番と偶数番の一方の画素列の各画素と他方の画素列の各画素とに書込み、これらの赤、緑、青の各単位色の左眼用及び右眼用画像データの書込みにそれぞれ同期させて、前記光源３４から、赤、緑、青の３色のうちの書込み画像データの色の第１または第２の照明光を出射させるように構成する。

【００９９】

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２分割した２つのフィールド毎に、赤、緑、青の３色の色データからなる左眼用画像データと右眼用画像データとを、前記奇数番と偶数番の一方の画素列の各画素と他方の画素列の各画素とに書込み、それに同期させて、前記光源３４から第１または第２の白色照明光を出射させるように構成する。

【０１００】

図１１及び図１２は前記第２の実施例の液晶表示装置の表示原理図であり、図１１は前記光源３４から前記第１の照明光を照射させたときの左眼用画像と右眼用画像の表示原理、図１２は前記光源３４から前記第２の照明光を照射させたときの左眼用画像と右眼用画像の表示原理を示している。

【０１０１】

この液晶表示装置は、前記液晶表示パネル１の複数の画素のうち、前記奇数番の画素列の各画素に左眼用画像データを書込み、前記偶数番の画素列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３４から前記第１の照明光を照射させて１列置きの第１の左眼用画像と１列置きの第１の右眼用画像を表示させ、それに続けて、前記偶数番の画素列の各画素に左眼用画像データを書込み、前記奇数番の画素列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３４から前記第２の照明光を照射させて前記第１の左眼用画像の列間の