明図である。（実施例３）
【図１９】本発明の表示装置を説明するための概略断面図である。（実施例４）
【図２０】本発明の表示装置を説明するための概略断面図である。
【図２１】本発明の表示装置を説明するための概略断面図である。（実施例５）
【図２２】本発明の表示装置を説明するための概略断面図である。
【図２３】本発明の表示装置を説明するための概略断面図である。（実施例６）
【図２４】本発明の表示装置を説明するための概略断面図である。（実施例７）
【図２５】本発明の表示装置に係る部材の直線偏光の透過軸と液晶層の配向方向の一例を示す説明図である。（実施例７）
【図２６】本発明の表示装置を説明するための概略斜視図である。（実施例８）
【図２７】本発明の表示装置を説明するための概略斜視図である。（実施例９）
【図２８】本発明の表示装置を説明するための概略断面図である。（実施例１０）
【図２９】本発明の表示装置を説明するための概略断面図である。（実施例１１）
【図３０】本発明の表示装置を説明するための概略断面図である。（実施例１２）
【図３１】本発明の表示装置を備える遊技機を説明するための概略正面図である。（実施例１３）
【図３２】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１３）
【図３３】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１４）
【図３４】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１５）
【図３５】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１６）
【図３６】本発明の表示装置を備える遊技機を説明するための概略正面図である。（実施例１７）
【図３７】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１７）
【図３８】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１８）
【図３９】本発明の表示装置を備える遊技機の表示部とその近傍の概略断面図である。（実施例１９）
【図４０】本発明の表示装置を備えるゲーム機を説明するための概略斜視図である。（実施例２０）
【図４１】本発明の表示装置を備えるゲーム機を説明するための概略斜視図である。（実施例２１）
【図４２】本発明の表示装置を説明するための概略断面図である。（実施例２２）
【図４３】従来の表示装置を説明するための概略断面図である。
【符号の説明】
【０４８０】
１…液晶表示素子、２…ハーフミラー（偏光分離素子）、３…全反射ミラー、４…偏光変換素子、５…リール表示素子、６…ハーフミラー、３００…パチンコ遊技機、３１０…表示部、３１１，５３１，６３１Ａ，６３１Ｂ…開口部、３２０…遊戯板、５００…ゲーム機、５１０，６１０…表示装置、５３０，６３０…筐体、６００…ゲーム機。

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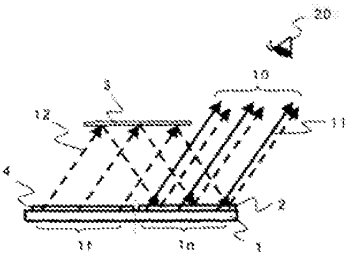
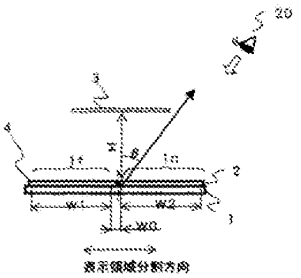
【図１】

図 1



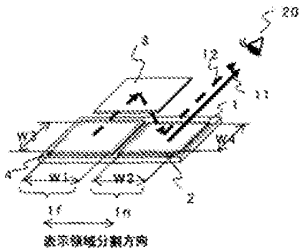
【図２】

図 2



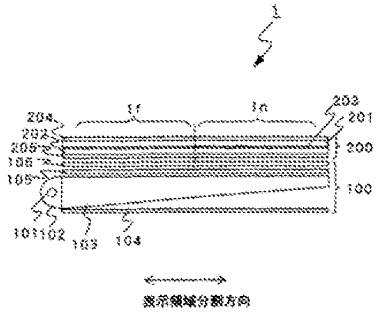
【図３】

図 3



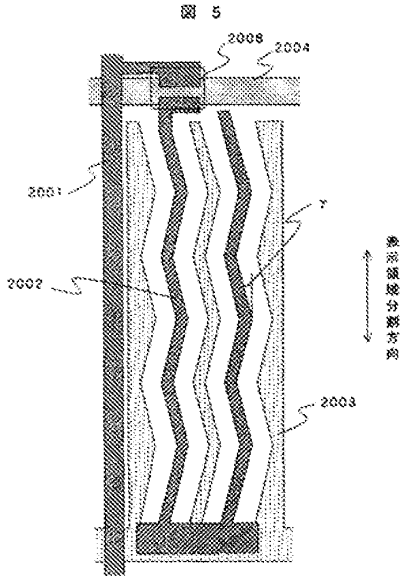
【図４】

図 4



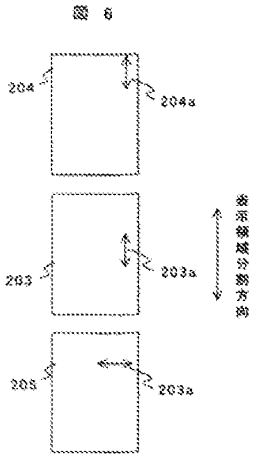
【図５】

図 5



【図６】

図 6



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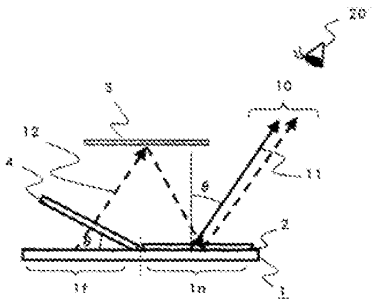
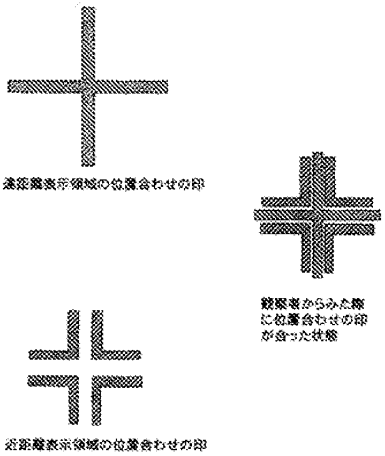
【図７】

図 7



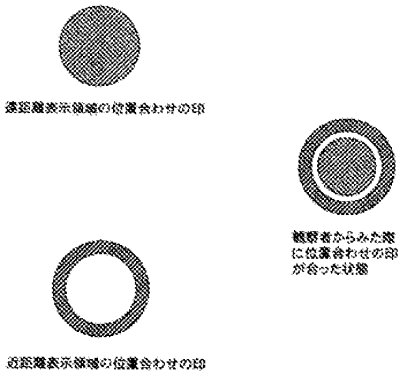
【図８】

図 8



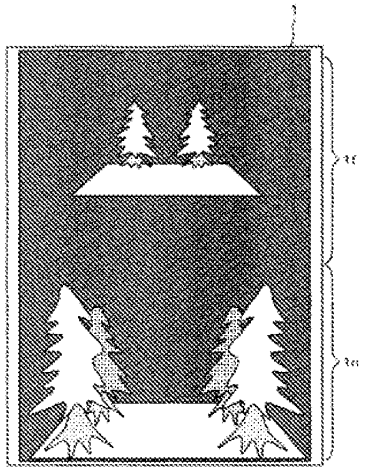
【図９】

図 9



【図１０】

図 10



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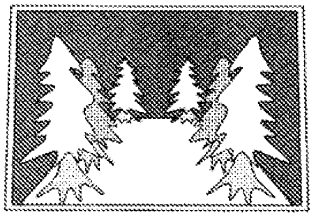
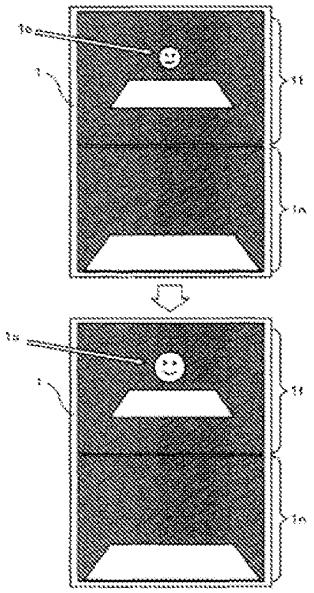
【図１１】

図 11



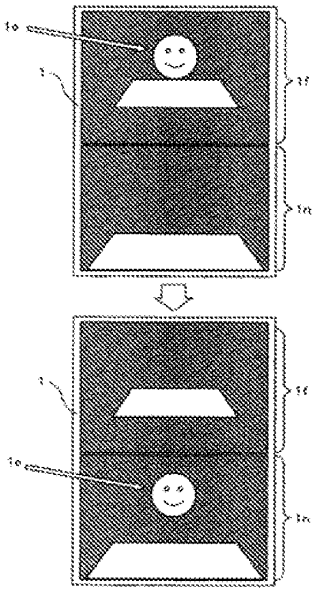
【図１２】

図 12



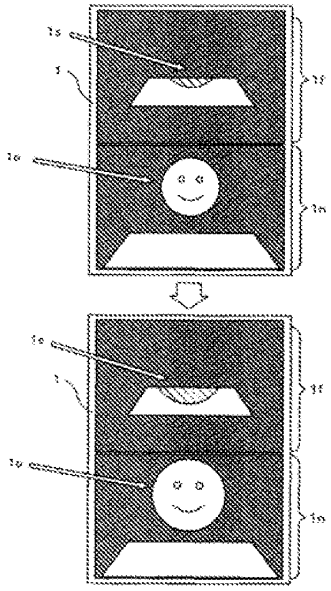
【図１３】

図 13



【図１４】

図 14



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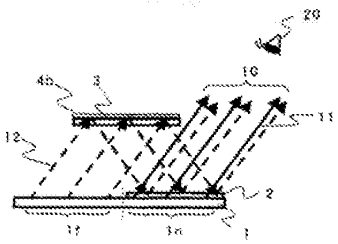
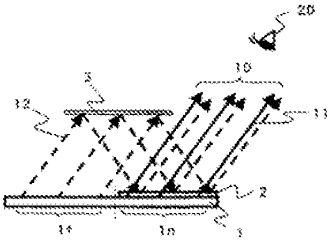
【図１５】

図 15



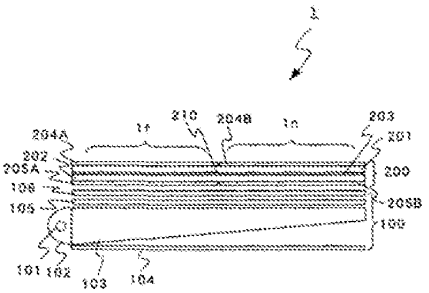
【図１６】

図 16



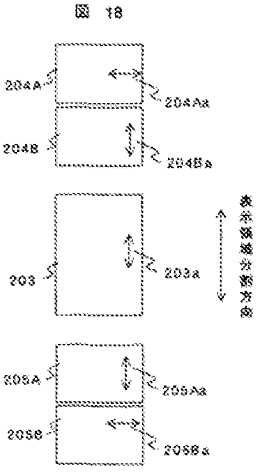
【図１７】

図 17



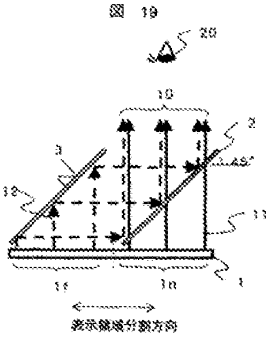
【図１８】

図 18



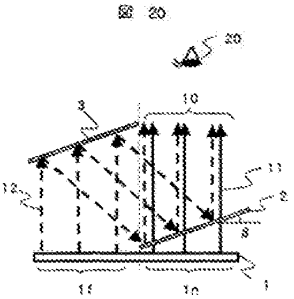
【図１９】

図 19



【図２０】

図 20



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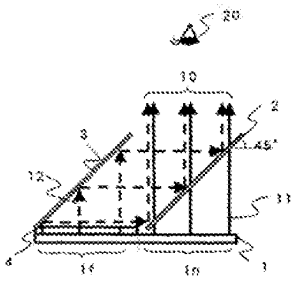
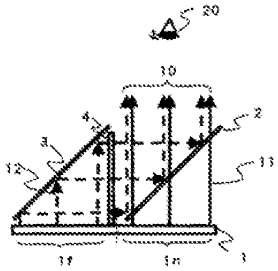
【図２１】

図 21



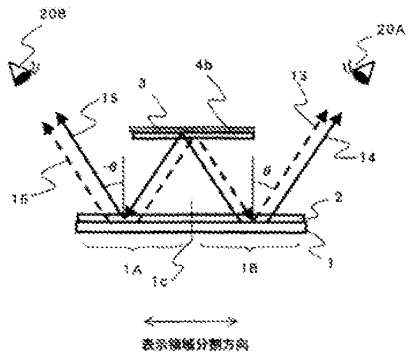
【図２２】

図 22



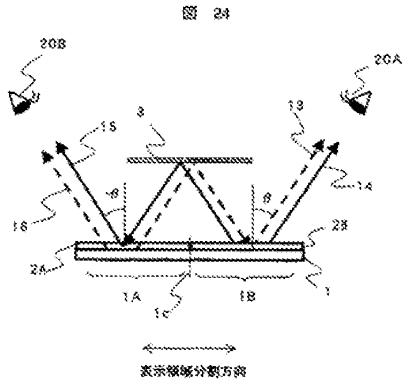
【図２３】

図 23



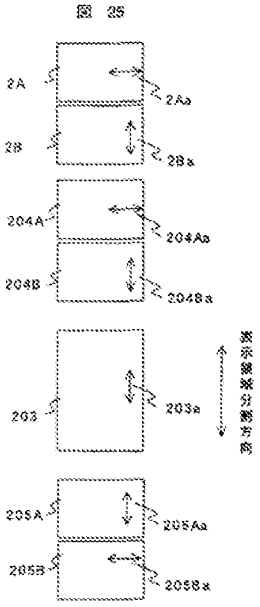
【図２４】

図 24



【図２５】

図 25



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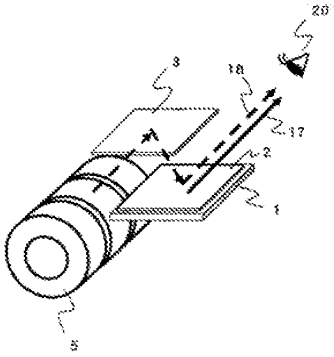
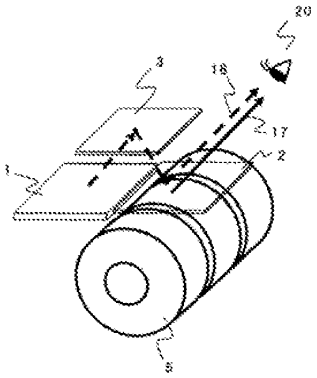
【図２６】

図 26



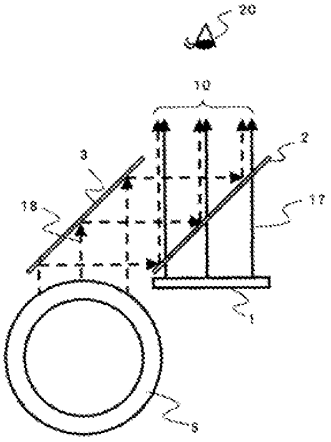
【図２７】

図 27



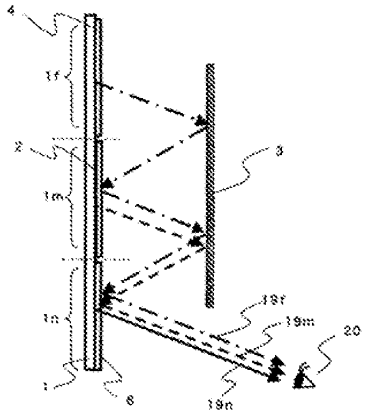
【図２８】

図 28



【図２９】

図 29



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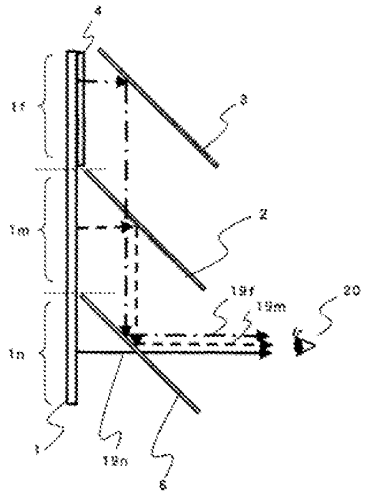
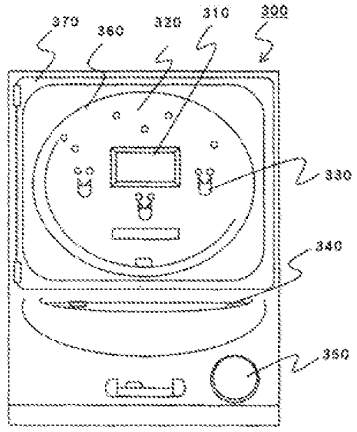
【図３０】

図 30



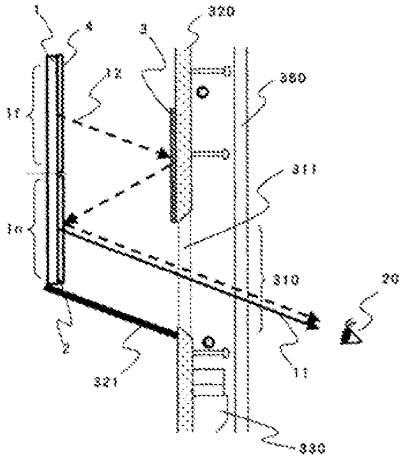
【図３１】

図 31



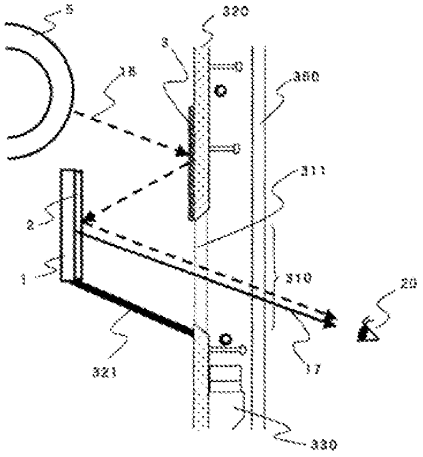
【図３２】

図 32



【図３３】

図 33



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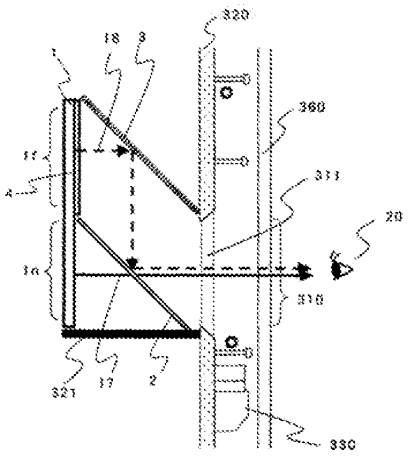
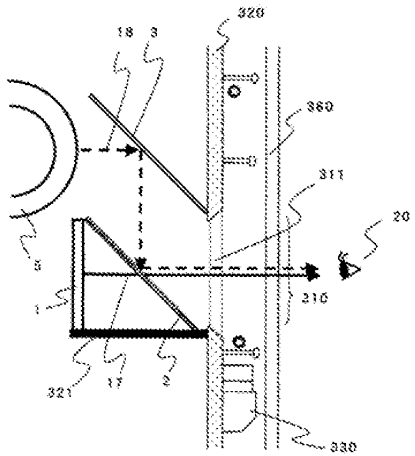
【図３４】

図 34



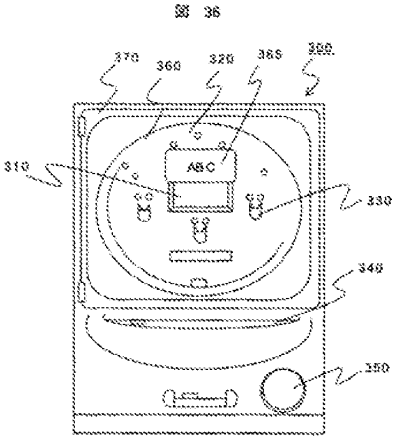
【図３５】

図 35



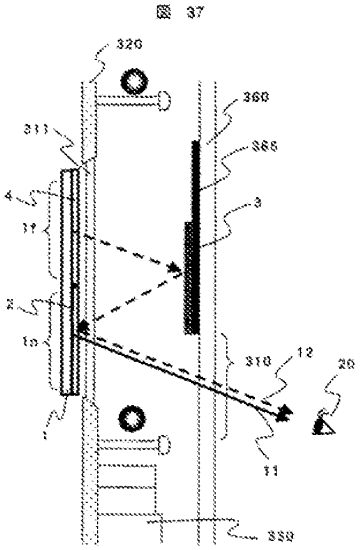
【図３６】

図 36



【図３７】

図 37



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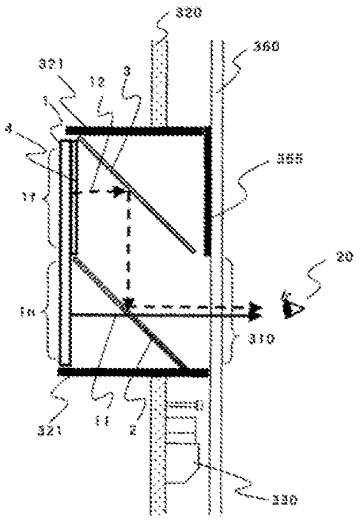
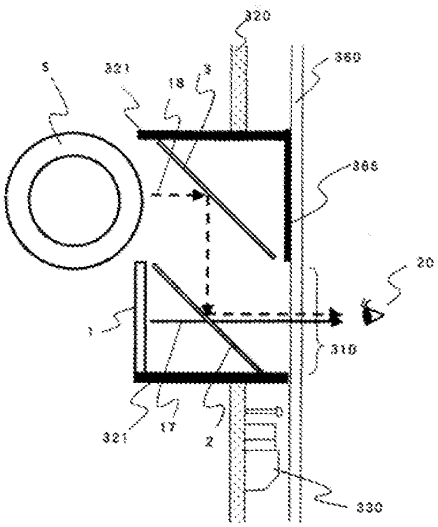
【図３８】

図 38



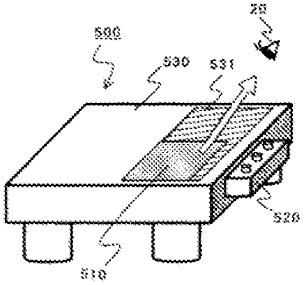
【図３９】

図 39



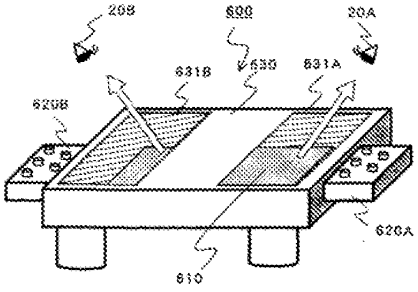
【図４０】

図 40



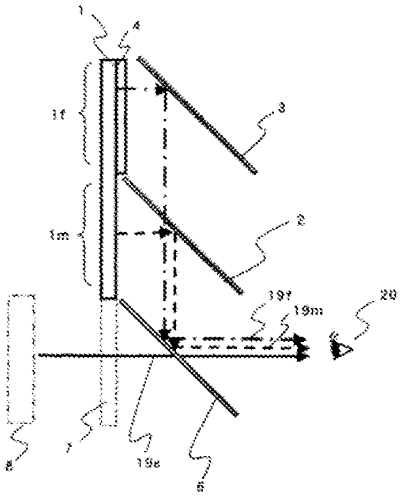
【図４１】

図 41



【図４２】

図 42



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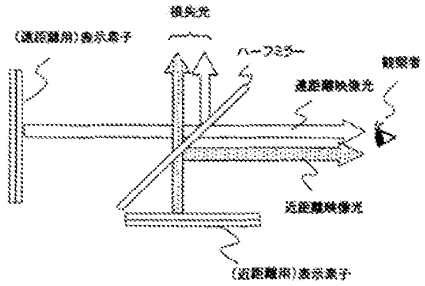
【図４３】

図 43



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Espacenet

Bibliographic data: JP2007094035 (A) — 2007-04-12

SURFACE LIGHT SOURCE AND LIQUID CRYSTAL DISPLAY DEVICE

Inventor(s): DAIKU YASUHIRO ± (DAIKU YASUHIRO)

Applicant(s): CASIO COMPUTER CO LTD ± (CASIO COMPUT CO LTD)

Classification: - international: ***F21V8/00; G02B27/22; G02F1/13; G02F1/133; G02F1/1335; G02F1/13357; G02F1/13363; H04N13/04;*** *F21Y103/00*
- cooperative: **G02F1/13362; H04N13/0411; H04N13/0418; H04N13/0486;** G02F2001/133607; G02F2413/09

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Also published as: JP4626467 (B2) US2007069978 (A1) US7916221 (B2) US2010073601 (A1) US8144293 (B2) more

Abstract of JP2007094035 (A)

PROBLEM TO BE SOLVED: To display a three-dimensional image of high resolution and high quality. ;SOLUTION: A liquid crystal display device has, on the opposite side of a liquid crystal panel from its observation side, a light guide plate 8, first and second light emission bodies 24 and 25, first and second linear polarizing elements 26 and 27 which are arranged having their axes 26a and 27a of transmission orthogonally, a phase difference element 28 where a plurality of [lambda]/2 phase difference parts 29 and no-phase-difference parts 30 are formed by turns, and a lens array 31 which emits light having been transmitted through a [lambda]/2 phase difference part 29 in a first emitting direction and light having been transmitted through a no-phase-difference part 30 in a second emitting direction.; The first and second light emission bodies 24 and 25 illuminate to emit linear polarized light beams having orthogonal relationship toward the left and right eyes of a display observer through the liquid crystal display panel 1. ;COPYRIGHT: (C)2007,JPO&INPIT

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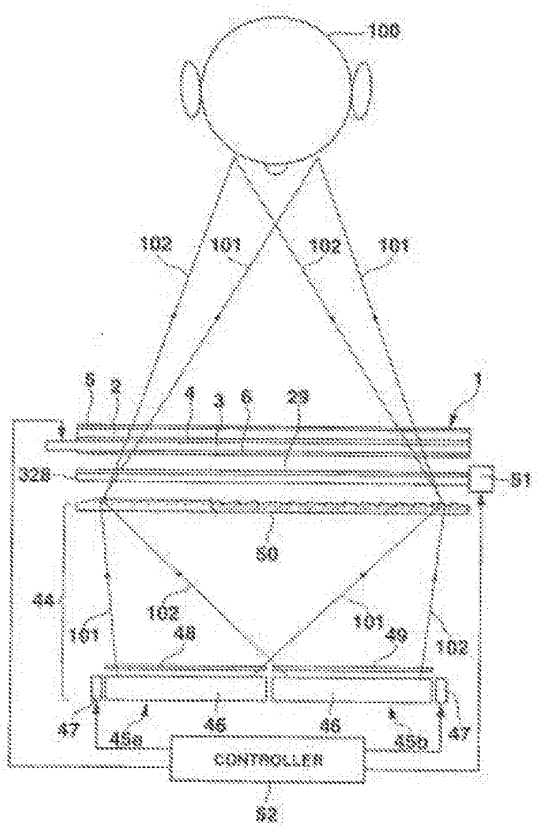

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JP,2007-094035,A

PAJ Detail Image
CLAIMS DETAILED DESCRIPTION
DRAWINGS

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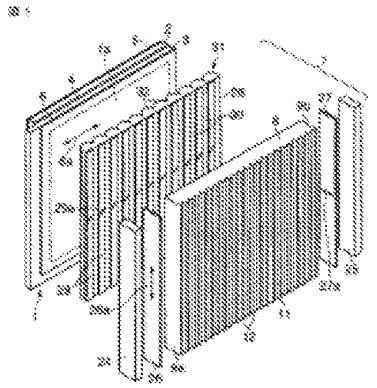
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
This invention relates to the liquid crystal display which displays the surface light source and the aforementioned three dimensional image for displaying a three-dimensional three dimensional image on a liquid crystal display.
[Background of the Invention]
[0002]
As a liquid crystal display which displays a three dimensional image, Among a plurality of pixel rows which were along the vertical direction of the screen of a liquid crystal display panel conventionally, Display the image for left eyes by each pixel of the pixel row in every other one, and it displays the image for right eyes by each pixel of the pixel row in other every other one, The lenticular lens which distributes the emitted light from the pixel row in aforementioned every other one, and the emitted light from the pixel row in other every other one in the direction of a left eye and the direction of a right eye of a display observer for the image for left eyes, and the image for right eyes, Or there is a thing made it a plurality of permeation parts and shade parts parallel to the aforementioned pixel row make an observer's left eye and right eye observe via the parallax barrier which arranged alternately and was formed in stripe shape (a Patent document 1, 2, three references).
[Patent document 1] The publication-number 3 No. -119889 gazette
[Patent document 2] The publication-number 7 No. -005455 gazette
[Patent document 3] Japanese Published Patent Application No. H10-268230 (JP H10-268230A)
[Description of the Invention]
[Problem to be solved by the invention]
[0003]
An object of this invention is to provide the surface light source which can obtain the liquid crystal display which displays a three dimensional image by a different new system from the former. An object of this invention is to provide the liquid crystal display which can display the aforementioned three dimensional image by a new system.
[Means for solving problem]
[0004]
The surface light source of this invention,
A light guide means by which has a reflective surface which turns to the aforementioned emission face the incidence part in which light is entered, the emission face to which the light which entered from the aforementioned incidence part is emitted, and the light which entered from the aforementioned incidence part, and it reflects, draws the light which entered from the aforementioned incidence part, and it is emitted from the aforementioned emission face,
The 1st which makes oppose to the aforementioned incidence part of the aforementioned light guide means, is arranged, and is turned on selectively, and a second photogen,
The 1st which has a transmission axis in one direction, made the above-mentioned 1st and second photogen's outgoing radiation side and each transmission axis cross at right angles substantially, respectively, and is arranged, and a second linear polarization element,
The phase difference element which formed alternately a plurality of lambda / 2 phase-contrast parts which give 1/2 wave of phase contrast between the ordinary light of the transmitted light, and extraordinary light, and a plurality of non-phase contrast parts which do not have phase



Representative drawing

Representative drawing | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 11 | 12 | 13 | 14 | 15 | 16

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contrast substantially in the direction which made oppose to the emission face of the aforementioned light guide means, has been arranged, and met the emission face of the aforementioned light guide means,
An opposite side provides with the side which opposes to the aforementioned light guide means of the aforementioned phase difference element, It has a plurality of lenses which correspond to a plurality of regions which consist of every one lambda / 2 phase contrast parts, and non-phase contrast part which the aforementioned phase difference element adjoins, respectively, It is emitted from the emission face of the aforementioned light guide means, and the light which transmitted lambda / 2 phase contrast parts of said plurality of regions of the aforementioned phase difference element is emitted to the first emission direction that inclined in one direction to the direction defined preliminarily, It has a lens array which emits the light which transmitted the non-phase contrast part of said plurality of regions to the second emission direction leaning to the counter direction to the above-mentioned direction defined preliminarily with aforementioned one direction,
By one lighting of the 1st [above-mentioned] and a second photogen, emit one side of the linear polarization of two directions which intersect perpendicularly substantially to the above-mentioned first emission direction, emit the linear polarization of another side to the above-mentioned second emission direction, respectively, and by lighting of the photogen of another side, Aforementioned one linear polarization is emitted to the above-mentioned second emission direction, and the linear polarization of aforementioned another side is emitted to the above-mentioned first emission direction.
[0005]
A first liquid crystal display of this invention,
The liquid crystal display panel which a polarizing plate is arranged in a viewing side and its opposite side, respectively, a plurality of pixels which control the penetration of light have the screen area arranged to matrix form, and image data is written in said plurality of pixels, and displays the image according to the image data,
A light guide means by which has a reflective surface which turns to the aforementioned emission face the incidence part in which light is entered, the emission face to which the light which entered from the aforementioned incidence part is emitted, and the light which entered from the aforementioned incidence part, and it reflects, draws the light which entered from the aforementioned incidence part, and it is emitted from the aforementioned emission face, The 1st which makes oppose to the aforementioned incidence part of the aforementioned light guide means, is arranged, and is turned on selectively, and a second photogen, The 1st which has a transmission axis in one direction, made the above-mentioned 1st and second photogen's outgoing radiation side and each transmission axis cross at right angles substantially, respectively, and is arranged, and a second linear polarization element, In the direction which made oppose to the emission face of the aforementioned light guide means, has been arranged, and met the emission face of the aforementioned light guide means, The phase difference element which formed alternately a plurality of lambda / 2 phase-contrast parts which give 1/2 wave of phase contrast, and a plurality of non-phase contrast parts which do not have phase contrast substantially between the ordinary light of the transmitted light, and extraordinary light, An opposite side provides with the side which opposes to the aforementioned light guide means of the aforementioned phase difference element, It has a plurality of lenses which correspond to a plurality of regions which consist of every one lambda / 2 phase contrast parts, and non-phase contrast part which the aforementioned phase difference element adjoins, respectively, It is emitted from the emission face of the aforementioned light guide means, and the light which transmitted lambda / 2 phase contrast parts of said plurality of regions of the aforementioned phase difference element is emitted to the first emission direction that inclined in one direction to the direction defined preliminarily, It has a lens array which emits the light which transmitted the non-phase contrast part of said plurality of regions to the second emission direction leaning to the counter direction to the above-mentioned direction defined preliminarily with aforementioned one direction, The aforementioned lens array is made to oppose to the aforementioned liquid crystal display panel in an opposite side with the viewing side of the aforementioned liquid crystal display panel. And one side of the 1st [above-mentioned] and a second emission direction is turned in the direction which inclined in a display observer's direction of a left eye to the normal line direction of the aforementioned liquid crystal display panel, The emission direction of another side is arranged towards the direction which inclined in the aforementioned observer's direction of a right eye to the aforementioned normal line direction, and by one lighting of the 1st [above-mentioned] and a second photogen, Emit the linear polarization which intersects perpendicularly substantially linear polarization substantially parallel to the transmission axis of the opposite side polarizing plate of the aforementioned liquid crystal display panel in the aforementioned left eye direction with the transmission axis of the aforementioned opposite side polarizing plate in the aforementioned right eye direction, and by lighting of the photogen of another side, The surface light source which emits the transmission axis of the aforementioned opposite side polarizing plate, and substantially parallel linear polarization in the aforementioned left eye direction for the linear polarization which intersects perpendicularly with the transmission axis of the aforementioned opposite side polarizing plate substantially in the aforementioned right eye direction,
The image data for left eyes and the image data for right eyes for displaying a three dimensional image on a plurality of pixels of the aforementioned liquid crystal display panel are written in alternately, It had the driving means which makes it synchronize with the writing of the aforementioned image data for left eyes, makes aforementioned one photogen of the aforementioned surface light source turn on, makes it synchronize with the writing of the aforementioned image data for left eyes, and makes the photogen of another side of the aforementioned surface light source turn on.
[0006]

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In this first liquid crystal display, the aforementioned light guide means of the aforementioned surface light source, From the emission face, emit the light which had the directivity in which the peak of emitted light strength exists in the normal line direction of the aforementioned liquid crystal display panel, and the aforementioned lens array, One side of the light which transmitted lambda / 2 phase contrast parts of a plurality of regions of the aforementioned phase difference element, and the light which transmitted the non-phase contrast part, It is preferable for it to be emitted in the direction of the angle range where the peak of emitted light strength exists in the aforementioned left eye direction to the normal line direction of the aforementioned liquid crystal display panel, and to emit the light of another side in the direction of the angle range where the peak of emitted light strength exists in the aforementioned right eye direction to the aforementioned normal line direction.

[0007]

A second liquid crystal display of this invention,

The liquid crystal display panel which a polarizing plate is arranged in a viewing side and its opposite side, respectively, a plurality of pixels which control the penetration of light have the screen area arranged to matrix form, and image data is written in said plurality of pixels, and displays the image according to the image data,

With the viewing side of the aforementioned liquid crystal display panel, it is arranged in an opposite side and turns to the aforementioned liquid crystal display panel, The light source which irradiates selectively the second illumination light which consists of linear polarization substantially parallel to the first illumination light which consists of the linear polarization which intersects perpendicularly with the transmission axis of the opposite side polarizing plate of the aforementioned liquid crystal display panel substantially, and the transmission axis of the aforementioned opposite side polarizing plate,

Among a plurality of regions divided for a number of every pixels which have been arranged between the aforementioned light source and the aforementioned liquid crystal display panel, and provided preliminarily the screen area of the aforementioned liquid crystal display panel in the right and left directions of the aforementioned screen, The phase difference element in which a plurality of non-phase contrast parts which make correspond to the first region in every other one, respectively, and form a plurality of lambda / 2 phase-contrast parts which give 1/2 wave of phase contrast between the ordinary light of the transmitted light and extraordinary light, and it is made to correspond to the second region in other every other one, respectively, and do not have phase contrast substantially were formed,

Each pixel respectively corresponding to the first region in aforementioned every other { the inside of a plurality of pixels of the aforementioned liquid crystal display panel, and } one, The image data for left eyes and the image data for right eyes for displaying a three dimensional image on each pixel respectively corresponding to the second region in other every other one are written in alternately, Each pixel respectively corresponding to { make it synchronize with the writing of these image data, make the above-mentioned first illumination light irradiate from the aforementioned light source, and } the first region in aforementioned every other one, It had the driving means which writes alternately the image data for right eyes, and the image data for left eyes in each pixel respectively corresponding to the second region in every other { besides the above } one, synchronizes it with the writing of these image data, and makes the above-mentioned second illumination light irradiate to it from the aforementioned light source.

[0008]

In this second liquid crystal display, the aforementioned driving means, Each pixel respectively corresponding to the first region in aforementioned { of the aforementioned liquid crystal display panel } every other one to a first display period, The image data for left eyes and the image data for right eyes are alternately written in each pixel respectively corresponding to the second region in every other { besides the above } one, It is preferable to write alternately the image data for right eyes and the image data for left eyes in the second display period which follows the above-mentioned first display period at each pixel respectively corresponding to the above-mentioned first region of the aforementioned liquid crystal display panel and each pixel respectively corresponding to the above-mentioned second region.

[0009]

The 3rd liquid crystal display of this invention,

The liquid crystal display panel which a polarizing plate is arranged in a viewing side and its opposite side, respectively, a plurality of pixels which control the penetration of light have the screen area arranged to matrix form, and image data is written in said plurality of pixels, and displays the image according to the image data,

With the viewing side of the aforementioned liquid crystal display panel, it is arranged in an opposite side and turns to the aforementioned liquid crystal display panel, It consists of linear polarization which intersects perpendicularly with the transmission axis of the opposite side polarizing plate of the aforementioned liquid crystal display panel substantially, And the first illumination light that had the directivity in which the peak of emitted light strength exists in the direction which inclined in the direction of the eye of either right or left of a display observer to the normal line direction of the aforementioned liquid crystal display panel, The light source which irradiates selectively the second illumination light which had the directivity in which the peak of emitted light strength exists in the direction which consisted of linear polarization substantially parallel to the transmission axis of the aforementioned opposite side polarizing plate, and inclined in the direction of the eye of the aforementioned observer's another side to the aforementioned normal line direction,

Among a plurality of regions divided for a number of every pixels which have been arranged between the aforementioned light source and the aforementioned liquid crystal display panel, and provided preliminarily the screen area of the aforementioned liquid crystal display panel in the vertical direction of the aforementioned screen, The phase difference element in which a plurality of non-phase contrast parts which make correspond to the first region in every other one, respectively, and form a plurality of lambda / 2 phase-contrast parts which give 1/2 wave

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of phase contrast between the ordinary light of the transmitted light and extraordinary light, and it is made to correspond to the second region in other every other one, respectively, and do not have phase contrast substantially were formed,
The phase difference element transportation device which moves the aforementioned phase difference element to the vertical direction of the screen of the aforementioned liquid crystal display panel by the stroke corresponding to the pitch of aforementioned lambda / 2 phase contrast parts, and a non-phase contrast part, and makes said plurality of lambda / 2 phase contrast parts, and non-phase contrast parts oppose to the above-mentioned first region and the second region of the aforementioned liquid crystal display panel alternately,
When aforementioned lambda / 2 phase contrast parts of the aforementioned phase difference element are made to oppose to the first region in aforementioned [of the aforementioned liquid crystal display panel] every other one and the aforementioned non-phase contrast part is made to oppose to the second region in every other [besides the above] one, The image data for left eyes of the image data for the right and left eyes for displaying a three dimensional image on each pixel of the above-mentioned first region among a plurality of pixels of the aforementioned liquid crystal display panel is written in, Write the image data for right eyes in each pixel of the above-mentioned second region, make it synchronize with the writing of these image data, and it makes the 1st [above-mentioned] and the second illumination light irradiate from the aforementioned light source. When aforementioned lambda / 2 phase contrast parts of the aforementioned phase difference element are made to oppose to the above-mentioned second region of the aforementioned liquid crystal display panel and the aforementioned non-phase contrast part is made to oppose to the above-mentioned first region, It had the driving means to which write the image data for right eyes in each pixel of the above-mentioned first region of the aforementioned liquid crystal display panel, write the image data for left eyes in each pixel of the above-mentioned second region, make it synchronize with the writing of these image data, and it makes the 1st [above-mentioned] and the second illumination light irradiate from the aforementioned light source.
[0010]
In this 3rd liquid crystal display, the aforementioned driving means, At a first display period to each pixel of the first region in aforementioned [of the aforementioned liquid crystal display panel] every other one, and each pixel of the second region in every other [besides the above] one, It is preferable to write in alternately the image data for left eyes and the image data for right eyes, and to write alternately the image data for right eyes and the image data for left eyes in each pixel of the above-mentioned first region of the aforementioned liquid crystal display panel and each pixel of the above-mentioned second region at the second display period which follows the above-mentioned first display period.
[0011]
The 4th liquid crystal display of this invention,
The liquid crystal display panel which a polarizing plate is arranged in a viewing side and its opposite side, respectively, a plurality of pixels which control the penetration of light have the screen area arranged to matrix form, and image data is written in said plurality of pixels, and displays the image according to the image data,
The light source which is arranged in an opposite side and irradiates the illumination light towards the aforementioned liquid crystal display panel with the viewing side of the aforementioned liquid crystal display panel,
Among a plurality of regions divided for a number of every pixels which have been arranged at the viewing side of the aforementioned liquid crystal display panel, and provided preliminarily the screen area of the aforementioned liquid crystal display panel in the right and left directions of the aforementioned screen, The phase difference element in which a plurality of non-phase contrast parts which make correspond to the first region in every other one, respectively, and form a plurality of lambda / 2 phase-contrast parts which give 1/2 wave of phase contrast between the ordinary light of the transmitted light and extraordinary light, and it is made to correspond to the second region in other every other one, respectively, and do not have phase contrast substantially were formed,
The image data for one eyes of the image data for the right and left eyes for displaying a three dimensional image on each pixel corresponding to a plurality of lambda / 2 phase-contrast parts of the aforementioned phase difference element among a plurality of pixels of the aforementioned liquid crystal display panel is written in, The driving means which writes the image data for the eyes of another side in each pixel corresponding to a plurality of non-phase contrast parts of the aforementioned phase difference element,
The linear polarization element for left eyes which makes the light which transmitted one side of a plurality of lambda / 2 phase-contrast parts of the aforementioned phase difference element, and a non-phase contrast part among the image light which consists of the linear polarization emitted from the aforementioned liquid crystal display panel, and was emitted to the viewing side transmit, It had the polarization eyeglass for observation which has a linear polarization element for right eyes which makes the light which transmitted another side of a plurality of lambda / 2 phase-contrast parts of the aforementioned phase difference element, and a non-phase contrast part, and was emitted to the aforementioned viewing side transmit.
[0012]
As for a plurality of lambda / 2 phase contrast parts, and non-phase contrast parts of the aforementioned phase difference element, in this 4th liquid crystal display, it is preferable to make the screen area of the aforementioned liquid crystal display panel alternately equivalent to a plurality of regions divided into the right and left directions of the aforementioned screen for every pixel, and to form it in them.
[Effect of the Invention]
[0013]
The surface light source of this invention has a reflective surface which turns to the aforementioned emission face the incidence part in which light is entered, the emission face to

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which the light which entered from the aforementioned incidence part is emitted, and the light which entered from the aforementioned incidence part, and it reflects, A light guide means by which draws the light which entered from the aforementioned incidence part, and it is emitted from the aforementioned emission face, The 1st which makes oppose to the aforementioned incidence part of the aforementioned light guide means, is arranged, and is turned on selectively, and a second photogen, The 1st which has a transmission axis in one direction, made the above-mentioned 1st and second photogen's outgoing radiation side and each transmission axis cross at right angles substantially, respectively, and is arranged, and a second linear polarization element, The phase difference element which formed alternately a plurality of lambda / 2 phase contrast parts, and non-phase contrast parts in the direction which made oppose to the emission face of the aforementioned light guide means, has been arranged, and met the emission face of the aforementioned light guide means, An opposite side provides with the side which opposes to the aforementioned light guide means of the aforementioned phase difference element, It has a plurality of lenses which correspond to a plurality of regions which consist of every one lambda / 2 phase contrast parts, and non-phase contrast part which the aforementioned phase difference element adjoins, respectively, It is emitted from the emission face of the aforementioned light guide means, and the light which transmitted lambda / 2 phase contrast parts of said plurality of regions of the aforementioned phase difference element is emitted to the first emission direction that inclined in one direction to the direction defined preliminarily, Have a lens array which emits the light which transmitted the non-phase contrast part of said plurality of regions to the second emission direction leaning to the counter direction to the above-mentioned direction defined preliminarily with aforementioned one direction, and by one lighting of the 1st [above-mentioned] and a second photogen, Emit one side of the linear polarization of two directions which intersect perpendicularly substantially to the above-mentioned first emission direction, emit the linear polarization of another side to the above-mentioned second emission direction, respectively, and by lighting of the photogen of another side, Since it is what emits aforementioned one linear polarization to the above-mentioned second emission direction, and emits the linear polarization of aforementioned another side to the above-mentioned first emission direction, When the viewing side of the liquid crystal display panel which has arranged the polarizing plate to a viewing side and its opposite side, respectively arranges this surface light source to an opposite side, The image data for left eyes and the image data for right eyes are alternately written in a plurality of pixels of the aforementioned liquid crystal display panel, The liquid crystal display which makes it synchronize with the writing of the aforementioned image data for left eyes, makes aforementioned one photogen of the aforementioned surface light source turn on, makes it synchronize with the writing of the aforementioned image data for left eyes, makes the photogen of another side of the aforementioned surface light source turn on, and displays a three dimensional image can be obtained.

[0014]

As for the first liquid crystal display of this invention, a polarizing plate is arranged in a viewing side and its opposite side, respectively, A plurality of pixels which control the penetration of light have the screen area arranged to matrix form, With the viewing side of the liquid crystal display panel which image data is written in said plurality of pixels, and displays the image according to the image data, to an opposite side, The lens array is made for the surface light source of the aforementioned composition to oppose to the aforementioned liquid crystal display panel. And one side of the 1st [above-mentioned] and a second emission direction is turned in the direction which inclined in a display observer's direction of a left eye to the normal line direction of the aforementioned liquid crystal display panel, The emission direction of another side is turned in the direction which inclined in the aforementioned observer's direction of a right eye to the aforementioned normal line direction, Substantially the transmission axis of the opposite side polarizing plate of the aforementioned liquid crystal display panel, and parallel linear polarization by one lighting of the 1st [above-mentioned] and a second photogen in the aforementioned left eye direction, The linear polarization which intersects perpendicularly with the transmission axis of the aforementioned opposite side polarizing plate substantially is emitted in the aforementioned right eye direction, In the aforementioned left eye direction, arrange the linear polarization which intersects perpendicularly with the transmission axis of the aforementioned opposite side polarizing plate substantially by lighting of the photogen of another side so that linear polarization substantially parallel to the transmission axis of the aforementioned opposite side polarizing plate may be emitted in the aforementioned right eye direction, and in it by the aforementioned driving means, The image data for left eyes and the image data for right eyes are alternately written in a plurality of pixels of the aforementioned liquid crystal display panel, In order to make it synchronize with the writing of the aforementioned image data for left eyes, to make aforementioned one photogen of the aforementioned surface light source turn on, to make it synchronize with the writing of the aforementioned image data for left eyes and to make it make the photogen of another side of the aforementioned surface light source turn on, A high quality three dimensional image with high resolution of both the image for left eyes and the image for right eyes can be displayed.

[0015]

In this first liquid crystal display, the aforementioned light guide means of the aforementioned surface light source, From the emission face, emit the light which had the directivity in which the peak of emitted light strength exists in the normal line direction of the aforementioned liquid crystal display panel, and the aforementioned lens array, One side of the light which transmitted lambda / 2 phase contrast parts of a plurality of regions of the aforementioned phase difference element, and the light which transmitted the non-phase contrast part, It is emitted in the direction of the angle range where the peak of emitted light strength exists in the aforementioned left eye direction to the normal line direction of the aforementioned liquid crystal display panel, It is preferable to emit the light of another side in the direction of the angle range where the peak of emitted light strength exists in the aforementioned right eye

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direction to the aforementioned normal line direction, and it can display a high more nearly quality three dimensional image with both high luminance and contrast of the aforementioned image for left eyes, and the image for right eyes by doing in this way.

[0016]

With the viewing side of the aforementioned liquid crystal display panel, the second liquid crystal display of this invention to an opposite side, The light source which irradiates selectively the second illumination light which consists of linear polarization substantially parallel to the first illumination light which consists of the linear polarization which intersects perpendicularly with the transmission axis of the opposite side polarizing plate of the aforementioned liquid crystal display panel substantially, and the transmission axis of the aforementioned opposite side polarizing plate is arranged towards the aforementioned liquid crystal display panel, Among a plurality of regions which divided the screen area of the aforementioned liquid crystal display panel between the aforementioned light source and the aforementioned liquid crystal display panel for a number of every pixels preliminarily provided in the right and left directions of the aforementioned screen, Arrange the phase difference element which made it correspond to the first region in every other one, respectively, formed a plurality of lambda / 2 phase-contrast parts, made it correspond to the second region in other every other one, respectively, and formed the non-phase contrast part in it, and by the aforementioned driving means, Each pixel respectively corresponding to the first region in aforementioned every other [the inside of a plurality of pixels of the aforementioned liquid crystal display panel, and] one, The image data for left eyes and the image data for right eyes for displaying a three dimensional image on each pixel respectively corresponding to the second region in other every other one are written in alternately, Each pixel respectively corresponding to [make it synchronize with the writing of these image data, make the above-mentioned first illumination light irradiate from the aforementioned light source, and] the first region in aforementioned every other one, The image data for right eyes and the image data for left eyes are alternately written in each pixel respectively corresponding to the second region in every other [besides the above] one, Since it is made to synchronize with the writing of these image data and is made to make the above-mentioned second illumination light irradiate from the aforementioned light source, a high quality three dimensional image with high resolution of both the image for left eyes and the image for right eyes can be displayed.

[0017]

In this second liquid crystal display, the aforementioned driving means, Each pixel respectively corresponding to the first region in aforementioned [of the aforementioned liquid crystal display panel] every other one to a first display period, The image data for left eyes and the image data for right eyes are alternately written in each pixel respectively corresponding to the second region in every other [besides the above] one, Each pixel respectively corresponding to the above-mentioned first region of the aforementioned liquid crystal display panel to the second display period which follows the above-mentioned first display period, The high more nearly quality three dimensional image which makes high the driving duty of the aforementioned liquid crystal display panel, and does not have a flicker in each pixel respectively corresponding to the above-mentioned second region when it is preferable to write in alternately and it carries out the image data for right eyes and the image data for left eyes in this way can be displayed.

[0018]

With the viewing side of the aforementioned liquid crystal display panel, the 3rd liquid crystal display of this invention to an opposite side, It consists of linear polarization which intersects perpendicularly with the transmission axis of the opposite side polarizing plate of the aforementioned liquid crystal display panel substantially towards the aforementioned liquid crystal display panel, And the first illumination light that had the directivity in which the peak of emitted light strength exists in the direction which inclined in the direction of the eye of either right or left of a display observer to the normal line direction of the aforementioned liquid crystal display panel, The light source which irradiates selectively the second illumination light which had the directivity in which the peak of emitted light strength exists in the direction which consisted of linear polarization substantially parallel to the transmission axis of the aforementioned opposite side polarizing plate, and inclined in the direction of the eye of the aforementioned observer's another side to the aforementioned normal line direction is arranged, Among a plurality of regions which divided the screen area of the aforementioned liquid crystal display panel between the aforementioned light source and the aforementioned liquid crystal display panel for a number of every pixels preliminarily provided in the vertical direction of the aforementioned screen, The phase difference element which made it correspond to the first region in every other one, respectively, formed a plurality of lambda / 2 phase-contrast parts, made it correspond to the second region in other every other one, respectively, and formed the non-phase contrast part in it is arranged, Move the aforementioned phase difference element to the vertical direction of the screen of the aforementioned liquid crystal display panel by the aforementioned phase difference element transportation device, and it makes said plurality of lambda / 2 phase contrast parts, and non-phase contrast parts oppose to the above-mentioned first region and the second region of the aforementioned liquid crystal display panel alternately. When aforementioned lambda / 2 phase contrast parts of the aforementioned phase difference element are made to oppose to the first region in aforementioned [of the aforementioned liquid crystal display panel] every other one and the aforementioned non-phase contrast part is made to oppose to the second region in every other [besides the above] one by the aforementioned driving means, The image data for left eyes is written in each pixel of the above-mentioned first region among a plurality of pixels of the aforementioned liquid crystal display panel, Write the image data for right eyes in each pixel of the above-mentioned second region, make it synchronize with the writing of these image data, and it makes the 1st [above-mentioned] and the second illumination light irradiate from the aforementioned light source. When aforementioned lambda / 2 phase

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contrast parts of the aforementioned phase difference element are made to oppose to the above-mentioned second region of the aforementioned liquid crystal display panel and the aforementioned non-phase contrast part is made to oppose to the above-mentioned first region, The image data for right eyes is written in each pixel of the above-mentioned first region of the aforementioned liquid crystal display panel, In order to write the image data for left eyes in each pixel of the above-mentioned second region, to make it synchronize with the writing of these image data and to make it make the 1st [above-mentioned] and the second illumination light irradiate from the aforementioned light source, with high resolution of both the image for left eyes, and the image for right eyes. A high quality three dimensional image can be displayed.

[0019]

In this 3rd liquid crystal display, the aforementioned driving means, At a first display period to each pixel of the first region in aforementioned [of the aforementioned liquid crystal display panel] every other one, and each pixel of the second region in every other [besides the above [one, At the second display period which writes in alternately the image data for left eyes, and the image data for right eyes, and follows the above-mentioned first display period, When it is preferable to write alternately the image data for right eyes and the image data for left eyes in each pixel of the above-mentioned first region of the aforementioned liquid crystal display panel and each pixel of the above-mentioned second region and it does in this way, The high more nearly quality three dimensional image which makes high the driving duty of the aforementioned liquid crystal display panel, and does not have a flicker can be displayed.

[0020]

With the viewing side of the aforementioned liquid crystal display panel, the 4th liquid crystal display of this invention to an opposite side, Arrange the light source which irradiates the illumination light towards the aforementioned liquid crystal display panel, and to the viewing side of the aforementioned liquid crystal display panel, Among a plurality of regions divided for a number of every pixels which provided preliminarily the screen area of the aforementioned liquid crystal display panel in the right and left directions of the aforementioned screen, Arrange the phase difference element which made it correspond to the first region in every other one, respectively, formed a plurality of lambda / 2 phase-contrast parts, made it correspond to the second region in other every other one, respectively, and formed a plurality of non-phase contrast parts in it, and by the aforementioned driving means, The image data for one eyes of the image data for the right and left eyes for displaying a three dimensional image on each pixel corresponding to a plurality of lambda / 2 phase-contrast parts of the aforementioned phase difference element among a plurality of pixels of the aforementioned liquid crystal display panel is written in, The image data for the eyes of another side is written in each pixel corresponding to a plurality of non-phase contrast parts of the aforementioned phase difference element, The linear polarization element for left eyes which makes the light which transmitted one side of a plurality of lambda / 2 phase-contrast parts of the aforementioned phase difference element, and a non-phase contrast part among the image light which consists of the linear polarization emitted from the aforementioned liquid crystal display panel, and was emitted to the viewing side transmit, Since it is made to make it observe with the polarization eyeglass for observation which has a linear polarization element for right eyes which makes the light which transmitted another side of a plurality of lambda / 2 phase-contrast parts of the aforementioned phase difference element, and a non-phase contrast part, and was emitted to the aforementioned viewing side transmit, a three dimensional image can be displayed.

[0021]

In this 4th liquid crystal display, a plurality of lambda / 2 phase contrast parts, and non-phase contrast parts of the aforementioned phase difference element, it is preferable to make the screen area of the aforementioned liquid crystal display panel alternately equivalent to a plurality of regions divided for every pixel, and to form it in the right and left directions of the aforementioned screen, and it can display three dimensional images with sufficient resolution of both the image for left eyes, and the image for right eyes by doing in this way.

[Best Mode of Carrying Out the Invention]

[0022]

(First embodiment)

Fig.1 - Fig.7 show the first working example of this invention, Fig.1 is an exploded perspective view of a liquid crystal display, and Fig.2 is a plan view of the aforementioned liquid crystal display.

[0023]

This liquid crystal display is provided with the following.

The polarizing plates 5 and 6 are arranged like Fig.1 and Fig.2 in a viewing side (in Fig.2, it is the upper part), and its opposite side, respectively, The liquid crystal display panel 1 which a plurality of pixels (not shown) which control a penetration of light have the screen area 1a arranged to matrix form in a line writing direction and a line direction, and image data is written in said plurality of pixels, and displays an image according to the image data.

The surface light source 7 arranged with a viewing side of the aforementioned liquid crystal display panel in an opposite side.

The driving means 33 of the aforementioned liquid crystal display panel 1 and the surface light source 7.

[0024]

The aforementioned liquid crystal display panel 1 is an active-matrix liquid crystal display panel, The internal structure is among the inner surfaces to which the pair of transparent bases 2 and 3 joined via the sealing material 4 of frame shape oppose although not illustrated. A plurality of transparent picture element electrodes which made the line writing direction (right and left directions of a screen), and the line direction (vertical direction of a screen) arrange to matrix form, and were formed in them with one substrate, for example, a viewing side, at the inner

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surface of the substrate 3 of an opposite side, A plurality of TFT(s) (thin film transistor) connected to these picture element electrodes, respectively, A plurality of gate wires which supply a gating signal to TFT of each line, and a plurality of data wiring which supplies an image data signal to TFT of each sequence are provided, The transparent counterelectrode of the shape of an one-sheet film which opposes to said plurality of picture element electrodes is provided by the inner surface of the substrate (substrate of a viewing side) 2 of another side, and the liquid crystal layer is enclosed with the region surrounded with the aforementioned sealing material 4 between the above-mentioned pair of substrates 2 and 3.

[0025]

This liquid crystal display panel 1 is the TN type thing which carried out twist orientation of the liquid crystal element of the aforementioned liquid crystal layer on the twist square of 90 degrees substantially between the above-mentioned pair of substrates 2 and 3, that viewing side polarizing plate 5 and opposite side polarizing plate 6 make each transmission axis intersect perpendicularly, or parallel are used and they are arranged. In Fig.1, 6a is a transmission axis of the aforementioned opposite side polarizing plate 6.

[0026]

The aforementioned surface light source 7 is provided with the following.

It has the reflective surface 11 which turns to the aforementioned emission face 10 the incidence parts 9a and 9b in which light is entered, the emission face 10 to which the light which entered from the aforementioned incidence parts 9a and 9b is emitted, and the light which entered from the aforementioned incidence parts 9a and 9b, and it reflects, The light guide means 8 by which draws light which entered from the aforementioned incidence parts 9a and 9b, and it is emitted from the aforementioned emission face 10.

The 1st which makes oppose to the incidence parts 9a and 9b of the aforementioned light guide means 8, is arranged, and is turned on selectively, and the second photogens 24 and 25.

The 1st which has the transmission axes 26a and 27a in one direction, made the above-mentioned 1st and second photogens 24 and 25 outgoing radiation side and each transmission axes 26a and 27a cross at right angles substantially, respectively, and is arranged, and the second linear polarization elements 26 and 27.

The lens array 31 by which the phase difference element 28 which made oppose to the emission face 10 of the aforementioned light guide means 8, and is arranged, and a side which opposes to the aforementioned light guide means 8 of the aforementioned phase difference element 28 were provided by opposite side.

[0027]

The aforementioned light guide means 8 consists of transparent sheets, such as an acrylic resin plate which has the plane shape of the rectangular shape corresponding to the screen area 1a of the aforementioned liquid crystal display panel 1, The incidence parts 9a and 9b are formed in the two end faces which oppose mutually, respectively, the emission face 10 is formed in one side of two plate surfaces, and the reflective surface 11 which turns to the aforementioned emission face 10 the light which entered into the plate surface of another side from the aforementioned incidence parts 9a and 9b, and it reflects is formed. Hereinafter, this light guide means 8 is called light guide plate, and those incidence parts 9a and 9b are called incident end face.

[0028]

The emission face 10 of this light guide plate 8 is formed in the flat surface, and a plurality of elongated grooves 12 of linear shape substantially parallel to the length direction of the aforementioned incident end faces 9a and 9b, i.e., the cross direction of the light guide plate 8, are formed in the reflective surface 11 at constant pitch in the length direction of the aforementioned light guide plate 8.

[0029]

The aforementioned light guide plate 8 is led in the length direction of the light guide plate 8, carrying out internal reflection of the light which entered from the aforementioned incident end faces 9a and 9b according to the flat surface part and the aforementioned emission face 10 between each elongated groove 12 of the aforementioned reflective surface 11, Internal reflection of the light which entered into each elongated groove 12 of the aforementioned reflective surface 11 is carried out in the direction to which the angle to the normal line direction of the aforementioned emission face 10 becomes small according to the groove surface of the aforementioned elongated groove 12, and it is made to emit from the aforementioned emission face 10.

[0030]

Each elongated groove 12 of the reflective surface 11 of this light guide plate 8, it is formed in the sectional shape of the shape of an isosceles triangle which has two groove surfaces which inclined in one direction of incident end face 9a, and the direction of incident end face 9b of another side at an angle of 45 degrees substantially to the normal line direction of the aforementioned emission face 10, respectively, Internal reflection of the light which entered from one incident end face 9a of the aforementioned light guide plate 8 is carried out in the direction near the normal of the aforementioned emission face 10 according to the groove surface on aforementioned one incident end face 9a side, Internal reflection of the light which entered from the incident end face 9b of another side of the aforementioned light guide plate 8 is carried out in the direction near the normal of the aforementioned emission face 10 according to the groove surface on the incident end face 9b side of aforementioned another side.

[0031]

Therefore, the light which enters into the aforementioned light guide plate 8 from the incident end face 9a of one of these and the incident end face 9b of another side, and it emits from the emission face 10 of the aforementioned light guide plate 8 is the light which had the directivity in which the peak of emitted light strength exists in the normal line direction of the aforementioned emission face 10, respectively.

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[0032]
Although the elongated groove 12 of the reflective surface 11 of the aforementioned light guide plate 8 is exaggerated largely by a diagram, The light which is formed in the pitch smaller than it in which the aforementioned elongated groove 12 is comparable as the picture element pitch of the aforementioned liquid crystal display panel 1, therefore is emitted from the emission face 10 of the aforementioned light guide plate 8 is the light of uniform intensity distribution without strength unevenness.
[0033]
The 1st [above-mentioned] and the second photogens 24 and 25 consist of a light emitting element array which arranged a plurality of solid light emitting devices, such as LED (light emitting diode), make the emission face oppose to one incident end face 9a of the aforementioned light guide plate 8, and the incident end face 9b of another side, respectively, and are arranged.
[0034]
The 1st [above-mentioned] and the second linear polarization elements 26 and 27. Between the above-mentioned first photogens 24 that are formed in the form corresponding to the incident end faces 9a and 9b of the aforementioned light guide plate 8, and are arranged at one incident end face 9a and the outside of the aforementioned light guide plate 8, The transmission axes 26a and 27a of each linear polarization element 26 and 27 are made to intersect perpendicularly substantially between the incident end face 9b of another side of the aforementioned light guide plate 8, and the above-mentioned second photogen 25 arranged at the outside, and it is arranged.
[0035]
As shown in Fig.1, in this working example the above-mentioned first linear polarization element 26, The transmission axis 26a was substantially made parallel with the cross direction (the length direction of the incident end faces 9a and 9b) of the aforementioned light guide plate 8, and has been arranged, the transmission axis 27a was substantially made parallel with the board thickness direction (height direction of the incident end faces 9a and 9b) of the aforementioned light guide plate 8, and the above-mentioned second linear polarization element 27 is arranged.
[0036]
The phase difference element 28 which made oppose to the emission face 10 of the aforementioned light guide plate 8, and is arranged, A plurality of lambda / 2 phase-contrast parts 29 which give 1/2 wave of phase contrast in the direction along the emission face 10 of the aforementioned light guide plate 8 between the ordinary light of the transmitted light, and extraordinary light, A plurality of non-phase contrast parts 30 which do not have phase contrast substantially are formed alternately, and said plurality of lambda / 2 phase-contrast parts 29 have the lagging axis 29a in the direction which inclined 45 degrees substantially to the cross direction (the length direction of the incident end faces 9a and 9b) of the aforementioned light guide plate 8, as shown in Fig.1.
[0037]
Namely, the lagging axis 29a of said plurality of lambda / 2 phase-contrast parts 29, The linear polarization which transmits the above-mentioned first linear polarization element 26 from the above-mentioned first photogen 24, and enters into the aforementioned light guide plate 8, and it emits from the emission face 10 of the aforementioned light guide plate 8, The above-mentioned second linear polarization element 27 is transmitted from the above-mentioned second photogen 25, and it enters into the aforementioned light guide plate 8, and crosses at an angle of 45 degrees substantially to the plane of polarization of both of linear polarization emitted from the emission face 10 of the aforementioned light guide plate 8.
[0038]
the width with a plurality of each other same lambda / 2 phase contrast parts 29, and non-phase contrast parts 30 of this phase difference element 28 -- and while met the emission face 10 of the aforementioned light guide plate 8, and it is formed in stripe shape parallel to a direction (the length direction of the incident end faces 9a and 9b), for example, the cross direction of the aforementioned light guide plate 8.
[0039]
Although aforementioned lambda / 2 phase contrast parts 29, and the non-phase contrast part 30 are exaggerated largely by a diagram, this lambda / 2 phase-contrast part 29, and the non-phase contrast part 30 are formed in the smallest possible width and pitch.
[0040]
The aforementioned phase difference element 28 to one surface of the transparent sheet in which birefringence is not substantially shown to the transmitted light, Elongated-shaped lambda / 2 phase difference films which consists of an uniaxial stretched film are put in order and stuck on stripe shape, or [for example,] Or apply or print a polymer liquid crystal to the above-mentioned transparent sheet surface, and it forms a plurality of lambda/2 phase difference layers by while having defined the polymer liquid crystal preliminarily, and carrying out orientation and polymer-izing so that a molecule major axis may be equal to a direction, Said plurality of non-phase contrast parts 30 are formed by the portion which said plurality of lambda / 2 phase-contrast parts 29 are formed by the formation part of these lambda/2 phase difference layers, and does not form the lambda/2 aforementioned phase difference layer of the above-mentioned transparent sheet.
[0041]
The lens array 31 provided by the opposite side with the side which opposes to the aforementioned light guide plate 8 of the aforementioned phase difference element 28, Have a plurality of lenses 32 which correspond to a plurality of regions which consist of every one lambda / 2 phase contrast parts 29, and non-phase contrast part 30 which the aforementioned phase difference element 28 adjoins, respectively, and these lenses 32, It is formed in the elongated shape which has the substantially same width as the sum total width of above-

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mentioned every one adjacent lambda / 2 phase contrast parts 29, and the non-phase contrast part 30 in parallel with the length direction of lambda / 2 phase contrast parts 29, and the non-phase contrast part 30 formed in the aforementioned stripe shape.
[0042]
In this working example, with the surface in which lambda / 2 phase contrast parts 29 of the aforementioned phase difference element 28 were formed, although the aforementioned lens array 31 is integrally formed in the opposite surface, the aforementioned lens array 31 may make what was manufactured separately from the aforementioned phase difference element 28 oppose to the aforementioned phase difference element 28, and may arrange it.
[0043]
The light which emitted the aforementioned lens array 31 from the emission face 10 of the aforementioned light guide plate 8, and transmitted lambda / 2 phase contrast parts 29 of said plurality of regions of the aforementioned phase difference element 28 with said plurality of lenses 32, It is emitted to the first emission direction that inclined in one direction to the direction defined preliminarily, and the light which transmitted the non-phase contrast part 30 of said plurality of regions is emitted to the second emission direction leaning to the counter direction with aforementioned one direction to the above-mentioned direction defined preliminarily with said plurality of lenses 32.
[0044]
In this working example, make into the normal line direction of the emission face 10 of the aforementioned light guide plate 8 the above-mentioned direction defined preliminarily, and are parallel to the normal line direction of the emission face 10 of the aforementioned light guide plate 8 in a plurality of lenses 32 of the aforementioned lens array 31, And it forms in a symmetrical convex lens around the center of the surface passing through the boundary between lambda / 2 phase contrast parts 29 of said plurality of regions, and the non-phase contrast part 30.
[0045]
The aforementioned lens array 31 enters into the aforementioned light guide plate 8 from the incident end faces 9a and 9b, Among the light which was reflected by the groove surface of each elongated groove 12 of the reflective surface 11 of the aforementioned light guide plate 8, and was emitted to the direction near the normal of the emission face 10 to the aforementioned emission face 10 of the aforementioned light guide plate 8, The light which transmitted lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28, It is emitted in the direction of the angle range where the peak of emitted light strength exists in the first emission direction leaning to the counter direction to the normal line direction of the emission face 10 of the aforementioned light guide plate 8 with the aforementioned lambda / 2 phase contrast part 29 side, The light which transmitted the non-phase contrast part 30 of a plurality of regions of the aforementioned phase difference element 28 is emitted in the direction of the angle range where the peak of emitted light strength exists in the second emission direction leaning to the counter direction with the aforementioned non-phase contrast part 30 side to the normal line direction of the emission face 10 of the aforementioned light guide plate 8.
[0046]
Namely, the aforementioned surface light source 7 by one lighting of the 1st [above-mentioned] and the second photogens 24 and 25, One side of the linear polarization of two directions which intersect perpendicularly substantially is emitted to the above-mentioned first emission direction, the linear polarization of another side is emitted to the above-mentioned second emission direction, respectively, by lighting of the photogen of another side, aforementioned one linear polarization is emitted to the above-mentioned second emission direction, and the linear polarization of aforementioned another side is emitted to the above-mentioned first emission direction.
[0047]
Fig.4 and Fig.5 are the emitted light diagrams from the aforementioned surface light source 7, and an emitted light line when Fig.4 makes the above-mentioned first photogen 24 turn on, and Fig.5 show the emitted light line at the time of making the above-mentioned second photogen 25 turn on.
[0048]
Like Fig.4, when the first photogen 24 of the aforementioned surface light source 7 is made to turn on, The light from this first photogen 24 by the above-mentioned first linear polarization element 26, It is considered as the linear polarization S parallel to the transmission axis 26a, enters into the aforementioned light guide plate 8 from the incident end face 9a of one of these, it is reflected by the groove surface on aforementioned one incident end face 9a side of each elongated groove 12 of the reflective surface 11 of the aforementioned light guide plate 8, and is emitted to the direction near the normal of the emission face 10 to the aforementioned emission face 10 of the aforementioned light guide plate 8.
[0049]
The aforementioned linear polarization S emitted from the emission face 10 of the aforementioned light guide plate 8. The light which entered into the aforementioned phase difference element 28, and entered into lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28 among the light, Aforementioned lambda / 2 phase contrast parts 29 which have the lagging axis 29a in 45-degree angular orientation substantially to the plane of polarization, It becomes the linear polarization P which intersects perpendicularly substantially to the linear polarization S which rotated 90 degrees of planes of polarization by this lambda / 2 phase-contrast part 29, transmitted, transmitted the above-mentioned first linear polarization element 26, and entered into the aforementioned light guide plate 8, and enters into the aforementioned lens array 31.
[0050]
The light which entered into the non-phase contrast part 30 of a plurality of regions of the

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aforementioned phase difference element 28 among the lights which were emitted from the emission face 10 of the aforementioned light guide plate 8, and entered into the aforementioned phase difference element 28, It enters into the aforementioned lens array 31 with the linear polarization S which transmitted the aforementioned non-phase contrast part 30, without changing a polarization condition substantially, transmitted the above-mentioned first linear polarization element 26, and entered into the aforementioned light guide plate 8.
[0051]
And one linear polarization P from lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28 among the linear polarization P and S of the two aforementioned directions. It is condensed by the portion corresponding to aforementioned lambda / 2 phase contrast parts 29 of each lens 32 of the aforementioned lens array 31, It is emitted to the first emission direction leaning to the counter direction to the normal line direction of the emission face 10 of the aforementioned light guide plate 8 with the aforementioned lambda / 2 phase contrast part 29 side, The linear polarization S of another side from the non-phase contrast part 30 of a plurality of regions of the aforementioned phase difference element 28. It is condensed by the portion corresponding to the aforementioned non-phase contrast part 30 of each lens 32 of the aforementioned lens array 31, and is emitted to the second emission direction leaning to the counter direction with the aforementioned non-phase contrast part 30 side to the normal line direction of the emission face 10 of the aforementioned light guide plate 8.
[0052]
When the second photogen 25 of the aforementioned surface light source 7 is made to turn on like Fig.5, The light from this second photogen 25 by the above-mentioned second linear polarization element 27, It is considered as the linear polarization P parallel to the transmission axis 27a, enters into the aforementioned light guide plate 8 from the incident end face 9b of the another side, it is reflected by the groove surface on the incident end face 9b side of aforementioned another side of each elongated groove 12 of the reflective surface 11 of the aforementioned light guide plate 8, and is emitted to the direction near the normal of the emission face 10 to the aforementioned emission face 10 of the aforementioned light guide plate 8.
[0053]
The aforementioned linear polarization P emitted from the emission face 10 of the aforementioned light guide plate 8. The light which entered into the aforementioned phase difference element 28, and entered into lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28 among the light, Aforementioned lambda / 2 phase contrast parts 29 which have the lagging axis 29a in 45-degree angular orientation substantially to the plane of polarization, It becomes the linear polarization S which intersects perpendicularly substantially to the linear polarization P which rotated 90 degrees of planes of polarization by this lambda / 2 phase-contrast part 29, transmitted, transmitted the above-mentioned second linear polarization element 27, and entered into the aforementioned light guide plate 8, and enters into the aforementioned lens array 31.
[0054]
The light which entered into the non-phase contrast part 30 of a plurality of regions of the aforementioned phase difference element 28 among the lights which were emitted from the emission face 10 of the aforementioned light guide plate 8, and entered into the aforementioned phase difference element 28, It enters into the aforementioned lens array 31 with the linear polarization P which transmitted the aforementioned non-phase contrast part 30, without changing a polarization condition substantially, transmitted the above-mentioned second linear polarization element 27, and entered into the aforementioned light guide plate 8.
[0055]
And one linear polarization P from the non-phase contrast part 30 of a plurality of regions of the aforementioned phase difference element 28 among the linear polarization P and S of the two aforementioned directions. It is condensed by the portion corresponding to the aforementioned non-phase contrast part 30 of each lens 32 of the aforementioned lens array 31, It is emitted to the second emission direction leaning to the counter direction to the normal line direction of the emission face 10 of the aforementioned light guide plate 8 with the aforementioned non-phase contrast part 30 side, The linear polarization S of another side from lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28. It is condensed by the portion corresponding to aforementioned lambda / 2 phase contrast parts 29 of each lens 32 of the aforementioned lens array 31, and is emitted to the first emission direction leaning to the counter direction with the aforementioned lambda / 2 phase contrast part 29 side to the normal line direction of the emission face 10 of the aforementioned light guide plate 8.
[0056]
the emitted light intensity distribution figure of the linear polarization P and S of the aforementioned two directions when Fig.6 makes the first photogen 24 from the aforementioned surface light source 7 turn on -- Fig.7 -- the above -- the surface light source -- seven -- being second -- a photogen -- 25 -- switching on the light -- having made -- the time -- the above -- two -- a ** -- a direction -- linear polarization -- P -- S -- emitted light -- intensity distribution -- a figure -- it is -- Fig.6 -- and -- Fig.7 -- setting -- a positive angle -- a degree -- The angle of inclination of the above-mentioned first emission direction and the degree of negative angle are the angles of inclination of the above-mentioned second emission direction to the aforementioned normal line direction (0 degree) to the normal line direction (0 degree) of the emission face 10 of the aforementioned light guide plate 8.
[0057]
Thus, the aforementioned surface light source 7 by lighting of the above-mentioned first photogen 24, One linear polarization P of two directions which intersect perpendicularly substantially in the direction of the angle range where the peak of emitted light strength exists

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in the first emission direction that inclined in one direction to the normal line direction of the emission face 10 of the aforementioned light guide plate 8, The linear polarization S of another side is emitted in the direction of the angle range where the peak of emitted light strength exists in the above-mentioned second emission direction leaning to the counter direction to the normal line direction of the emission face 10 of the aforementioned light guide plate 8 with aforementioned one direction, respectively, By lighting of the above-mentioned second photogen 25, the linear polarization S of another side is emitted in the direction of the angle range where the peak of emitted light strength exists in the above-mentioned first emission direction, respectively in the direction of the angle range where the peak of emitted light strength exists aforementioned one linear polarization P in the above-mentioned second emission direction.

[0058]

Therefore, when the viewing side of the aforementioned liquid crystal display panel 1 which has arranged the polarizing plates 5 and 6 to a viewing side and its opposite side, respectively arranges the aforementioned surface light source 7 to an opposite side, The image data for left eyes and the image data for right eyes for displaying a three dimensional image on a plurality of pixels of the aforementioned liquid crystal display panel 1 are written in alternately, The liquid crystal display which makes it synchronize with the writing of the aforementioned image data for left eyes, makes one photogen 24 or 25 of the aforementioned surface light source 7 turn on, makes it synchronize with the writing of the aforementioned image data for left eyes, makes the photogen 25 or 24 of another side of the aforementioned surface light source 7 turn on, and displays a three dimensional image can be obtained.

[0059]

With the viewing side of the aforementioned liquid crystal display panel 1, the liquid crystal display shown in Fig.1 and Fig.2 arranges the aforementioned surface light source 7 to an opposite side, and to it the aforementioned surface light source 7, Make the aforementioned lens array 31 oppose to the aforementioned liquid crystal display panel 1, and it coincides the normal line direction of the emission face 10 of the aforementioned light guide plate 8 with the normal line direction of the aforementioned liquid crystal display panel 1, It is arranged towards the direction which inclined the emission direction of another side in the aforementioned observer's direction of a right eye to the normal line direction of the aforementioned liquid crystal display panel 1 towards the direction which inclined one side of the 1st [above-mentioned] and a second emission direction in a display observer's direction of a left eye to the normal line direction of the aforementioned liquid crystal display panel 1.

[0060]

Therefore, the light guide plate 8 of the aforementioned surface light source 7 emits the light which had the directivity in which the peak of emitted light strength exists in the normal line direction of the aforementioned liquid crystal display panel 1 from the emission face 10, The lens array 31 of the aforementioned surface light source 7 one side of the light which transmitted lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28, and the light which transmitted the non-phase contrast part 30, It is emitted in the direction of the angle range where the peak of emitted light strength exists in a display observer's direction of a left eye to the normal line direction of the aforementioned liquid crystal display panel 1, and the light of another side is emitted in the direction of the angle range where the peak of emitted light strength exists in the aforementioned observer's direction of a right eye to the aforementioned normal line direction.

[0061]

Direction of the transmission axes 26a and 27a of the 1st and the second linear polarization elements 26 and 27 of the aforementioned surface light source 7, According to direction of the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1, by one lighting of the 1st [above-mentioned] and the second photogens 24 and 25, Emit the linear polarization which intersects parallel linear polarization perpendicularly in the aforementioned left eye direction substantially with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 as substantially as the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 in the aforementioned right eye direction, and by lighting of the photogen of another side, The linear polarization which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially is set up in the aforementioned left eye direction to emit parallel linear polarization in the aforementioned right eye direction substantially with the transmission axis 6a of the aforementioned opposite side polarizing plate 6.

[0062]

The driving means 33 of the aforementioned liquid crystal display panel 1 and the surface light source 7, The image data for left eyes and the image data for right eyes for displaying a three dimensional image on a plurality of pixels of the aforementioned liquid crystal display panel 1 are written in alternately, It consists of a drive circuit which makes it synchronize with the writing of the aforementioned image data for left eyes, makes aforementioned one photogen 24 or 25 of the aforementioned surface light source 7 turn on, makes it synchronize with the writing of the aforementioned image data for left eyes, and makes the photogen 25 or 24 of another side of the aforementioned surface light source 7 turn on.

[0063]

In the liquid crystal display of this working example, as shown in Fig.1, the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 is made parallel with the right and left directions of a screen, By setting up to have mentioned above the length direction of each lens 32 of the transmission axes 26a and 27a of the 1st and the second linear polarization elements 26 and 27 of the aforementioned surface light source 7 and the lagging axis 29a of a plurality of lambda / 2 phase-contrast parts 29 of the phase difference element 28, and the lens array 31, from the aforementioned surface light source 7,

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By lighting of the above-mentioned first photogen 24, substantially the parallel linear polarization P with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 in the aforementioned left eye direction, Make the linear polarization S which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially emit in the aforementioned right eye direction, and by lighting of the second photogen 25, The linear polarization S which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially in the aforementioned left eye direction, it is made to make the parallel linear polarization P emit in the aforementioned right eye direction substantially with the transmission axis 6a of the aforementioned opposite side polarizing plate 6, it constitutes so that the aforementioned driving means 33 is synchronized with the writing of the image data for left eyes to a plurality of pixels of the aforementioned liquid crystal display panel 1, and the first photogen 24 of the aforementioned surface light source 7 may be made to turn on, it may be made to synchronize with the writing of the image data for left eyes and the second photogen 25 of the aforementioned surface light source 7 may be made to turn on.

[0064]

With the viewing side of the aforementioned liquid crystal display panel 1, this liquid crystal display to an opposite side, The lens array 31 is made for the surface light source 7 of the aforementioned composition to oppose to the aforementioned liquid crystal display panel 1. And the above-mentioned first emission direction is turned in the direction which inclined in a display observer's direction of a left eye to the normal line direction of the aforementioned liquid crystal display panel 1, The above-mentioned second emission direction is turned in the direction which inclined in the aforementioned observer's direction of a right eye to the aforementioned normal line direction, Substantially the parallel linear polarization P by lighting of the above-mentioned first photogen 24 with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 in the aforementioned left eye direction, The linear polarization S which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially is emitted in the aforementioned right eye direction, The linear polarization S which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially by lighting of the above-mentioned second photogen 25 in the aforementioned left eye direction, Arrange so that the parallel linear polarization P may be substantially emitted in the aforementioned right eye direction with the transmission axis 6a of the aforementioned opposite side polarizing plate 6, and by the aforementioned driving means 33, Write alternately the image data for left eyes, and the image data for right eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, make it synchronize with the writing of the aforementioned image data for left eyes, and it makes the first photogen 24 of the aforementioned surface light source 7 turn on. Since it is made to synchronize with the writing of the aforementioned image data for left eyes and is made to make the second photogen 25 of the aforementioned surface light source 7 turn on, a high quality three dimensional image with high resolution of both the image for left eyes and the image for right eyes can be displayed.

[0065]

Fig.3 is an emitted light diagram when displaying the time of displaying the image for left eyes of the aforementioned liquid crystal display, and the image for right eyes, and an emitted light line in case (a) displays the image for left eyes, and (b) show the emitted light line in case the image for right eyes displays.

[0066]

The aforementioned liquid crystal display writes the image data for left eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, Make it synchronize with the writing of the image data for left eyes, make the first photogen 24 of the aforementioned surface light source 7 turn on, and it displays the image for left eyes, Write the image data for right eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, make it synchronize with the writing of the image data for right eyes, the second photogen 25 of the aforementioned surface light source 7 is made to turn on, and the image for right eyes is displayed.

[0067]

Namely, when the first photogen 24 of the aforementioned surface light source 7 is made to turn on, The parallel linear polarization P substantially from the aforementioned surface light source 7 like Fig.4 with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 in the aforementioned left eye direction, The linear polarization S which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially is emitted in the aforementioned right eye direction, The linear polarization S which transmitted and entered into the aforementioned liquid crystal display panel 1, and emitted the aforementioned opposite side polarizing plate 6 in the aforementioned right eye direction at it as the linear polarization P emitted in the aforementioned left eye direction among such linear polarization P and S showed Fig.3 (a) by the arrow is absorbed with the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1.

[0068]

Therefore, when write the image data for left eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, it is made to synchronize with the writing of the image data for left eyes and the first photogen 24 of the aforementioned surface light source 7 is made to turn on, From the aforementioned liquid crystal display panel 1, the image light corresponding to the aforementioned image data for left eyes is emitted in a display observer's direction of a left eye, and the image for left eyes is observed by the aforementioned observer's left eye.

[0069]

When the second photogen 25 of the aforementioned surface light source 7 is made to turn on, like Fig.5, From the aforementioned surface light source 7, the parallel linear polarization P

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substantially with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 in the aforementioned right eye direction, The linear polarization S which intersects perpendicularly with the transmission axis 6a of the aforementioned opposite side polarizing plate 6 substantially is emitted in the aforementioned left eye direction, The linear polarization S which transmitted and entered into the aforementioned liquid crystal display panel 1, and emitted the aforementioned opposite side polarizing plate 6 in the aforementioned left eye direction at it as the linear polarization P emitted in the aforementioned right eye direction among such linear polarization P and S showed Fig.3 (b) by the arrow is absorbed with the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1.

[0070]

Therefore, when write the image data for right eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, it is made to synchronize with the writing of the image data for right eyes and the second photogen 25 of the aforementioned surface light source 7 is made to turn on, From the aforementioned liquid crystal display panel 1, the image light corresponding to the aforementioned image data for right eyes is emitted in a display observer's direction of a right eye, and the image for right eyes is observed by the aforementioned observer's right and left eye.

[0071]

Thus, the aforementioned liquid crystal display writes the image data for left eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, Make it synchronize with the writing of the image data for left eyes, make the first photogen 24 of the aforementioned surface light source 7 turn on, and it displays the image for left eyes on the aforementioned liquid crystal display panel 1, It is what writes the image data for left eyes in a plurality of pixels of the aforementioned liquid crystal display panel 1, makes it synchronize with the writing of the image data for left eyes, makes the second photogen 25 of the aforementioned surface light source 7 turn on, and displays the image for right eyes on the aforementioned liquid crystal display panel 1, Since this liquid crystal display can display the aforementioned image for left eyes, and the image for right eyes using all the pixels of the aforementioned liquid crystal display panel 1, respectively, it can display a high quality three dimensional image with high resolution of both the image for left eyes, and the image for right eyes.

[0072]

And from the emission face 10 of the light guide plate 8 of the aforementioned surface light source 7, make this liquid crystal display emit and the light which had the directivity in which the peak of emitted light strength exists in the normal line direction of the aforementioned liquid crystal display panel 1 by the lens array 31 of the aforementioned surface light source 7, One side of the light which transmitted lambda / 2 phase contrast parts 29 of a plurality of regions of the aforementioned phase difference element 28, and the light which transmitted the non-phase contrast part 30, You make it emitted in the direction of the angle range where the peak of emitted light strength exists in a display observer's direction of a left eye to the normal line direction of the aforementioned liquid crystal display panel 1. Since he is trying to make the light of another side emit in the direction of the angle range where the peak of emitted light strength exists in the aforementioned observer's direction of a right eye to the aforementioned normal line direction, a high more nearly quality three dimensional image with both high luminance and contrast of the aforementioned image for left eyes and the image for right eyes can be displayed.

[0073]

The aforementioned liquid crystal display does not make the aforementioned liquid crystal display panel 1 equipped with a color filter. The 1st and the second photogens 24 and 25 of the aforementioned surface light source 7 are made to be equipped with red LED, green LED, and blue LED, respectively. Red and a green and blue light of 3 colors from these photogens 24 and 25 also with the field sequential liquid crystal display it was made to make emit selectively, The liquid crystal display makes the aforementioned liquid crystal display panel 1 correspond to a plurality of pixels, respectively, and makes red and the green and blue color filter of 3 colors have, and it made it make emit white light, respectively from the 1st and the second photogens 24 and 25 of the aforementioned surface light source 7 may be sufficient.

[0074]

In the case of the aforementioned field sequential liquid crystal display, Every six fields which divided one for displaying one three-dimensional color picture for the aforementioned driving means 33 into six. Choose one image data in the image data for left eyes of red and a 3-color green and blue unit color, and the image data for right eyes in any order, and it writes in each pixel of the aforementioned liquid crystal display panel 1 sequentially, Make it synchronize with the writing of the image data for left eyes of red and each green and blue unit color, respectively, and The red of the first photogen 24 of the aforementioned surface light source 7, LED of the color of the write-in image data of the green and blue LED of 3 colors is made to turn on. It constitutes so that it may be made to synchronize with the writing of the image data for right eyes of red and each green and blue unit color, respectively and LED of the color of the red of the second photogen 25 of the aforementioned surface light source 7 and the write-in image data of the green and blue LED of 3 colors may be made to turn on.

[0075]

In the case of the liquid crystal display which the aforementioned liquid crystal display panel 1 was made to equip with red and the green and blue color filter of 3 colors, One for displaying one three-dimensional color picture for the aforementioned driving means 33 to one side of the two fields divided into two, Red and the image data for left eyes which consists of green and blue color data of 3 colors are written in each pixel of the aforementioned liquid crystal display panel 1, On another side of the two aforementioned fields, red and the image data for right eyes which consists of green and blue color data of 3 colors are written in each pixel of the aforementioned liquid crystal display panel 1, It constitutes so that it is made to synchronize

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with the writing of the aforementioned image data for left eyes, and the first photogen 24 of the aforementioned surface light source 7 may be made to turn on, it may be made to synchronize with the writing of the aforementioned image data for right eyes and the second photogen 25 of the aforementioned surface light source 7 may be made to turn on.
[0076]
The light guide means of the aforementioned surface light source 7 has a reflective surface which turns to the aforementioned emission face the incidence part in which not only the above-mentioned light guide plate 8 but light is entered, the emission face to which the light which entered from the aforementioned incidence part is emitted, and the light which entered from the aforementioned incidence part, and it reflects, As long as it draws the light which entered from the aforementioned incidence part and is emitted from the aforementioned emission face, the thing of other composition may be used.
[0077]
Fig.8 is a plan view of the liquid crystal display in which the modification of the 1st working example of the above is shown, and it considers this modification as the composition provided with the light guide means 13 which consists the surface light source 7 of the prism sheet 14 and the light reflector 16.
[0078]
This light guide means 13 to the prism forming face of the prism sheet 14 which formed a plurality of thin long prism 15 in one surface in parallel each other, Provide space between the aforementioned prism sheets 14, and it arranges the aforementioned light reflector 16 oppositely to it, The incidence parts 17a and 17b in which light is entered by two ends of the direction orthogonal to the length direction of the aforementioned thin long prism 15 of space between the aforementioned prism sheet 14 and the light reflector 16 are formed, The emission face 14a of the light which entered from the aforementioned incidence parts 17a and 17b by the opposite surface with the prism forming face of the aforementioned prism sheet 14 is formed, The reflective surface 16a which turns the light which entered from the aforementioned incidence parts 17a and 17b according to the aforementioned prism sheet 14 of the aforementioned light reflector 16 and the surface which opposes to the aforementioned emission face 14a, and it reflects is formed.
[0079]
To the figure, as an arrow and ****** showed, this light guide means 13 the light which entered from the aforementioned incidence parts 17a and 17b, Reflect according to the reflective surface 16a of the aforementioned light reflector 16, enter the aforementioned prism sheet 14, the light is made refracted with a plurality of thin long prism 15 of the aforementioned prism sheet 14, and it is emitted to the normal line direction of the emission face 14a to the aforementioned emission face 14a of the aforementioned prism sheet 14.
[0080]
And make the surface light source 7 of this working example oppose to the incidence parts 17a and 17b of the aforementioned two ends of the aforementioned light guide means 13, respectively, and it arranges the 1st and the second photogens 24 and 25, The 1st which has a transmission axis in one direction, and the second linear polarization elements 26 and 27 are arranged to the these photogens 24 and 25 outgoing radiation side, respectively, It is made to oppose to the emission face 14a of the aforementioned light guide means 13, and the aforementioned phase difference element 28 is arranged, and with the side which opposes to the aforementioned light guide means 13 of this phase difference element 28, the aforementioned lens array 31 is provided to an opposite side, and it is constituted.
[0081]
Fig.9 is other modifications of the 1st working example of the above a perspective view of the light guide means of the shown surface light source, the 1st, a second photogen and the 1st, and a second linear polarization element, and this modification, The incidence part (henceforth an incident end face) 19 as for which the aforementioned light guide means enters light in the end surface of a transparent sheet is formed, It is considered as the light guide plate 18 which formed the flat emission face 20 to which the light which entered into one side of two plate surfaces of the aforementioned transparent sheet from the aforementioned incident end face 19 is emitted, and formed the reflective surface 21 which turns to the aforementioned emission face 20 the light which entered into the plate surface of another side of the aforementioned transparent sheet from the aforementioned incidence part 19, and it reflects.
[0082]
From the one end side in which the aforementioned incident end face 19 was formed, the reflective surface 21 of this light guide plate 18 consists of an inclined plane leaning stair-like in the direction which becomes close to the aforementioned emission face 20 toward the other end side, and according to each stepped surface of that stair-like inclined plane, The thin long reflection part 22 which carries out internal reflection of the light which entered from the aforementioned incident end face 19 to the direction near the normal of the aforementioned emission face 20 is formed.
[0083]
The surface light source of this working example is made to oppose to the incident end face 19 of the end of the aforementioned light guide plate 18. The 1st and the second photogens 24 and 25 of every plurality of form (the figure every two) which divided the aforementioned incident end face 19 into even number in the length direction are alternately arranged side by side in the length direction of the aforementioned incident end face 19, To the these photogens 24 and 25 outgoing radiation side, make each transmission axis intersect perpendicularly substantially, arrange the 1st [above-mentioned] and the second linear polarization elements 26 and 27, and further, respectively between the incident end face 19 of the aforementioned light guide plate 18, and the aforementioned linear polarization elements 26 and 27, Although it is emitted from the 1st [above-mentioned] and the second photogens 24 and 25, and the diffusion board 23 for making uniform intensity distribution of the linear polarization which

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transmitted the 1st [above-mentioned] and the second linear polarization elements 26 and 27, and entering the aforementioned light guide plate 18 is arranged and being omitted in Fig.9. It is made to oppose to the emission face 20 of the aforementioned light guide plate 18, the aforementioned phase difference element 28 is arranged, and the aforementioned lens array 31 is provided by the opposite side with the side which opposes to the aforementioned light guide plate 18 of this phase difference element 28.

[0084]

The surface light source of each modification shown in the aforementioned Fig.8 and Fig.9, Like [since it is a thing of the above composition] the surface light source 7 of the first working example mentioned above, by one lighting of the 1st [above-mentioned] and the second photogens 24 and 25, To the first emission direction that inclined in one direction to the normal line direction of the emission face 20 of the aforementioned light guide plate 18, one side of the linear polarization of two directions which intersect perpendicularly substantially, The linear polarization of another side is emitted to the second emission direction leaning to the counter direction to the normal line direction of the emission face 20 of the aforementioned light guide plate 18 with aforementioned one direction, by lighting of the photogen of another side, aforementioned one linear polarization can be emitted to the above-mentioned second emission direction, and the linear polarization of aforementioned another side can be emitted to the above-mentioned first emission direction.

[0085]

Therefore, a high quality three dimensional image with both high luminance and contrast of the image for left eyes and the image for right eyes can be displayed by arranging this surface light source to an opposite side with the viewing side of the aforementioned liquid crystal display panel 1, and constituting a liquid crystal display.

[0086]

(Second embodiment)

Fig.10 is a plan view of the liquid crystal display in which the second working example of this invention is shown. In this working example, a same sign is given to the figure at the thing corresponding to the liquid crystal display of the first working example mentioned above, and that description is identically omitted about a thing.

[0087]

A liquid crystal display of this working example is provided with the following.

The aforementioned liquid crystal display panel 1.

With the viewing side of the aforementioned liquid crystal display panel 1, it is arranged in an opposite side and turns to the aforementioned liquid crystal display panel 1. First illumination light which consists of linear polarization which intersects perpendicularly with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 substantially, the transmission axis 6a of the aforementioned opposite side polarizing plate 6, and the light source 34 that irradiates selectively second illumination light which consists of parallel linear polarization substantially.

Between the aforementioned light source 34 and the aforementioned liquid crystal display panel 1, they are contiguity or the phase difference element 28 which made carry out a plane of composition and is substantially arranged in parallel with the aforementioned liquid crystal display panel 1 to the aforementioned liquid crystal display panel 1.

The driving means 43 of the aforementioned liquid crystal display panel 1 and the light source 34.

[0088]

The aforementioned light source 34 is the surface light source which irradiates the first illumination light and second illumination light of uniform intensity distribution towards the aforementioned liquid crystal display panel 1, For example, it consists of transparent sheets, such as an acrylic resin plate which has the plane shape of the rectangular shape corresponding to the screen area 1a of the aforementioned liquid crystal display panel 1, The incident end faces 36a and 36b in which light is entered, respectively are formed in the two end faces which oppose mutually, The emission face 37 to which the light which entered into one side of two plate surfaces from the aforementioned incidence parts 36a and 36b is emitted is formed, The light guide plate 35 with which the reflective surface 38 which turns to the aforementioned emission face 37 the light which entered from the aforementioned incidence parts 36a and 36b, and carries out internal reflection to the plate surface of another side was formed, The 1st which makes oppose to the two incident end faces 36a and 36b of the aforementioned light guide plate 35, respectively, is arranged, and is turned on selectively, and the second photogens 39 and 40, It has a transmission axis in one direction, and is constituted by the 1st which made each transmission axis intersect perpendicularly substantially, and is arranged at the above-mentioned 1st and second photogens 39 and 40 outgoing radiation side, respectively, and the second linear polarization elements 41 and 42.

[0089]

The 1st [above-mentioned] and the second photogens 39 and 40 consist of a light emitting element array which arranged a plurality of solid light emitting devices, such as LED, make the emission face oppose to one incident end face 36a of the aforementioned light guide plate 35, and the incident end face 36b of another side, respectively, and are arranged.

[0090]

The 1st [above-mentioned] and the second linear polarization elements 41 and 42, Between the above-mentioned first photogens 39 that are formed in the form corresponding to the incident end faces 36a and 36b of the aforementioned light guide plate 35, and are arranged at one incident end face 36a and the outside of the aforementioned light guide plate 35, The transmission axis of each linear polarization element 41 and 42 is made to intersect perpendicularly substantially between the incident end face 36b of another side of the aforementioned light guide plate 35, and the above-mentioned second photogen 40 arranged

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at the outside, and it is arranged.
[0091]
In this working example, make that transmission axis parallel substantially with the cross direction (the length direction of the incident end faces 36a and 36b) of the aforementioned light guide plate 35, and it arranges the above-mentioned first linear polarization element 41, The transmission axis was substantially made parallel with the board thickness direction (height direction of the incident end faces 36a and 36b) of the aforementioned light guide plate 35, and the above-mentioned second linear polarization element 42 is arranged.
[0092]
This light source 34 is selectively turned on by the aforementioned driving means 43, and the above-mentioned first photogen 39 and the second photogen 40 by lighting of the above-mentioned first photogen 39, From the emission face 37 of the aforementioned light guide plate 35, emit the first illumination light which consists of linear polarization parallel to the transmission axis of the above-mentioned first linear polarization element 41, and by lighting of the above-mentioned second photogen 40, The second illumination light which consists of the linear polarization which intersects perpendicularly substantially to linear polarization parallel to the transmission axis of the above-mentioned second linear polarization element 42, i.e., the first illumination light, is emitted from the emission face 37 of the aforementioned light guide plate 35.
[0093]
As for this light source 34, the viewing side of the aforementioned liquid crystal display panel 1 is among the 1st [above-mentioned] emitted to an opposite side from the emission face 37 of the aforementioned light guide plate 35, and the second illumination light. The transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 and the plane of polarization of the first illumination light are made to cross at right angles substantially, the plane of polarization of the second illumination light is substantially made parallel with the transmission axis 6a of the aforementioned opposite side polarizing plate 6, and it is arranged.
[0094]
The aforementioned phase difference element 28 is among a plurality of regions divided for a number of every pixels which provided preliminarily the screen area 1a of the aforementioned liquid crystal display panel 1 in the right and left directions of the aforementioned screen. Make it correspond to the first region in every other one, respectively, and it forms a plurality of lambda / 2 phase-contrast parts 29 which give 1/2 wave of phase contrast between the ordinary light of the transmitted light, and extraordinary light, Make it correspond to the second region in other every other one, respectively, form a plurality of non-phase contrast parts 30 which do not have phase contrast substantially, and said plurality of lambda / 2 phase-contrast parts 29, It has a lagging axis in the direction which inclined 45 degrees substantially to the cross direction (the length direction of the incident end faces 36a and 36b) of the aforementioned light guide plate 35.
[0095]
Namely, the lagging axis of said plurality of lambda / 2 phase-contrast parts 29, The first illumination light which consists of the linear polarization which transmits the above-mentioned first linear polarization element 41 from the first photogen 39 of the aforementioned light source 34, and enters into the aforementioned light guide plate 35, and it emits from the emission face 37 of the aforementioned light guide plate 35, The above-mentioned second linear polarization element 42 is transmitted from the above-mentioned second photogen 40, and it enters into the aforementioned light guide plate 35, and crosses at an angle of 45 degrees substantially to the plane of polarization of both of second illumination light which consists of the linear polarization emitted from the emission face 37 of the aforementioned light guide plate 35.
[0096]
In this working example, the screen area 1a of the aforementioned liquid crystal display panel 1 is divided into the right and left directions of the aforementioned screen for every pixel row, A plurality of lambda / 2 phase contrast parts 29, and non-phase contrast parts 30 of the aforementioned phase difference element 28 are made to correspond to the first region in every other [of each region divided for every pixel row of the aforementioned liquid crystal display panel 1] one, and the second region in other every other one, respectively, and it forms in the vertical stripe shape along the vertical direction of the aforementioned screen.
[0097]
The aforementioned driving means 43 is to a first display period among a plurality of pixels of the aforementioned liquid crystal display panel 1. The first region in aforementioned every other one, i.e., the pixel row in every other [which opposes at a plurality of lambda / 2 phase-contrast parts 29 of the aforementioned phase difference element 28 on the line which saw from the viewing side of the display and inclined leftward (the display observer's M direction of a left eye) to the normal line direction of the aforementioned liquid crystal display panel 1] row, For example, each pixel of the pixel row of No. odd and the second region in every other [besides the above] one, That is, the pixel row in other every other [which oppose at a plurality of lambda / 2 phase-contrast parts 29 of the aforementioned phase difference element 28 on the line which saw from the viewing side of the display and inclined rightward (the display observer's M direction of a right eye) to the normal line direction of the aforementioned liquid crystal display panel 1] row, For example, each pixel which corresponds alternately the image data for left eyes and the image data for right eyes for displaying a three dimensional image on each pixel of the pixel row of No. even to writing, respectively, The image data for left eyes and the image data for right eyes for displaying a three dimensional image on each pixel respectively corresponding to the second region in other every other one are written in alternately, At the second display period which makes it synchronize with the writing of these image data, makes the above-mentioned first illumination light irradiate from the

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aforementioned light source 34, and follows the above-mentioned first display period Each pixel of the pixel row of aforementioned No. odd, It consists of a drive circuit which writes alternately the image data for right eyes, and the image data for left eyes in each pixel of the pixel row of aforementioned No. even, synchronizes it with the writing of these image data, and makes the above-mentioned second illumination light irradiate to it from the aforementioned light source 34.

[0098]

This liquid crystal display also with a field sequential liquid crystal display. The liquid crystal display which the aforementioned liquid crystal display panel 1 was made to equip with red and the green and blue color filter of 3 colors may be sufficient, and in the case of a field sequential liquid crystal display, Every six fields which divided one for displaying one three-dimensional color picture for the aforementioned driving means 43 into six. The image data for left eyes and the image data for right eyes of one unit color in red and a 3-color green and blue unit color. It writes in each pixel of one pixel row of aforementioned No. odd and No. even, and each pixel of the pixel row of another side, It is made to synchronize with the writing of the object for the left eyes of such red and each green and blue unit color, and the image data for right eyes, respectively, and it constitutes from the aforementioned light source 34 so that the 1st or the second illumination light of the color of red and the write-in green and blue image data of the 3 colors may be made to emit.

[0099]

In the case of the liquid crystal display which the aforementioned liquid crystal display panel 1 was made to equip with red and the green and blue color filter of 3 colors, Every two fields which divided one for displaying one three-dimensional color picture for the aforementioned driving means 43 into two. It constitutes so that red, and the green and blue image data for left eyes and image data for right eyes which consists of color data of 3 colors may be written in each pixel of one pixel row of aforementioned No. odd and No. even, and each pixel of the pixel row of another side, may be synchronized with it and the 1st or second white illumination light may be made to emit from the aforementioned light source 34.

[0100]

Fig.11 and Fig.12 are the display principle figures of the liquid crystal display of the above-mentioned second working example, The display principle of the image for left eyes when Fig.11 makes the above-mentioned first illumination light irradiate from the aforementioned light source 34, and the image for right eyes, and Fig.12 show the display principle of the image for left eyes at the time of making the above-mentioned second illumination light irradiate from the aforementioned light source 34, and the image for right eyes.

[0101]

This liquid crystal display writes the image data for left eyes in each pixel of the pixel row of aforementioned No. odd among a plurality of pixels of the aforementioned liquid crystal display panel 1, Write the image data for right eyes in each pixel of the pixel row of aforementioned No. even, make it synchronize with the writing of these image data, make the above-mentioned first illumination light irradiate from the aforementioned light source 34, and it displays the first image for left eyes in every other row, and the first image for right eyes in every other row, The image data for left eyes is written in each pixel of the pixel row of aforementioned No. even after it, Write the image data for right eyes in each pixel of the pixel row of aforementioned No. odd, make it synchronize with the writing of these image data, make the above-mentioned second illumination light irradiate from the aforementioned light source 34, and it displays the second image for right eyes between the sequences of the second image for left eyes between the sequences of the above-mentioned first image for left eyes, and the above-mentioned first image for right eyes, A high definition three dimensional image is displayed by these four images.

[0102]

Namely, when the above-mentioned first illumination light which consists of the linear polarization which intersects perpendicularly with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 substantially from the aforementioned light source 34 is made to irradiate, The light which transmitted a plurality of lambda / 2 phase-contrast parts 29 of the aforementioned phase difference element 28 among the first illumination light, and rotated 90 degrees of planes of polarization, The aforementioned opposite side polarizing plate 6 is transmitted to the aforementioned liquid crystal display panel 1, it enters into it, and the light which transmitted a plurality of non-phase contrast parts 30 of the aforementioned phase difference element 28 without changing a polarization condition substantially is absorbed with the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1.

[0103]

Therefore, the image data for left eyes is written in each pixel of the pixel row of the aforementioned No. odd of the aforementioned liquid crystal display panel 1, When write the image data for right eyes in each pixel of the pixel row of No. even, it is made to synchronize with the writing of these image data and the above-mentioned first illumination light is made to irradiate from the aforementioned light source 34, Among the light which transmitted a plurality of lambda / 2 phase-contrast parts 29 of the aforementioned phase difference element 28, The light which entered into each pixel (pixel smeared away in Fig.11) Da of the pixel row of aforementioned No. odd which wrote in the aforementioned image data for left eyes, It is emitted toward the observer's M left eye as the image L1 for left eyes displayed on the pixel, The light which entered into each pixel (it is a white pixel in Fig.11) Db of the pixel row of aforementioned No. even which wrote in the aforementioned image data for right eyes is emitted toward the observer's M right eye as the image R1 for right eyes displayed from the pixel. Therefore, an observer's left eye can be made to be able to observe the image for left eyes for every pixel row of No. odd, and can be made to observe the image for right eyes for every pixel row of No. even to a right eye.

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[0104]
When the above-mentioned second illumination light which consists of parallel linear polarization is made to irradiate substantially from the aforementioned light source 34 with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1, The light transmitted without changing a polarization condition substantially a plurality of non-phase contrast parts 30 of the aforementioned phase difference element 28 among the second illumination light, The aforementioned opposite side polarizing plate 6 is transmitted to the aforementioned liquid crystal display panel 1, it enters into it, and the light which transmitted a plurality of lambda / 2 phase-contrast parts 29 of the aforementioned phase difference element 28, and rotated 90 degrees of planes of polarization is absorbed with the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1.
[0105]
Therefore, the image data for left eyes is written in each pixel of the pixel row of the aforementioned No. even of the aforementioned liquid crystal display panel 1, When write the image data for right eyes in each pixel of the pixel row of aforementioned No. odd, it is made to synchronize with the writing of these image data and the above-mentioned second illumination light is made to irradiate from the aforementioned light source 34, the light which was alike and entered into each pixel (pixel smeared away in Fig.12) Db of the pixel row of aforementioned No. even which wrote in the aforementioned image data for left eyes among the lights which transmitted a plurality of non-phase contrast parts 30 of the aforementioned phase difference element 28, It is emitted toward the observer's M left eye as the image L2 for left eyes displayed on the pixel, The light which entered into each pixel (it is a white pixel in Fig.12) Da of the pixel row of aforementioned No. odd which wrote in the aforementioned image data for right eyes is emitted toward the observer's M right eye as the image R2 for right eyes displayed on the pixel. Therefore, an observer's left eye can be made to be able to observe the image for left eyes for every pixel row of No. even, and can be made to observe the image for right eyes for every pixel row of No. odd to a right eye.
[0106]
Fig.13 is a mimetic diagram of the display image of the aforementioned liquid crystal display panel 1 in the liquid crystal display of the above-mentioned second working example, and (a), The image R1 for right eyes displayed by the pixel row of the image L1 for left eyes and aforementioned No. even displayed by the pixel row of the aforementioned No. odd at the time of making the above-mentioned first illumination light irradiate from the aforementioned light source 34 like Fig.11 is shown, (b) shows the image R2 for right eyes displayed by the pixel row of the image L2 for left eyes, and aforementioned No. odd displayed by the pixel row of the aforementioned No. even at the time of making the above-mentioned second illumination light irradiate from the aforementioned light source 34 like Fig.12.
[0107]
Namely, when the above-mentioned first illumination light is made to irradiate from the aforementioned light source 34, this liquid crystal display, A plurality of non-phase contrast parts 30 of the aforementioned phase difference element 28 act as a parallax barrier, The display observer's M left eye is made to observe the image L1 for left eyes displayed by the pixel row of aforementioned No. odd, When the display observer's M right eye is made to observe the image R1 for right eyes displayed by the pixel row of aforementioned No. even and the above-mentioned second illumination light is made to irradiate from the aforementioned light source 34, A plurality of lambda / 2 phase-contrast parts 29 of the aforementioned phase difference element 28 act as a parallax barrier, make the display observer's M left eye observe the image L2 for left eyes displayed by the pixel row of aforementioned No. even, and make the display observer's M left eye observe the image R2 for right eyes displayed by the pixel row of aforementioned No. odd.
[0108]
Therefore, the display observer's M left eye is made to observe the high-resolution image for left eyes (the display example of Fig.13 character image of A) by the image L2 for left eyes displayed by the image L1 for left eyes and the pixel row of No. even which were displayed by the pixel row of aforementioned No. odd. The aforementioned observer's M right eye can be made to observe the high-resolution image for right eyes (the display example of Fig.13 character image of Z) by the image R1 for right eyes displayed by the pixel row of aforementioned No. even, and the image R2 for right eyes displayed by the pixel row of aforementioned No. odd.
[0109]
Although a plurality of lambda / 2 phase contrast parts 29, and non-phase contrast parts 30 of the aforementioned phase difference element 28 are made to correspond to the first region in every other [of each region divided for every pixel row of the aforementioned liquid crystal display panel 1] one, and the second region in other every other one, respectively and are formed in them in this working example, The screen area 1a of the aforementioned liquid crystal display panel 1 The pixel row of plurality [right and left directions / of the aforementioned screen], For example, it divides for every pixel row of about 2-10 rows, and a plurality of lambda / 2 phase contrast parts 29, and non-phase contrast parts 30 of the aforementioned phase difference element 28 may be made to correspond to the first region in every other [of each region divided for every pixel rows of said plurality of of the aforementioned liquid crystal display panel 1] one, and the second region in other every other one, respectively, and may be formed in them.
[0110]
Thus, with the viewing side of the aforementioned liquid crystal display panel 1, the liquid crystal display of this working example to an opposite side, The first illumination light which consists of the linear polarization which intersects perpendicularly with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 substantially, the transmission axis 6a of the aforementioned opposite side polarizing plate 6,

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and the light source 34 that irradiates selectively the second illumination light which consists of parallel linear polarization substantially are arranged towards the aforementioned liquid crystal display panel 1. Among a plurality of regions which divided the screen area 1a of the aforementioned liquid crystal display panel 1 for a number of every pixels preliminarily provided in the right and left directions of the aforementioned screen between the aforementioned light source 34 and the aforementioned liquid crystal display panel 1, Arrange the phase difference element 28 which made it correspond to the first region in every other one, respectively, formed a plurality of lambda / 2 phase-contrast parts 29, made it correspond to the second region in other every other one, respectively, and formed a plurality of non-phase contrast parts 30 in it, and by the driving means 43, Each pixel respectively corresponding to the first region in aforementioned every other [the inside of a plurality of pixels of the aforementioned liquid crystal display panel 1, and] one, Each pixel respectively corresponding to [write alternately the image data for left eyes, and the image data for right eyes in each pixel respectively corresponding to the second region in other every other one, make it synchronize with the writing of these image data, make the above-mentioned first illumination light irradiate from the aforementioned light source 34, and] the first region in aforementioned every other one, The image data for right eyes and the image data for left eyes are alternately written in each pixel respectively corresponding to the second region in every other [besides the above] one, Since it is made to synchronize with the writing of these image data and is made to make the above-mentioned second illumination light irradiate from the aforementioned light source 34, a high quality three dimensional image with high resolution of both the image for left eyes and the image for right eyes can be displayed.

[0111]

Each pixel respectively corresponding to [to a first display period / in the liquid crystal display of this working example] the first region in aforementioned [of the aforementioned liquid crystal display panel 1] every other one by the aforementioned driving means 43, The image data for left eyes and the image data for right eyes are alternately written in each pixel respectively corresponding to the second region in every other [besides the above] one, Each pixel respectively corresponding to the above-mentioned first region of the aforementioned liquid crystal display panel 1 to the second display period which follows the above-mentioned first display period, Since he is trying to write alternately the image data for right eyes, and the image data for left eyes in each pixel respectively corresponding to the above-mentioned second region, a high more nearly quality three dimensional image without a flicker can be displayed.

[0112]

(A 3rd embodiment)

Fig.14 and Fig.15 are the perspective views and plan views of a liquid crystal display showing the 3rd working example of this invention. In this working example, a same sign is given to the figure at the thing corresponding to the liquid crystal display of the first working example mentioned above, and that description is identically omitted about a thing.

[0113]

A liquid crystal display of this working example is provided with the following.

The aforementioned liquid crystal display panel 1.

With the viewing side of the aforementioned liquid crystal display panel 1, it is arranged in an opposite side and turns to the aforementioned liquid crystal display panel 1. First illumination light a that had the directivity in which a peak of emitted light strength exists in the direction which consisted of linear polarization which intersects perpendicularly with the transmission axis 6a of the opposite side polarizing plate 6 of the aforementioned liquid crystal display panel 1 substantially, and inclined in the direction of an eye of either right or left of the display observer M to a normal line direction of the aforementioned liquid crystal display panel 1.

The light source 44 which irradiates selectively the second illumination light b which had the directivity in which a peak of emitted light strength exists in the direction which became the transmission axis 6a of the aforementioned opposite side polarizing plate 6 from parallel linear polarization substantially, and inclined in the direction of an eye of the aforementioned observer's M another side to a normal line direction of the aforementioned liquid crystal display panel 1.

Between the aforementioned light source 44 and the aforementioned liquid crystal display panel 1, to the aforementioned liquid crystal display panel 1, contiguity or the phase difference element 28 which made carry out a plane of composition and is substantially arranged in parallel with the aforementioned liquid crystal display panel 1, The phase difference element transportation device 51 which moves the aforementioned phase difference element 28 to a vertical direction of a screen of the aforementioned liquid crystal display panel 1, and the driving means 52 of the aforementioned liquid crystal display panel 1 and the light source 44.

[0114]

The aforementioned light source 44 is the surface light source which irradiates the first illumination light a and the second illumination light b of uniform intensity distribution towards the aforementioned liquid crystal display panel 1. For example, the 1st respectively corresponding to the region in the right half of the screen area 1a of the aforementioned liquid crystal display panel 1, and the region of a left half and the second light source parts 45a and 45b, The 1st which has the transmission axes 48a and 49a in one direction, made the outgoing radiation side of the 1st [above-mentioned] and the second light source parts 45a and 45b, and each transmission axes 48a and 49a cross at right angles substantially, respectively, and is arranged, and the second linear polarization elements 48 and 49, See from the viewing side of the aforementioned liquid crystal display panel 1, and it is emitted from the right-hand side first light source part 45a, The first illumination light a made linear polarization parallel to the transmission axis 48a by the above-mentioned first linear polarization element 48 The direction of one eye of the display observer M, For example, make it condense in the direction of a left

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eye, see from the aforementioned viewing side, and it is emitted from the left-hand side second light source part 45b, It is constituted by circular Fresnel lens 50 which makes the second illumination light b made linear polarization parallel to the transmission axis 49a by the above-mentioned second linear polarization element 49 condense in the direction of a right eye, i.e., direction, of an eye of another side of the aforementioned observer M.

CONTINUE

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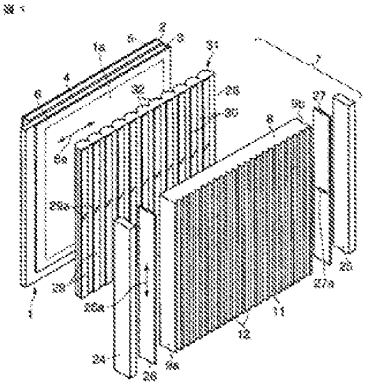
(54)【発明の名称】面光源及び液晶表示装置

(57)【要約】　(修正有)
【課題】解像度が高い高品質の三次元画像を表示する。
【解決手段】液晶表示パネル１の観察側とは反対側に、導光板８と、第１と第２の発光体２４，２５と、各々の透過軸２６ａ，２７ａを直交させて配置された第１と第２の直線偏光素子２６，２７と、複数のλ／２位相差部２９と無位相差部３０とを交互に形成した位相差素子２８と、そのλ／２位相差部２９を透過した光を第１の出射方向に出射し、無位相差部３０を透過した光を第２の出射方向に出射するレンズアレイ３１とを備え、第１、第２の発光体２４、２５の点灯により、液晶表示パネル１を通して各々が直交関係となる直線偏光を表示観察者の左右眼方向に、出射する。
【選択図】図１

※、



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【特許請求の範囲】
【請求項１】
光を入射させる入射部と前記入射部から入射した光を出射する出射面と前記入射部から入射した光を前記出射面に向けて反射する反射面とを有し、前記入射部から入射した光を導いて前記出射面から出射する導光手段と、
前記導光手段の前記入射部に対向させて配置され、選択的に点灯される第１と第２の発光体と、
一方の方向に透過軸を有し、前記第１と第２の発光体の出射側にそれぞれ、各々の透過軸を実質的に直交させて配置された第１と第２の直線偏光素子と、
前記導光手段の出射面に対向させて配置され、前記導光手段の出射面に沿った方向に、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部と実質的に位相差の無い複数の無位相差部とを交互に形成した位相差素子と、
前記位相差素子の前記導光手段に対向する側とは反対側に設けられ、前記位相差素子の隣合う１つずつのλ／２位相差部と無位相差部とからなる複数の領域にそれぞれ対応する複数のレンズを有し、前記導光手段の出射面から出射し、前記位相差素子の前記複数の領域のλ／２位相差部を透過した光を予め定めた方向に対して一方の方向に傾いた第１の出射方向に出射し、前記複数の領域の無位相差部を透過した光を前記予め定めた方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射するレンズアレイとを備え、
前記第１と第２の発光体の一方の点灯により、実質的に直交する２つの方向の直線偏光の一方を前記第１の出射方向に、他方の直線偏光を前記第２の出射方向にそれぞれ出射し、他方の発光体の点灯により、前記一方の直線偏光を前記第２の出射方向に、前記他方の直線偏光を前記第１の出射方向に出射することを特徴とする面光源。
【請求項２】
観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、
光を入射させる入射部と前記入射部から入射した光を出射する出射面と前記入射部から入射した光を前記出射面に向けて反射する反射面とを有し、前記入射部から入射した光を導いて前記出射面から出射する導光手段と、前記導光手段の前記入射部に対向させて配置され、選択的に点灯される第１と第２の発光体と、一方の方向に透過軸を有し、前記第１と第２の発光体の出射側にそれぞれ、各々の透過軸を実質的に直交させて配置された第１と第２の直線偏光素子と、前記導光手段の出射面に対向させて配置され、前記導光手段の出射面に沿った方向に、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部と実質的に位相差の無い複数の無位相差部とを交互に形成した位相差素子と、前記位相差素子の前記導光手段に対向する側とは反対側に設けられ、前記位相差素子の隣合う１つずつのλ／２位相差部と無位相差部とからなる複数の領域にそれぞれ対応する複数のレンズを有し、前記導光手段の出射面から出射し、前記位相差素子の前記複数の領域のλ／２位相差部を透過した光を予め定めた方向に対して一方の方向に傾いた第１の出射方向に出射し、前記複数の領域の無位相差部を透過した光を前記予め定めた方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射するレンズアレイとを備え、前記液晶表示パネルの観察側とは反対側に、前記レンズアレイを前記液晶表示パネルに対向させ、且つ前記第１と第２の出射方向の一方を前記液晶表示パネルの法線方向に対して表示観察者の左眼方向に傾いた方向に向け、他方の出射方向を前記法線方向に対して前記観察者の右眼方向に傾いた方向に向けて配置され、前記第１と第２の発光体の一方の点灯により、前記液晶表示パネルの反対側偏光板の透過軸と実質的に平行な直線偏光を前記左眼方向に、前記反対側偏光板の透過軸と実質的に直交する直線偏光を前記右眼方向に出射し、他方の発光体の点灯により、前記反対側偏光板の透過軸と実質的に直交する直線偏光を前記左眼方向に、前記反対側偏光板の透過軸と実質的に平行な直線偏光を前記右眼方向に出射する面光源と、

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前記液晶表示パネルの複数の画素に三次元画像を表示するための左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源の前記一方の発光体を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源の他方の発光体を点灯させる駆動手段とを備えたことを特徴とする液晶表示装置。

【請求項３】

面光源の導光手段は、その出射面から、液晶表示パネルの法線方向に出射光強度のピークが存在する指向性をもった光を出射し、レンズアレイは、位相差素子の複数の領域のλ／２位相差部を透過した光と無位相差部を透過した光の一方を、前記液晶表示パネルの法線方向に対して左眼方向に出射光強度のピークが存在する角度範囲の方向に出射し、他方の光を、前記法線方向に対して右眼方向に出射光強度のピークが存在する角度範囲の方向に出射することを特徴とする請求項２に記載の液晶表示装置。

【請求項４】

観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、

前記液晶表示パネルの観察側とは反対側に配置され、前記液晶表示パネルに向けて、前記液晶表示パネルの反対側偏光板の透過軸と実質的に直交する直線偏光からなる第１の照明光と前記反対側偏光板の透過軸と実質的に平行な直線偏光からなる第２の照明光とを選択的に照射する光源と、

前記光源と前記液晶表示パネルとの間に配置され、前記液晶表示パネルの画面エリアを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部を形成した位相差素子と、

前記液晶表示パネルの複数の画素のうち、前記１つ置きの第１の領域にそれぞれ対応する各画素と、他の１つ置きの第２の領域にそれぞれ対応する各画素に、三次元画像を表示するための左眼用画像データと右眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源から前記第１の照明光を照射させ、前記１つ置きの第１の領域にそれぞれ対応する各画素と、前記他の１つ置きの第２の領域にそれぞれ対応する各画素に、右眼用画像データと左眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源から前記第２の照明光を照射させる駆動手段とを備えたことを特徴とする液晶表示装置。

【請求項５】

駆動手段は、第１の表示期間に、液晶表示パネルの１つ置きの第１の領域にそれぞれ対応する各画素と、他の１つ置きの第２の領域にそれぞれ対応する各画素とに、左眼用画像データと右眼用画像データとを交互に書込み、前記第１の表示期間に引き続く第２の表示期間に、前記液晶表示パネルの前記第１の領域にそれぞれ対応する各画素と、前記第２の領域にそれぞれ対応する各画素とに、右眼用画像データと左眼用画像データとを交互に書込むことを特徴とする請求項４に記載の液晶表示装置。

【請求項６】

観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、

前記液晶表示パネルの観察側とは反対側に配置され、前記液晶表示パネルに向けて、前記液晶表示パネルの反対側偏光板の透過軸と実質的に直交する直線偏光からなり、且つ前記液晶表示パネルの法線方向に対して表示観察者の左右いずれか一方の眼の方向に傾いた方向に出射光強度のピークが存在する指向性をもった第１の照明光と、前記反対側偏光板の透過軸と実質的に平行な直線偏光からなり、且つ前記法線方向に対して前記観察者の他方の眼の方向に傾いた方向に出射光強度のピークが存在する指向性をもった第２の照明光とを照射する光源と、

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前記光源と前記液晶表示パネルとの間に配置され、前記液晶表示パネルの画面エリアを前記画面の上下方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部を形成した位相差素子と、

前記位相差素子を前記λ／２位相差部と無位相差部のピッチに対応するストロークで前記液晶表示パネルの画面の上下方向に移動させ、前記複数のλ／２位相差部と無位相差部を前記液晶表示パネルの前記第１の領域と第２の領域とに交互に対向させる位相差素子移動手段と、

前記位相差素子の前記λ／２位相差部を前記液晶表示パネルの前記１つ置きの第１の領域に対向させ、前記無位相差部を前記他の１つ置きの第２の領域に対向させたときに、前記液晶表示パネルの複数の画素のうち、前記第１の領域の各画素に三次元画像を表示するための左右の眼用の画像データのうちの左眼用画像データを書込み、前記第２の領域の各画素に右眼用画像データを書込み、これらの画像データの書込みに同期させて前記光源から前記第１と第２の照明光を照射させ、前記位相差素子の前記λ／２位相差部を前記液晶表示パネルの前記第２の領域に対向させ、前記無位相差部を前記第１の領域に対向させたときに、前記液晶表示パネルの前記第１の領域の各画素に右眼用画像データを書込み、前記第２の領域の各画素に左眼用画像データを書込み、これらの画像データの書込みに同期させて前記光源から前記第１と第２の照明光を照射させる駆動手段とを備えたことを特徴とする液晶表示装置。

【請求項７】

駆動手段は、第１の表示期間に、液晶表示パネルの１つ置きの第１の領域の各画素と他の１つ置きの第２の領域の各画素とに、左眼用画像データと右眼用画像データとを交互に書込み、前記第１の表示期間に引き続く第２の表示期間に、前記液晶表示パネルの前記第１の領域の各画素と前記第２の領域の各画素とに、右眼用画像データと左眼用画像データとを交互に書込むことを特徴とする請求項６に記載の液晶表示装置。

【請求項８】

観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、

前記液晶表示パネルの観察側とは反対側に配置され、前記液晶表示パネルに向けて照明光を照射する光源と、

前記液晶表示パネルの観察側に配置され、前記液晶表示パネルの画面エリアを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部を形成した位相差素子と、

前記液晶表示パネルの複数の画素のうち、前記位相差素子の複数のλ／２位相差部に対応する各画素に三次元画像を表示するための左右の眼用の画像データのうちの一方の眼用の画像データを書込み、前記位相差素子の複数の無位相差部に対応する各画素に他方の眼用の画像データを書込む駆動手段と、

前記液晶表示パネルから出射した直線偏光からなる画像光のうち、前記位相差素子の複数のλ／２位相差部と無位相差部の一方を透過して観察側に出射した光を透過させる左眼用直線偏光素子と、前記位相差素子の複数のλ／２位相差部と無位相差部の他方を透過して前記観察側に出射した光を透過させる右眼用直線偏光素子とを有する観察用偏光眼鏡とを備えたことを特徴とする液晶表示装置。

【請求項９】

位相差素子の複数のλ／２位相差部と無位相差部は、液晶表示パネルの画面エリアを前記画面の左右方向に１つの画素毎に分割した複数の領域に交互に対応させて形成されていることを特徴とする請求項８に記載の液晶表示装置。

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【発明の詳細な説明】
【技術分野】
【０００１】
この発明は、液晶表示装置に立体的な三次元画像を表示させるための面光源及び前記三次元画像を表示する液晶表示装置に関する。
【背景技術】
【０００２】
三次元画像を表示する液晶表示装置としては、従来、液晶表示パネルの画面の上下方向に沿った複数の画素列のうち、１つ置きの画素列の各画素により左眼用画像を表示し、他の１つ置きの画素列の各画素により右眼用画像を表示し、その左眼用画像と右眼用画像とを、前記１つ置きの画素列からの出射光と他の１つ置きの画素列からの出射光とを表示観察者の左眼方向と右眼方向とに振り分けるレンチキュラーレンズ、あるいは前記画素列と平行な複数の透過部と遮光部が交互に並べてストライプ状に形成されたパララックスバリアを介して観察者の左眼と右眼とに観察させるようにしたものがある（特許文献１、２、３参照）。
【特許文献１】特開平　３－１１９８８９号公報
【特許文献２】特開平　７－００５４５５号公報
【特許文献３】特開平１０－２６８２３０号公報
【発明の開示】
【発明が解決しようとする課題】
【０００３】
この発明は、従来とは異なる新規な方式で三次元画像を表示する液晶表示装置を得ることができる面光源を提供することを目的としたものである。また、この発明は、新規な方式で前記三次元画像を表示することができる液晶表示装置を提供することを目的としたものである。
【課題を解決するための手段】
【０００４】
この発明の面光源は、
光を入射させる入射部と前記入射部から入射した光を出射する出射面と前記入射部から入射した光を前記出射面に向けて反射する反射面とを有し、前記入射部から入射した光を導いて前記出射面から出射する導光手段と、
前記導光手段の前記入射部に対向させて配置され、選択的に点灯される第１と第２の発光体と、
一方の方向に透過軸を有し、前記第１と第２の発光体の出射側にそれぞれ、各々の透過軸を実質的に直交させて配置された第１と第２の直線偏光素子と、
前記導光手段の出射面に対向させて配置され、前記導光手段の出射面に沿った方向に、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部と実質的に位相差の無い複数の無位相差部とを交互に形成した位相差素子と、
前記位相差素子の前記導光手段に対向する側とは反対側に設けられ、前記位相差素子の隣合う１つずつのλ／２位相差部と無位相差部とからなる複数の領域にそれぞれ対応する複数のレンズを有し、前記導光手段の出射面から出射し、前記位相差素子の前記複数の領域のλ／２位相差部を透過した光を予め定めた方向に対して一方の方向に傾いた第１の出射方向に出射し、前記複数の領域の無位相差部を透過した光を前記予め定めた方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射するレンズアレイとを備え、
前記第１と第２の発光体の一方の点灯により、実質的に直交する２つの方向の直線偏光の一方を前記第１の出射方向に、他方の直線偏光を前記第２の出射方向にそれぞれ出射し、他方の発光体の点灯により、前記一方の直線偏光を前記第２の出射方向に、前記他方の直線偏光を前記第１の出射方向に出射することを特徴とする。
【０００５】

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この発明の第１の液晶表示装置は、
観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、
光を入射させる入射部と前記入射部から入射した光を出射する出射面と前記入射部から入射した光を前記出射面に向けて反射する反射面とを有し、前記入射部から入射した光を導いて前記出射面から出射する導光手段と、前記導光手段の前記入射部に対向させて配置され、選択的に点灯される第１と第２の発光体と、一方の方向に透過軸を有し、前記第１と第２の発光体の出射側にそれぞれ、各々の透過軸を実質的に直交させて配置された第１と第２の直線偏光素子と、前記導光手段の出射面に対向させて配置され、前記導光手段の出射面に沿った方向に、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部と実質的に位相差の無い複数の無位相差部とを交互に形成した位相差素子と、前記位相差素子の前記導光手段に対向する側とは反対側に設けられ、前記位相差素子の隣合う１つずつのλ／２位相差部と無位相差部とからなる複数の領域にそれぞれ対応する複数のレンズを有し、前記導光手段の出射面から出射し、前記位相差素子の前記複数の領域のλ／２位相差部を透過した光を予め定めた方向に対して一方の方向に傾いた第１の出射方向に出射し、前記複数の領域の無位相差部を透過した光を前記予め定めた方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射するレンズアレイとを備え、前記液晶表示パネルの観察側とは反対側に、前記レンズアレイを前記液晶表示パネルに対向させ、且つ前記第１と第２の出射方向の一方を前記液晶表示パネルの法線方向に対して表示観察者の左眼方向に傾いた方向に向け、他方の出射方向を前記法線方向に対して前記観察者の右眼方向に傾いた方向に向けて配置され、前記第１と第２の発光体の一方の点灯により、前記液晶表示パネルの反対側偏光板の透過軸と実質的に平行な直線偏光を前記左眼方向に、前記反対側偏光板の透過軸と実質的に直交する直線偏光を前記右眼方向に出射し、他方の発光体の点灯により、前記反対側偏光板の透過軸と実質的に直交する直線偏光を前記左眼方向に、前記反対側偏光板の透過軸と実質的に平行な直線偏光を前記右眼方向に出射する面光源と、
前記液晶表示パネルの複数の画素に三次元画像を表示するための左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源の前記一方の発光体を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源の他方の発光体を点灯させる駆動手段とを備えたことを特徴とする。

【０００６】

この第１の液晶表示装置において、前記面光源の前記導光手段は、その出射面から、前記液晶表示パネルの法線方向に出射光強度のピークが存在する指向性をもった光を出射し、前記レンズアレイは、前記位相差素子の複数の領域のλ／２位相差部を透過した光と無位相差部を透過した光の一方を、前記液晶表示パネルの法線方向に対して前記左眼方向に出射光強度のピークが存在する角度範囲の方向に出射し、他方の光を、前記法線方向に対して前記右眼方向に出射光強度のピークが存在する角度範囲の方向に出射するのが好ましい。

【０００７】

この発明の第２の液晶表示装置は、
観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、
前記液晶表示パネルの観察側とは反対側に配置され、前記液晶表示パネルに向けて、前記液晶表示パネルの反対側偏光板の透過軸と実質的に直交する直線偏光からなる第１の照明光と前記反対側偏光板の透過軸と実質的に平行な直線偏光からなる第２の照明光とを選択的に照射する光源と、
前記光源と前記液晶表示パネルとの間に配置され、前記液晶表示パネルの画面エリアを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第

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１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部を形成した位相差素子と、

前記液晶表示パネルの複数の画素のうち、前記１つ置きの第１の領域にそれぞれ対応する各画素と、他の１つ置きの第２の領域にそれぞれ対応する各画素に、三次元画像を表示するための左眼用画像データと右眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源から前記第１の照明光を照射させ、前記１つ置きの第１の領域にそれぞれ対応する各画素と、前記他の１つ置きの第２の領域にそれぞれ対応する各画素に、右眼用画像データと左眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源から前記第２の照明光を照射させる駆動手段とを備えたことを特徴とする。

【０００８】

この第２の液晶表示装置において、前記駆動手段は、第１の表示期間に、前記液晶表示パネルの前記１つ置きの第１の領域にそれぞれ対応する各画素と、前記他の１つ置きの第２の領域にそれぞれ対応する各画素とに、左眼用画像データと右眼用画像データとを交互に書込み、前記第１の表示期間に引き続く第２の表示期間に、前記液晶表示パネルの前記第１の領域にそれぞれ対応する各画素と、前記第２の領域にそれぞれ対応する各画素とに、右眼用画像データと左眼用画像データとを交互に書込むのが好ましい。

【０００９】

この発明の第３の液晶表示装置は、

観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルと、

前記液晶表示パネルの観察側とは反対側に配置され、前記液晶表示パネルに向けて、前記液晶表示パネルの反対側偏光板の透過軸と実質的に直交する直線偏光からなり、且つ前記液晶表示パネルの法線方向に対して表示観察者の左右いずれか一方の眼の方向に傾いた方向に出射光強度のピークが存在する指向性をもった第１の照明光と、前記反対側偏光板の透過軸と実質的に平行な直線偏光からなり、且つ前記法線方向に対して前記観察者の他方の眼の方向に傾いた方向に出射光強度のピークが存在する指向性をもった第２の照明光とを選択的に照射する光源と、

前記光源と前記液晶表示パネルとの間に配置され、前記液晶表示パネルの画面エリアを前記画面の上下方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部を形成した位相差素子と、

前記位相差素子を前記λ／２位相差部と無位相差部のピッチに対応するストロークで前記液晶表示パネルの画面の上下方向に移動させ、前記複数のλ／２位相差部と無位相差部を前記液晶表示パネルの前記第１の領域と第２の領域とに交互に対向させる位相差素子移動手段と、

前記位相差素子の前記λ／２位相差部を前記液晶表示パネルの前記１つ置きの第１の領域に対向させ、前記無位相差部を前記他の１つ置きの第２の領域に対向させたときに、前記液晶表示パネルの複数の画素のうち、前記第１の領域の各画素に三次元画像を表示するための左右の眼用の画像データのうちの左眼用画像データを書込み、前記第２の領域の各画素に右眼用画像データを書込み、これらの画像データの書込みに同期させて前記光源から前記第１と第２の照明光を照射させ、前記位相差素子の前記λ／２位相差部を前記液晶表示パネルの前記第２の領域に対向させ、前記無位相差部を前記第１の領域に対向させたときに、前記液晶表示パネルの前記第１の領域の各画素に右眼用画像データを書込み、前記第２の領域の各画素に左眼用画像データを書込み、これらの画像データの書込みに同期させて前記光源から前記第１と第２の照明光を照射させる駆動手段とを備えたことを特徴とする。

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【００１０】
この第３の液晶表示装置において，前記駆動手段は、第１の表示期間に，前記液晶表示パネルの前記１つ置きの第１の領域の各画素と前記他の１つ置きの第２の領域の各画素とに、左眼用画像データと右眼用画像データとを交互に書込み、前記第１の表示期間に引き続く第２の表示期間に、前記液晶表示パネルの前記第１の領域の各画素と前記第２の領域の各画素とに，右眼用画像データと左眼用画像データとを交互に書込むのが好ましい。
【００１１】
この発明の第４の液晶表示装置は、
観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ，その画像データに応じた画像を表示する液晶表示パネルと、
前記液晶表示パネルの観察側とは反対側に配置され、前記液晶表示パネルに向けて照明光を照射する光源と、
前記液晶表示パネルの観察側に配置され，前記液晶表示パネルの画面エリアを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部を形成した位相差素子と、
前記液晶表示パネルの複数の画素のうち、前記位相差素子の複数のλ／２位相差部に対応する各画素に三次元画像を表示するための左右の眼用の画像データのうちの一方の眼用の画像データを書込み、前記位相差素子の複数の無位相差部に対応する各画素に他方の眼用の画像データを書込む駆動手段と、
前記液晶表示パネルから出射した直線偏光からなる画像光のうち、前記位相差素子の複数のλ／２位相差部と無位相差部の一方を透過して観察側に出射した光を透過させる左眼用直線偏光素子と、前記位相差素子の複数のλ／２位相差部と無位相差部の他方を透過して前記観察側に出射した光を透過させる右眼用直線偏光素子とを有する観察用偏光眼鏡とを備えたことを特徴とする。
【００１２】
この第４の液晶表示装置において、前記位相差素子の複数のλ／２位相差部と無位相差部は、前記液晶表示パネルの画面エリアを前記画面の左右方向に１つの画素毎に分割した複数の領域に交互に対応させて形成するのが好ましい。
【発明の効果】
【００１３】
この発明の面光源は、光を入射させる入射部と前記入射部から入射した光を出射する出射面と前記入射部から入射した光を前記出射面に向けて反射する反射面とを有し、前記入射部から入射した光を導いて前記出射面から出射する導光手段と、前記導光手段の前記入射部に対向させて配置され、選択的に点灯される第１と第２の発光体と、一方の方向に透過軸を有し、前記第１と第２の発光体の出射側にそれぞれ、各々の透過軸を実質的に直交させて配置された第１と第２の直線偏光素子と，前記導光手段の出射面に対向させて配置され、前記導光手段の出射面に沿った方向に、複数のλ／２位相差部と無位相差部とを交互に形成した位相差素子と、前記位相差素子の前記導光手段に対向する側とは反対側に設けられ、前記位相差素子の隣合う１つずつのλ／２位相差部と無位相差部とからなる複数の領域にそれぞれ対応する複数のレンズを有し、前記導光手段の出射面から出射し、前記位相差素子の前記複数の領域のλ／２位相差部を透過した光を予め定めた方向に対して一方の方向に傾いた第１の出射方向に出射し、前記複数の領域の無位相差部を透過した光を前記予め定めた方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射するレンズアレイとを備え、前記第１と第２の発光体の一方の点灯により、実質的に直交する２つの方向の直線偏光の一方を前記第１の出射方向に、他方の直線偏光を前記第２の出射方向にそれぞれ出射し、他方の発光体の点灯により、前記一方の直線偏光を前記第２の出射方向に，前記他方の直線偏光を前記第１の出射方向に出射するものであるため、こ

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の面光源を、観察側とその反対側とにそれぞれ偏光板を配置した液晶表示パネルの観察側とは反対側に配置することにより、前記液晶表示パネルの複数の画素に左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源の前記一方の発光体を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源の他方の発光体を点灯させて三次元画像を表示する液晶表示装置を得ることができる。

【００１４】

この発明の第１の液晶表示装置は、観察側とその反対側とにそれぞれ偏光板が配置され、光の透過を制御する複数の画素がマトリックス状に配列した画面エリアを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネルの観察側とは反対側に、前記構成の面光源を、そのレンズアレイを前記液晶表示パネルに対向させ、且つ前記第１と第２の出射方向の一方を前記液晶表示パネルの法線方向に対して表示観察者の左眼方向に傾いた方向に向け、他方の出射方向を前記法線方向に対して前記観察者の右眼方向に傾いた方向に向けて、前記第１と第２の発光体の一方の点灯により前記液晶表示パネルの反対側偏光板の透過軸と実質的に平行な直線偏光を前記左眼方向に、前記反対側偏光板の透過軸と実質的に直交する直線偏光を前記右眼方向に出射し、他方の発光体の点灯により前記反対側偏光板の透過軸と実質的に直交する直線偏光を前記左眼方向に、前記反対側偏光板の透過軸と実質的に平行な直線偏光を前記右眼方向に出射するように配置し、前記駆動手段により、前記液晶表示パネルの複数の画素に左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源の前記一方の発光体を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源の他方の発光体を点灯させるようにしたものであるため、左眼用画像と右眼用画像の両方の解像度が高い、高品質の三次元画像を表示することができる。

【００１５】

この第１の液晶表示装置において、前記面光源の前記導光手段は、その出射面から、前記液晶表示パネルの法線方向に出射光強度のピークが存在する指向性をもった光を出射し、前記レンズアレイは、前記位相差素子の複数の領域のλ／２位相差部を透過した光と無位相差部を透過した光の一方を、前記液晶表示パネルの法線方向に対して前記左眼方向に出射光強度のピークが存在する角度範囲の方向に出射し、他方の光を、前記法線方向に対して前記右眼方向に出射光強度のピークが存在する角度範囲の方向に出射するのが好ましく、このようにすることにより、前記左眼用画像と右眼用画像の両方の輝度及びコントラストが高い、より高品質の三次元画像を表示することができる。

【００１６】

この発明の第２の液晶表示装置は、前記液晶表示パネルの観察側とは反対側に、前記液晶表示パネルに向けて、前記液晶表示パネルの反対側偏光板の透過軸と実質的に直交する直線偏光からなる第１の照明光と前記反対側偏光板の透過軸と実質的に平行な直線偏光からなる第２の照明光とを選択的に照射する光源を配置し、前記光源と前記液晶表示パネルとの間に、前記液晶表示パネルの画面エリアを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて無位相差部を形成した位相差素子を配置し、前記駆動手段により、前記液晶表示パネルの複数の画素のうち、前記１つ置きの第１の領域にそれぞれ対応する各画素と、他の１つ置きの第２の領域にそれぞれ対応する各画素に、三次元画像を表示するための左眼用画像データと右眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源から前記第１の照明光を照射させ、前記１つ置きの第１の領域にそれぞれ対応する各画素と、前記他の１つ置きの第２の領域にそれぞれ対応する各画素に、右眼用画像データと左眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源から前記第２の照明光を照射させるようにしたものであるため、左眼用画像と右眼用画像の両方の解像度が高い、高品質の三次元画像を表示することができる。

【００１７】

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この第２の液晶表示装置において、前記駆動手段は、第１の表示期間に、前記液晶表示パネルの前記１つ置きの第１の領域にそれぞれ対応する各画素と、前記他の１つ置きの第２の領域にそれぞれ対応する各画素とに、左眼用画像データと右眼用画像データとを交互に書込み、前記第１の表示期間に引き続く第２の表示期間に、前記液晶表示パネルの前記第１の領域にそれぞれ対応する各画素と、前記第２の領域にそれぞれ対応する各画素とに、右眼用画像データと左眼用画像データとを交互に書込むのが好ましく、このようにすることにより、前記液晶表示パネルの駆動デューティを高くし、ちらつきの無い、より高品質の三次元画像を表示することができる。

【００１８】

この発明の第３の液晶表示装置は、前記液晶表示パネルの観察側とは反対側に、前記液晶表示パネルに向けて、前記液晶表示パネルの反対側偏光板の透過軸と実質的に直交する直線偏光からなり、且つ前記液晶表示パネルの法線方向に対して表示観察者の左右いずれか一方の眼の方向に傾いた方向に出射光強度のピークが存在する指向性をもった第１の照明光と、前記反対側偏光板の透過軸と実質的に平行な直線偏光からなり、且つ前記法線方向に対して前記観察者の他方の眼の方向に傾いた方向に出射光強度のピークが存在する指向性をもった第２の照明光とを選択的に照射する光源を配置し、前記光源と前記液晶表示パネルとの間に、前記液晶表示パネルの画面エリアを前記画面の上下方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて無位相差部を形成した位相差素子を配置し、前記位相差素子を前記位相差素子移動手段により前記液晶表示パネルの画面の上下方向に移動させて前記複数のλ／２位相差部と無位相差部を前記液晶表示パネルの前記第１の領域と第２の領域とに交互に対向させ、前記駆動手段により、前記位相差素子の前記λ／２位相差部を前記液晶表示パネルの前記１つ置きの第１の領域に対向させ、前記無位相差部を前記他の１つ置きの第２の領域に対向させたときに、前記液晶表示パネルの複数の画素のうち、前記第１の領域の各画素に左眼用画像データを書込み、前記第２の領域の各画素に右眼用画像データを書込み、これらの画像データの書込みに同期させて前記光源から前記第１と第２の照明光を照射させ、前記位相差素子の前記λ／２位相差部を前記液晶表示パネルの前記第２の領域に対向させ、前記無位相差部を前記第１の領域に対向させたときに、前記液晶表示パネルの前記第１の領域の各画素に右眼用画像データを書込み、前記第２の領域の各画素に左眼用画像データを書込み、これらの画像データの書込みに同期させて前記光源から前記第１と第２の照明光を照射させるようにしたものであるため、左眼用画像と右眼用画像の両方の解像度が高い、高品質の三次元画像を表示することができる。

【００１９】

この第３の液晶表示装置において、前記駆動手段は、第１の表示期間に、前記液晶表示パネルの前記１つ置きの第１の領域の各画素と前記他の１つ置きの第２の領域の各画素とに、左眼用画像データと右眼用画像データとを交互に書込み、前記第１の表示期間に引き続く第２の表示期間に、前記液晶表示パネルの前記第１の領域の各画素と前記第２の領域の各画素とに、右眼用画像データと左眼用画像データとを交互に書込むのが好ましく、このようにすることにより、前記液晶表示パネルの駆動デューティを高くし、ちらつきの無い、より高品質の三次元画像を表示することができる。

【００２０】

この発明の第４の液晶表示装置は、前記液晶表示パネルの観察側とは反対側に、前記液晶表示パネルに向けて照明光を照射する光源を配置し、前記液晶表示パネルの観察側に、前記液晶表示パネルの画面エリアを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて複数のλ／２位相差部を形成し、他の１つ置きの第２の領域にそれぞれ対応させて複数の無位相差部を形成した位相差素子を配置し、前記駆動手段により、前記液晶表示パネルの複数の画素のうち、前記位相差素子の複数のλ／２位相差部に対応する各画素に三次元画像を表示するための左右の眼用の画像データのうちの一方の眼用の画像データを書込み、前記位相差素子の複数

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の無位相差部に対応する各画素に他方の眼用の画像データを書込み、前記液晶表示パネルから出射した直線偏光からなる画像光のうち、前記位相差素子の複数のλ／２位相差部と無位相差部の一方を透過して観察側に出射した光を透過させる左眼用直線偏光素子と、前記位相差素子の複数のλ／２位相差部と無位相差部の他方を透過して前記観察側に出射した光を透過させる右眼用直線偏光素子とを有する観察用偏光眼鏡により観察させるようにしたものであるため、三次元画像を表示することができる。

【００２１】

この第４の液晶表示装置において、前記位相差素子の複数のλ／２位相差部と無位相差部は、前記液晶表示パネルの画面エリアを前記画面の左右方向に１つの画素毎に分割した複数の領域に交互に対応させて形成するのが好ましく、このようにすることにより、左眼用画像と右眼用画像の両方の解像度が充分な三次元画像を表示することができる。

【発明を実施するための最良の形態】

【００２２】

（第１の実施形態）

図１～図７はこの発明の第１の実施例を示しており、図１は液晶表示装置の分解斜視図、図２は前記液晶表示装置の平面図である。

【００２３】

この液晶表示装置は、図１及び図２のように、観察側（図２において上側）とその反対側とにそれぞれ偏光板５，６が配置され、光の透過を制御する複数の画素（図示せず）が行方向及び列方向にマトリックス状に配列した画面エリア１ａを有し、前記複数の画素に画像データが書込まれ、その画像データに応じた画像を表示する液晶表示パネル１と、前記液晶表示パネルの観察側とは反対側に配置された面光源７と、前記液晶表示パネル１と面光源７の駆動手段３３とを備えている。

【００２４】

前記液晶表示パネル１は、アクティブマトリックス液晶表示パネルであり、その内部構造は図示しないが、枠状のシール材４を介して接合された一対の透明基板２，３の対向する内面のうち、一方の基板、例えば観察側とは反対側の基板３の内面に、行方向（画面の左右方向）と列方向（画面の上下方向）とにマトリックス状に配列させて形成された複数の透明な画素電極と、これらの画素電極にそれぞれ接続された複数のＴＦＴ（薄膜トランジスタ）と、各行のＴＦＴにゲート信号を供給する複数のゲート配線と、各列のＴＦＴに画像データ信号を供給する複数のデータ配線が設けられ、他方の基板（観察側の基板）２の内面に、前記複数の画素電極に対向する一枚膜状の透明な対向電極が設けられ、前記一対の基板２，３間の前記シール材４で囲まれた領域に液晶層が封入されている。

【００２５】

また、この液晶表示パネル１は、前記液晶層の液晶分子を前記一対の基板２，３間において実質的に９０°の捩れ角でツイスト配向させたＴＮ型のものであり、その観察側偏光板５と反対側偏光板６は、それぞれの透過軸を直交させるか、あるいは平行にして配置されている。図１において、６ａは前記反対側偏光板６の透過軸である。

【００２６】

前記面光源７は、光を入射させる入射部９ａ，９ｂと前記入射部９ａ，９ｂから入射した光を出射する出射面１０と前記入射部９ａ，９ｂから入射した光を前記出射面１０に向けて反射する反射面１１とを有し、前記入射部９ａ，９ｂから入射した光を導いて前記出射面１０から出射する導光手段８と、前記導光手段８の入射部９ａ，９ｂに対向させて配置され、選択的に点灯される第１と第２の発光体２４，２５と、一方の方向に透過軸２６ａ，２７ａを有し、前記第１と第２の発光体２４，２５の出射側にそれぞれ、各々の透過軸２６ａ，２７ａを実質的に直交させて配置された第１と第２の直線偏光素子２６，２７と、前記導光手段８の出射面１０に対向させて配置された位相差素子２８と、前記位相差素子２８の前記導光手段８に対向する側とは反対側に設けられたレンズアレイ３１とを備えている。

【００２７】

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前記導光手段８は、前記液晶表示パネル１の画面エリア１ａに対応する矩形状の平面形状を有するアクリル樹脂板等の透明板からなっており、その互いに対向する２つの端面にそれぞれ入射部９ａ，９ｂが形成され、２つの板面の一方に出射面１０が形成され、他方の板面に、前記入射部９ａ，９ｂから入射した光を前記出射面１０に向けて反射する反射面１１が形成されている。以下，この導光手段８を導光板、その入射部９ａ，９ｂを入射端面という。

【００２８】

この導光板８の出射面１０は平坦面に形成されており、反射面１１には、前記入射端面９ａ，９ｂの長さ方向、つまり導光板８の幅方向と実質的に平行な直線状の複数の細長溝１２が，前記導光板８の長さ方向に一定ピッチで形成されている。

【００２９】

前記導光板８は、前記入射端面９ａ，９ｂから入射した光を、前記反射面１１の各細長溝１２間の平坦面部と前記出射面１０とにより内面反射しながら導光板８の長さ方向に導き、前記反射面１１の各細長溝１２に入射した光を、前記細長溝１２の溝面により前記出射面１０の法線方向に対する角度が小さくなる方向に内面反射して前記出射面１０から出射させる。

【００３０】

この導光板８の反射面１１の各細長溝１２は、前記出射面１０の法線方向に対して一方の入射端面９ａ方向と他方の入射端面９ｂ方向とにそれぞれ実質的に４５°の角度で傾いた２つの溝面を有する二等辺三角形状の断面形状に形成されており、前記導光板８の一方の入射端面９ａから入射した光を、前記一方の入射端面９ａ側の溝面により前記出射面１０の法線付近の方向に内面反射し、前記導光板８の他方の入射端面９ｂから入射した光を、前記他方の入射端面９ｂ側の溝面により前記出射面１０の法線付近の方向に内面反射する。

【００３１】

そのため、前記導光板８にその一方の入射端面９ａ及び他方の入射端面９ｂから入射し、前記導光板８の出射面１０から出射する光はそれぞれ、前記出射面１０の法線方向に出射光強度のピークが存在する指向性をもった光である。

【００３２】

なお、図では前記導光板８の反射面１１の細長溝１２を大きく誇張しているが、前記細長溝１２は、前記液晶表示パネル１の画素ピッチと同程度またはそれよりも小さいピッチで形成されており、したがって、前記導光板８の出射面１０から出射する光は、強度むらの無い均一な強度分布の光である。

【００３３】

また、前記第１と第２の発光体２４，２５は、ＬＥＤ（発光ダイオード）等の複数の固体発光素子を配列した発光素子アレイからなっており，その出射面を前記導光板８の一方の入射端面９ａと他方の入射端面９ｂにそれぞれ対向させて配置されている。

【００３４】

さらに、前記第１と第２の直線偏光素子２６，２７は、前記導光板８の入射端面９ａ，９ｂに対応する形状に形成されており、前記導光板８の一方の入射端面９ａとその外側に配置された前記第１の発光体２４との間と、前記導光板８の他方の入射端面９ｂとその外側に配置された前記第２の発光体２５との間に、それぞれの直線偏光素子２６，２７の透過軸２６ａ，２７ａを実質的に直交させて配置されている。

【００３５】

この実施例では、図１に示したように、前記第１の直線偏光素子２６を、その透過軸２６ａを前記導光板８の幅方向（入射端面９ａ，９ｂの長さ方向）と実質的に平行にして配置し、前記第２の直線偏光素子２７を、その透過軸２７ａを前記導光板８の板厚方向（入射端面９ａ，９ｂの高さ方向）と実質的に平行にして配置している。

【００３６】

また、前記導光板８の出射面１０に対向させて配置された位相差素子２８は、前記導光

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板８の出射面１０に沿った方向に、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部２９と、実質的に位相差の無い複数の無位相差部３０とを交互に形成したものであり、前記複数のλ／２位相差部２９は、図１に示したように、前記導光板８の幅方向（入射端面９ａ、９ｂの長さ方向）に対して実質的に４５°傾いた方向に遅相軸２９ａを有している。

【００３７】

すなわち、前記複数のλ／２位相差部２９の遅相軸２９ａは、前記第１の発光体２４から前記第１の直線偏光素子２６を透過して前記導光板８に入射し、前記導光板８の出射面１０から出射する直線偏光と、前記第２の発光体２５から前記第２の直線偏光素子２７を透過して前記導光板８に入射し、前記導光板８の出射面１０から出射する直線偏光の両方の偏光面に対して実質的に４５°の角度で交差している。

【００３８】

この位相差素子２８の複数のλ／２位相差部２９と無位相差部３０は、互いに同じ幅に、且つ、前記導光板８の出射面１０に沿った一方の方向、例えば前記導光板８の幅方向（入射端面９ａ、９ｂの長さ方向）と平行なストライプ状に形成されている。

【００３９】

なお、図では前記λ／２位相差部２９と無位相差部３０を大きく誇張しているが、このλ／２位相差部２９と無位相差部３０は、できるだけ小さい幅及びピッチで形成されている。

【００４０】

前記位相差素子２８は、透過光に対して実質的に複屈折性を示さない透明シートの一方の面に、例えば、一軸延伸フィルムからなる細長形状のλ／２位相差フィルムをストライプ状に並べて貼付けるか、あるいは、前記透明シート面に高分子液晶を塗布または印刷し、その高分子液晶を予め定めた一方の方向に分子長軸が揃うように配向させてポリマー化することにより複数のλ／２位相差層を形成したものであり、これらのλ／２位相差層の形成部により前記複数のλ／２位相差部２９が形成され、前記透明シートの前記λ／２位相差層を形成しない部分により前記複数の無位相差部３０が形成されている。

【００４１】

また、前記位相差素子２８の前記導光板８に対向する側とは反対側に設けられたレンズアレイ３１は、前記位相差素子２８の隣合う１つずつのλ／２位相差部２９と無位相差部３０とからなる複数の領域にそれぞれ対応する複数のレンズ３２を有しており、これらのレンズ３２は、前記ストライプ状に形成されたλ／２位相差部２９及び無位相差部３０の長さ方向と平行で、且つ前記隣合う１つずつのλ／２位相差部２９と無位相差部３０の合計幅と実質的に同じ幅を有する細長形状に形成されている。

【００４２】

なお、この実施例では、前記位相差素子２８のλ／２位相差部２９を形成した面とは反対面に前記レンズアレイ３１を一体に形成しているが、前記レンズアレイ３１は、前記位相差素子２８とは別に製作したものを前記位相差素子２８に対向させて配置してもよい。

【００４３】

前記レンズアレイ３１は、前記導光板８の出射面１０から出射し、前記位相差素子２８の前記複数の領域のλ／２位相差部２９を透過した光を、前記複数のレンズ３２により、予め定めた方向に対して一方の方向に傾いた第１の出射方向に出射し、前記複数の領域の無位相差部３０を透過した光を、前記複数のレンズ３２により、前記予め定めた方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射する。

【００４４】

この実施例では、前記予め定めた方向を、前記導光板８の出射面１０の法線方向とし、前記レンズアレイ３１の複数のレンズ３２を、前記導光板８の出射面１０の法線方向と平行で、且つ前記複数の領域のλ／２位相差部２９と無位相差部３０の境界を通る面を中心として左右対称な凸レンズに形成している。

【００４５】

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前記レンズアレイ３１は、前記導光板８にその入射端面９ａ，９ｂから入射し、前記導光板８の反射面１１の各細長溝１２の溝面により反射されて前記導光板８の出射面１０から前記出射面１０の法線付近の方向に出射した光のうち、前記位相差素子２８の複数の領域のλ／２位相差部２９を透過した光を、前記導光板８の出射面１０の法線方向に対して前記λ／２位相差部２９側とは反対方向に傾いた第１の出射方向に出射光強度のピークが存在する角度範囲の方向に出射し、前記位相差素子２８の複数の領域の無位相差部３０を透過した光を，前記導光板８の出射面１０の法線方向に対して前記無位相差部３０側とは反対方向に傾いた第２の出射方向に出射光強度のピークが存在する角度範囲の方向に出射する。

【００４６】

すなわち、前記面光源７は、前記第１と第２の発光体２４，２５の一方の点灯により、実質的に直交する２つの方向の直線偏光の一方を前記第１の出射方向に，他方の直線偏光を前記第２の出射方向にそれぞれ出射し、他方の発光体の点灯により，前記一方の直線偏光を前記第２の出射方向に，前記他方の直線偏光を前記第１の出射方向に出射する。

【００４７】

図４及び図５は前記面光源７からの出射光線図であり、図４は前記第１の発光体２４を点灯させたときの出射光線、図５は前記第２の発光体２５を点灯させたときの出射光線を示している。

【００４８】

図４のように、前記面光源７の第１の発光体２４を点灯させたときは、この第１の発光体２４からの光が、前記第１の直線偏光素子２６により、その透過軸２６ａに平行な直線偏光Ｓとされて前記導光板８にその一方の入射端面９ａから入射し、前記導光板８の反射面１１の各細長溝１２の前記一方の入射端面９ａ側の溝面により反射されて前記導光板８の出射面１０から前記出射面１０の法線付近の方向に出射する。

【００４９】

前記導光板８の出射面１０から出射した前記直線偏光Ｓは、前記位相差素子２８に入射し、その光のうち、前記位相差素子２８の複数の領域のλ／２位相差部２９に入射した光が、その偏光面に対して実質的に４５°の角度方向に遅相軸２９ａを有する前記λ／２位相差部２９を、このλ／２位相差部２９により偏光面を９０°回転されて透過し、前記第１の直線偏光素子２６を透過して前記導光板８に入射した直線偏光Ｓに対して実質的に直交する直線偏光Ｐとなって前記レンズアレイ３１に入射する。

【００５０】

また、前記導光板８の出射面１０から出射して前記位相差素子２８に入射した光のうち、前記位相差素子２８の複数の領域の無位相差部３０に入射した光は、前記無位相差部３０を実質的に偏光状態を変えずに透過し、前記第１の直線偏光素子２６を透過して前記導光板８に入射した直線偏光Ｓのまま前記レンズアレイ３１に入射する。

【００５１】

そして、前記２つの方向の直線偏光Ｐ，Ｓのうち、前記位相差素子２８の複数の領域のλ／２位相差部２９からの一方の直線偏光Ｐは、前記レンズアレイ３１の各レンズ３２の前記λ／２位相差部２９に対応する部分により集光され、前記導光板８の出射面１０の法線方向に対して前記λ／２位相差部２９側とは反対方向に傾いた第１の出射方向に出射し、前記位相差素子２８の複数の領域の無位相差部３０からの他方の直線偏光Ｓは、前記レンズアレイ３１の各レンズ３２の前記無位相差部３０に対応する部分により集光され、前記導光板８の出射面１０の法線方向に対して前記無位相差部３０側とは反対方向に傾いた第２の出射方向に出射する。

【００５２】

また、図５のように、前記面光源７の第２の発光体２５を点灯させたときは、この第２の発光体２５からの光が、前記第２の直線偏光素子２７により、その透過軸２７ａに平行な直線偏光Ｐとされて前記導光板８にその他方の入射端面９ｂから入射し、前記導光板８の反射面１１の各細長溝１２の前記他方の入射端面９ｂ側の溝面により反射されて前記導

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光板８の出射面１０から前記出射面１０の法線付近の方向に出射する。

【００５３】

前記導光板８の出射面１０から出射した前記直線偏光Ｐは、前記位相差素子２８に入射し、その光のうち、前記位相差素子２８の複数の領域のλ／２位相差部２９に入射した光が、その偏光面に対して実質的に４５°の角度方向に遅相軸２９ａを有する前記λ／２位相差部２９を、このλ／２位相差部２９により偏光面を９０°回転されて透過し、前記第２の直線偏光素子２７を透過して前記導光板８に入射した直線偏光Ｐに対して実質的に直交する直線偏光Ｓとなって前記レンズアレイ３１に入射する。

【００５４】

また、前記導光板８の出射面１０から出射して前記位相差素子２８に入射した光のうち、前記位相差素子２８の複数の領域の無位相差部３０に入射した光は、前記無位相差部３０を実質的に偏光状態を変えずに透過し、前記第２の直線偏光素子２７を透過して前記導光板８に入射した直線偏光Ｐのまま前記レンズアレイ３１に入射する。

【００５５】

そして、前記２つの方向の直線偏光Ｐ，Ｓのうち、前記位相差素子２８の複数の領域の無位相差部３０からの一方の直線偏光Ｐは、前記レンズアレイ３１の各レンズ３２の前記無位相差部３０に対応する部分により集光され、前記導光板８の出射面１０の法線方向に対して前記無位相差部３０側とは反対方向に傾いた第２の出射方向に出射し、前記位相差素子２８の複数の領域のλ／２位相差部２９からの他方の直線偏光Ｓは、前記レンズアレイ３１の各レンズ３２の前記λ／２位相差部２９に対応する部分により集光され、前記導光板８の出射面１０の法線方向に対して前記λ／２位相差部２９側とは反対方向に傾いた第１の出射方向に出射する。

【００５６】

図６は前記面光源７からの第１の発光体２４を点灯させたときの前記２つの方向の直線偏光Ｐ，Ｓの出射光強度分布図、図７は前記面光源７の第２の発光体２５を点灯させたときの前記２つの方向の直線偏光Ｐ，Ｓの出射光強度分布図であり、図６及び図７において、正の角度は、前記導光板８の出射面１０の法線方向（０°）に対して前記第１の出射方向の傾き角、負の角度は、前記法線方向（０°）に対して前記第２の出射方向の傾き角である。

【００５７】

このように、前記面光源７は、前記第１の発光体２４の点灯により、実質的に直交する２つの方向の一方の直線偏光Ｐを、前記導光板８の出射面１０の法線方向に対して一方の方向に傾いた第１の出射方向に出射光強度のピークが存在する角度範囲の方向に、他方の直線偏光Ｓを、前記導光板８の出射面１０の法線方向に対して前記一方の方向とは反対方向に傾いた前記第２の出射方向に出射光強度のピークが存在する角度範囲の方向にそれぞれ出射し、前記第２の発光体２５の点灯により、前記一方の直線偏光Ｐを前記第２の出射方向に出射光強度のピークが存在する角度範囲の方向に、他方の直線偏光Ｓを前記第１の出射方向に出射光強度のピークが存在する角度範囲の方向にそれぞれ出射する。

【００５８】

そのため、前記面光源７を、観察側とその反対側とにそれぞれ偏光板５，６を配置した前記液晶表示パネル１の観察側とは反対側に配置することにより、前記液晶表示パネル１の複数の画素に三次元画像を表示するための左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源７の一方の発光体２４または２５を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源７の他方の発光体２５または２４を点灯させて三次元画像を表示する液晶表示装置を得ることができる。

【００５９】

図１及び図２に示した液晶表示装置は、前記液晶表示パネル１の観察側とは反対側に、前記面光源７を配置したものであり、前記面光源７は、前記レンズアレイ３１を前記液晶表示パネル１に対向させ、且つ、前記導光板８の出射面１０の法線方向を前記液晶表示パ

ネル１の法線方向に一致させて、前記第１と第２の出射方向の一方を前記液晶表示パネル１の法線方向に対して表示観察者の左眼方向に傾いた方向に向け、他方の出射方向を前記液晶表示パネル１の法線方向に対して前記観察者の右眼方向に傾いた方向に向けて配置されている。

【００６０】

したがって、前記面光源７の導光板８は、その出射面１０から、前記液晶表示パネル１の法線方向に出射光強度のピークが存在する指向性をもった光を出射し、前記面光源７のレンズアレイ３１は、前記位相差素子２８の複数の領域のλ／２位相差部２９を透過した光と無位相差部３０を透過した光の一方を、前記液晶表示パネル１の法線方向に対して表示観察者の左眼方向に出射光強度のピークが存在する角度範囲の方向に出射し、他方の光を、前記法線方向に対して前記観察者の右眼方向に出射光強度のピークが存在する角度範囲の方向に出射する。

【００６１】

さらに、前記面光源７の第１と第２の直線偏光素子２６，２７の透過軸２６ａ，２７ａの向きは、前記液晶表示パネル１の反対側偏光板６の透過軸６ａの向きに応じて、前記第１と第２の発光体２４，２５の一方の点灯により、前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に平行な直線偏光を前記左眼方向に、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光を前記右眼方向に出射し、他方の発光体の点灯により、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光を前記左眼方向に、前記反対側偏光板６の透過軸６ａと実質的に平行な直線偏光を前記右眼方向に出射するように設定されている。

【００６２】

また、前記液晶表示パネル１と面光源７の駆動手段３３は、前記液晶表示パネル１の複数の画素に三次元画像を表示するための左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源７の前記一方の発光体２４または２５を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源７の他方の発光体２５または２４を点灯させる駆動回路からなっている。

【００６３】

この実施例の液晶表示装置では、図１に示したように、前記液晶表示パネル１の反対側偏光板６の透過軸６ａを画面の左右方向と平行にし、前記面光源７の第１と第２の直線偏光素子２６，２７の透過軸２６ａ，２７ａ及び位相差素子２８の複数のλ／２位相差部２９の遅相軸２９ａとレンズアレイ３１の各レンズ３２の長さ方向を上述したように設定することにより、前記面光源７から、前記第１の発光体２４の点灯により、前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に平行な直線偏光Ｐを前記左眼方向に、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光Ｓを前記右眼方向に出射させ、第２の発光体２５の点灯により、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光Ｓを前記左眼方向に、前記反対側偏光板６の透過軸６ａと実質的に平行な直線偏光Ｐを前記右眼方向に出射させるようにし、前記駆動手段３３を、前記液晶表示パネル１の複数の画素への左眼用画像データの書込みに同期させて前記面光源７の第１の発光体２４を点灯させ、左眼用画像データの書込みに同期させて前記面光源７の第２の発光体２５を点灯させるように構成している。

【００６４】

この液晶表示装置は、前記液晶表示パネル１の観察側とは反対側に、前記構成の面光源７を、そのレンズアレイ３１を前記液晶表示パネル１に対向させ、且つ前記第１の出射方向を前記液晶表示パネル１の法線方向に対して表示観察者の左眼方向に傾いた方向に向け、前記第２の出射方向を前記法線方向に対して前記観察者の右眼方向に傾いた方向に向けて、前記第１の発光体２４の点灯により前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に平行な直線偏光Ｐを前記左眼方向に、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光Ｓを前記右眼方向に出射し、前記第２の発光体２５の点灯により前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光Ｓを前記左眼方向に、前

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記反対側偏光板６の透過軸６ａと実質的に平行な直線偏光Ｐを前記右眼方向に出射するように配置し、前記駆動手段３３により、前記液晶表示パネル１の複数の画素に左眼用画像データと右眼用画像データとを交互に書込み、前記左眼用画像データの書込みに同期させて前記面光源７の第１の発光体２４を点灯させ、前記左眼用画像データの書込みに同期させて前記面光源７の第２の発光体２５を点灯させるようにしたものであるため、左眼用画像と右眼用画像の両方の解像度が高い、高品質の三次元画像を表示することができる。

【００６５】

図３は前記液晶表示装置の左眼用画像を表示するときと右眼用画像を表示するときの出射光線図であり、（ａ）は左眼用画像を表示するときの出射光線、（ｂ）は右眼用画像の表示するときの出射光線を示している。

【００６６】

前記液晶表示装置は、前記液晶表示パネル１の複数の画素に左眼用画像データを書込み、その左眼用画像データの書込みに同期させて前記面光源７の第１の発光体２４を点灯させて左眼用画像を表示し、前記液晶表示パネル１の複数の画素に右眼用画像データを書込み、その右眼用画像データの書込みに同期させて前記面光源７の第２の発光体２５を点灯させて右眼用画像を表示する。

【００６７】

すなわち、前記面光源７の第１の発光体２４を点灯させたときは、図４のように、前記面光源７から、前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に平行な直線偏光Ｐが前記左眼方向に、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光Ｓが前記右眼方向に出射し、これらの直線偏光Ｐ，Ｓのうち、前記左眼方向に出射した直線偏光Ｐが、図３（ａ）に矢線で示したように前記液晶表示パネル１に前記反対側偏光板６を透過して入射し、前記右眼方向に出射した直線偏光Ｓが前記液晶表示パネル１の反対側偏光板６により吸収される。

【００６８】

そのため、前記液晶表示パネル１の複数の画素に左眼用画像データを書込み、その左眼用画像データの書込みに同期させて前記面光源７の第１の発光体２４を点灯させたときに、前記液晶表示パネル１から、前記左眼用画像データに対応する画像光が表示観察者の左眼方向に出射し、その左眼用画像が前記観察者の左眼により観察される。

【００６９】

また、前記面光源７の第２の発光体２５を点灯させたときに、図５のように、前記面光源７から、前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に平行な直線偏光Ｐが前記右眼方向に、前記反対側偏光板６の透過軸６ａと実質的に直交する直線偏光Ｓが前記左眼方向に出射し、これらの直線偏光Ｐ，Ｓのうち、前記右眼方向に出射した直線偏光Ｐが、図３（ｂ）に矢線で示したように前記液晶表示パネル１に前記反対側偏光板６を透過して入射し、前記左眼方向に出射した直線偏光Ｓが前記液晶表示パネル１の反対側偏光板６により吸収される。

【００７０】

そのため、前記液晶表示パネル１の複数の画素に右眼用画像データを書込み、その右眼用画像データの書込みに同期させて前記面光源７の第２の発光体２５を点灯させたときに、前記液晶表示パネル１から、前記右眼用画像データに対応する画像光が表示観察者の右眼方向に出射し、その右眼用画像が前記観察者の右左眼により観察される。

【００７１】

このように、前記液晶表示装置は、前記液晶表示パネル１の複数の画素に左眼用画像データを書込み、その左眼用画像データの書込みに同期させて前記面光源７の第１の発光体２４を点灯させて前記液晶表示パネル１に左眼用画像を表示し、前記液晶表示パネル１の複数の画素に左眼用画像データを書込み、その左眼用画像データの書込みに同期させて前記面光源７の第２の発光体２５を点灯させて前記液晶表示パネル１に右眼用画像を表示するものであり、この液晶表示装置は、前記左眼用画像と右眼用画像とをそれぞれ前記液晶表示パネル１の全ての画素を使用して表示することができるため、左眼用画像と右眼用画

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像の両方の解像度が高い、高品質の三次元画像を表示することができる。

【００７２】

しかも、この液晶表示装置は、前記面光源７の導光板８の出射面１０から、前記液晶表示パネル１の法線方向に出射光強度のピークが存在する指向性をもった光を出射させ、前記面光源７のレンズアレイ３１により、前記位相差素子２８の複数の領域のλ／２位相差部２９を透過した光と無位相差部３０を透過した光の一方を、前記液晶表示パネル１の法線方向に対して表示観察者の左眼方向に出射光強度のピークが存在する角度範囲の方向に出射させ、他方の光を、前記法線方向に対して前記観察者の右眼方向に出射光強度のピークが存在する角度範囲の方向に出射させるようにしているため、前記左眼用画像と右眼用画像の両方の輝度及びコントラストが高い、より高品質の三次元画像を表示することができる。

【００７３】

なお、前記液晶表示装置は，前記液晶表示パネル１にはカラーフィルタを備えさせず、前記面光源７の第１と第２の発光体２４，２５にそれぞれ、赤色ＬＥＤと緑色ＬＥＤと青色ＬＥＤとを備えさせて、これらの発光体２４，２５から赤、緑、青の３色の光を選択的に出射させるようにしたフィールドシーケンシャル液晶表示装置でも、前記液晶表示パネル１に複数の画素にそれぞれ対応させて赤、緑、青の３色のカラーフィルタを備えさせ、前記面光源７の第１と第２の発光体２４，２５からそれぞれ白色光を出射させるようにした液晶表示装置でもよい。

【００７４】

前記フィールドシーケンシャル液晶表示装置の場合は、前記駆動手段３３を、１つの三次元カラー画像を表示するための１フレームを６分割した６つのフィールド毎に、赤、緑、青の３色の単位色の左眼用画像データと右眼用画像データのうちの１つの画像データを任意の順序で選択して順次前記液晶表示パネル１の各画素に書込み、赤、緑、青の各単位色の左眼用画像データの書込みにそれぞれ同期させて前記面光源７の第１の発光体２４の赤、緑、青の３色のＬＥＤのうちの書込み画像データの色のＬＥＤを点灯させ、赤、緑、青の各単位色の右眼用画像データの書込みにそれぞれ同期させて前記面光源７の第２の発光体２５の赤、緑、青の３色のＬＥＤのうちの書込み画像データの色のＬＥＤを点灯させるように構成する。

【００７５】

また、前記液晶表示パネル１に赤，緑、青の３色のカラーフィルタを備えさせた液晶表示装置の場合は、前記駆動手段３３を、１つの三次元カラー画像を表示するための１フレームを２分割した２つのフィールドの一方に、赤、緑、青の３色の色データからなる左眼用画像データを前記液晶表示パネル１の各画素に書込み、前記２つのフィールドの他方に、赤、緑、青の３色の色データからなる右眼用画像データを前記液晶表示パネル１の各画素に書込み、前記左眼用画像データの書込みに同期させて前記面光源７の第１の発光体２４を点灯させ、前記右眼用画像データの書込みに同期させて前記面光源７の第２の発光体２５を点灯させるように構成する。

【００７６】

また、前記面光源７の導光手段は、上記導光板８に限らず、光を入射させる入射部と前記入射部から入射した光を出射する出射面と前記入射部から入射した光を前記出射面に向けて反射する反射面とを有し、前記入射部から入射した光を導いて前記出射面から出射するものであれば、他の構成のものでもよい。

【００７７】

図８は上記第１の実施例の変形例を示す液晶表示装置の平面図であり、この変形例は、面光源７を、プリズムシート１４と反射板１６とからなる導光手段１３を備えた構成としたものである。

【００７８】

この導光手段１３は、一方の面に複数の細長プリズム１５を互いに平行に形成したプリズムシート１４のプリズム形成面に、前記反射板１６を、前記プリズムシート１４との間

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に空間を設けて対向配置したものであり、前記プリズムシート１４と反射板１６との間の空間の前記細長プリズム１５の長さ方向と直交する方向の２つの端部により光を入射させる入射部１７ａ，１７ｂが形成され、前記プリズムシート１４のプリズム形成面とは反対面により前記入射部１７ａ，１７ｂから入射した光の出射面１４ａが形成され、前記反射板１６の前記プリズムシート１４と対向する面により前記入射部１７ａ，１７ｂから入射した光を前記出射面１４ａに向けて反射する反射面１６ａが形成されている。

【００７９】

この導光手段１３は、前記入射部１７ａ，１７ｂから入射した光を、図に矢線及び破矢線で示したように、前記反射板１６の反射面１６ａにより反射して前記プリズムシート１４に入射させ、その光を前記プリズムシート１４の複数の細長プリズム１５により屈折させて前記プリズムシート１４の出射面１４ａから前記出射面１４ａの法線方向に出射する。

【００８０】

そして、この実施例の面光源７は、前記導光手段１３の前記２つの端部の入射部１７ａ，１７ｂにそれぞれ対向させて第１と第２の発光体２４，２５を配置し、これらの発光体２４，２５の出射側にそれぞれ、一方の方向に透過軸を有する第１と第２の直線偏光素子２６，２７を配置し、前記導光手段１３の出射面１４ａに対向させて前記位相差素子２８を配置し、この位相差素子２８の前記導光手段１３に対向する側とは反対側に前記レンズアレイ３１を設けて構成されている。

【００８１】

図９は上記第１の実施例の他の変形例を示す面光源の導光手段と第１及び第２の発光体と第１及び第２の直線偏光素子の斜視図であり、この変形例は、前記導光手段を、透明板の一端面に光を入射させる入射部（以下、入射端面という）１９を形成し、前記透明板の２つの板面の一方に前記入射端面１９から入射した光を出射する平坦な出射面２０を形成し、前記透明板の他方の板面に、前記入射部１９から入射した光を前記出射面２０に向けて反射する反射面２１を形成した導光板１８としたものである。

【００８２】

この導光板１８の反射面２１は、前記入射端面１９を形成した一端側から他端側に向かって前記出射面２０に近くなる方向に階段状に傾いた傾斜面からなっており、その階段状傾斜面の各段差面により、前記入射端面１９から入射した光を前記出射面２０の法線付近の方向に内面反射する細長反射部２２が形成されている。

【００８３】

この実施例の面光源は、前記導光板１８の一端の入射端面１９に対向させて、前記入射端面１９をその長さ方向に偶数に分割した形状の複数ずつ（図では２つずつ）の第１と第２の発光体２４，２５を前記入射端面１９の長さ方向に交互に並べて配置し、これらの発光体２４，２５の出射側にそれぞれ前記第１と第２の直線偏光素子２６，２７を，それぞれの透過軸を実質的に直交させて配置し、さらに前記導光板１８の入射端面１９と前記直線偏光素子２６，２７との間に、前記第１及び第２の発光体２４，２５から出射し、前記第１及び第２の直線偏光素子２６，２７を透過した直線偏光の強度分布を均一にして前記導光板１８に入射させるための拡散板２３を配置したものであり、図９では省略しているが、前記導光板１８の出射面２０に対向させて前記位相差素子２８が配置され、この位相差素子２８の前記導光板１８に対向する側とは反対側に前記レンズアレイ３１が設けられている。

【００８４】

前記図８及び図９に示した各変形例の面光源は、上記のような構成のものであるため、上述した第１の実施例の面光源７と同様に、前記第１と第２の発光体２４，２５の一方の点灯により、実質的に直交する２つの方向の直線偏光の一方を前記導光板１８の出射面２０の法線方向に対して一方の方向に傾いた第１の出射方向に、他方の直線偏光を前記導光板１８の出射面２０の法線方向に対して前記一方の方向とは反対方向に傾いた第２の出射方向に出射し，他方の発光体の点灯により、前記一方の直線偏光を前記第２の出射方向に

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、前記他方の直線偏光を前記第１の出射方向に出射することができる。

【００８５】

したがって、この面光源を前記液晶表示パネル１の観察側とは反対側に配置して液晶表示装置を構成することにより、左眼用画像と右眼用画像の両方の輝度及びコントラストが高い、高品質の三次元画像を表示することができる。

【００８６】

（第２の実施形態）

図１０はこの発明の第２の実施例を示す液晶表示装置の平面図である。なお、この実施例において、上述した第１の実施例の液晶表示装置に対応するものには図に同符号を付し、同一にものについてはその説明を省略する。

【００８７】

この実施例の液晶表示装置は、前記液晶表示パネル１と、前記液晶表示パネル１の観察側とは反対側に配置され、前記液晶表示パネル１に向けて、前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に直交する直線偏光からなる第１の照明光と前記反対側偏光板６の透過軸６ａと実質的に平行な直線偏光からなる第２の照明光とを選択的に照射する光源３４と、前記光源３４と前記液晶表示パネル１との間に、前記液晶表示パネル１に近接または接面させて前記液晶表示パネル１と実質的に平行に配置された位相差素子２８と、前記液晶表示パネル１と光源３４の駆動手段４３とを備えている。

【００８８】

前記光源３４は、前記液晶表示パネル１に向けて均一な強度分布の第１の照明光と第２の照明光を照射する面光源であり、例えば、前記液晶表示パネル１の画面エリア１ａに対応する矩形状の平面形状を有するアクリル樹脂板等の透明板からなり、その互いに対向する２つの端面にそれぞれ光を入射させる入射端面３６ａ，３６ｂが形成され、２つの板面の一方に前記入射部３６ａ，３６ｂから入射した光を出射する出射面３７が形成され、他方の板面に、前記入射部３６ａ，３６ｂから入射した光を前記出射面３７に向けて内面反射する反射面３８が形成された導光板３５と、前記導光板３５の２つの入射端面３６ａ，３６ｂにそれぞれ対向させて配置され、選択的に点灯される第１と第２の発光体３９，４０と、一方の方向に透過軸を有し、前記第１と第２の発光体３９，４０の出射側にそれぞれ、各々の透過軸を実質的に直交させて配置された第１と第２の直線偏光素子４１，４２とにより構成されている。

【００８９】

なお、前記第１と第２の発光体３９、４０は、ＬＥＤ等の複数の固体発光素子を配列した発光素子アレイからなっており、その出射面を前記導光板３５の一方の入射端面３６ａと他方の入射端面３６ｂにそれぞれ対向させて配置されている。

【００９０】

また、前記第１と第２の直線偏光素子４１、４２は、前記導光板３５の入射端面３６ａ，３６ｂに対応する形状に形成されており、前記導光板３５の一方の入射端面３６ａとその外側に配置された前記第１の発光体３９との間と、前記導光板３５の他方の入射端面３６ｂとその外側に配置された前記第２の発光体４０との間に、それぞれの直線偏光素子４１，４２の透過軸を実質的に直交させて配置されている。

【００９１】

この実施例では、前記第１の直線偏光素子４１を、その透過軸を前記導光板３５の幅方向（入射端面３６ａ，３６ｂの長さ方向）と実質的に平行にして配置し、前記第２の直線偏光素子４２を、その透過軸を前記導光板３５の板厚方向（入射端面３６ａ，３６ｂの高さ方向）と実質的に平行にして配置している。

【００９２】

この光源３４は、前記駆動手段４３により前記第１の発光体３９と第２の発光体４０とを選択的に点灯され、前記第１の発光体３９の点灯により、前記第１の直線偏光素子４１の透過軸に平行な直線偏光からなる第１の照明光を前記導光板３５の出射面３７から出射し、前記第２の発光体４０の点灯により、前記第２の直線偏光素子４２の透過軸に平行な

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直線偏光、つまり第１の照明光に対して実質的に直交する直線偏光からなる第２の照明光を前記導光板３５の出射面３７から出射する。

【００９３】

この光源３４は、前記液晶表示パネル１の観察側とは反対側に、前記導光板３５の出射面３７から出射する前記第１と第２の照明光のうち、第１の照明光の偏光面を前記液晶表示パネル１の反対側偏光板６の透過軸６ａと実質的に直交させ、第２の照明光の偏光面を前記反対側偏光板６の透過軸６ａと実質的に平行にして配置されている。

【００９４】

前記位相差素子２８は、前記液晶表示パネル１の画面エリア１ａを前記画面の左右方向に予め定めた数の画素毎に分割した複数の領域のうち、１つ置きの第１の領域にそれぞれ対応させて、透過光の常光と異常光との間に１／２波長の位相差を与える複数のλ／２位相差部２９を形成し、他の１つ置きの第２の領域にそれぞれ対応させて、実質的に位相差の無い複数の無位相差部３０を形成したものであり、前記複数のλ／２位相差部２９は、前記導光板３５の幅方向（入射端面３６ａ，３６ｂの長さ方向）に対して実質的に４５°傾いた方向に遅相軸を有している。

【００９５】

すなわち、前記複数のλ／２位相差部２９の遅相軸は、前記光源３４の第１の発光体３９から前記第１の直線偏光素子４１を透過して前記導光板３５に入射し、前記導光板３５の出射面３７から出射する直線偏光からなる第１の照明光と、前記第２の発光体４０から前記第２の直線偏光素子４２を透過して前記導光板３５に入射し、前記導光板３５の出射面３７から出射する直線偏光からなる第２の照明光の両方の偏光面に対して実質的に４５°の角度で交差している。

【００９６】

この実施例では、前記液晶表示パネル１の画面エリア１ａを前記画面の左右方向に１画素列毎に分割し、前記位相差素子２８の複数のλ／２位相差部２９と無位相差部３０を、前記液晶表示パネル１の１画素列毎に分割された各領域の１つ置きの第１の領域と他の１つ置きの第２の領域とにそれぞれ対応させて、前記画面の上下方向に沿った縦ストライプ状に形成している。

【００９７】

また、前記駆動手段４３は、第１の表示期間に、前記液晶表示パネル１の複数の画素のうち、前記１つ置きの第１の領域、つまり表示の観察側から見て前記液晶表示パネル１の法線方向に対し左方向（表示観察者Ｍの左眼方向）に傾いた線上において前記位相差素子２８の複数のλ／２位相差部２９に対向する１列置きの画素列、例えば奇数番の画素列の各画素と、前記他の１つ置きの第２の領域、つまり表示の観察側から見て前記液晶表示パネル１の法線方向に対し右方向（表示観察者Ｍの右眼方向）に傾いた線上において前記位相差素子２８の複数のλ／２位相差部２９に対向する他の１列置きの画素列、例えば偶数番の画素列の各画素とに、三次元画像を表示するための左眼用画像データと右眼用画像データを交互に書込み、にそれぞれ対応する各画素と、他の１つ置きの第２の領域にそれぞれ対応する各画素に、三次元画像を表示するための左眼用画像データと右眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源３４から前記第１の照明光を照射させ、前記第１の表示期間に引き続く第２の表示期間に、前記奇数番の画素列の各画素と、前記偶数番の画素列の各画素とに、右眼用画像データと左眼用画像データを交互に書込み、これらの画像データの書込みに同期させて前記光源３４から前記第２の照明光を照射させる駆動回路からなっている。

【００９８】

なお、この液晶表示装置は、フィールドシーケンシャル液晶表示装置でも、前記液晶表示パネル１に赤、緑、青の３色のカラーフィルタを備えさせた液晶表示装置でもよく、フィールドシーケンシャル液晶表示装置の場合は、前記駆動手段４３を、１つの三次元カラー画像を表示するための１フレームを６分割した６つのフィールド毎に、赤、緑、青の３色の単位色のうちの１つの単位色の左眼用画像データと右眼用画像データとを、前記奇数

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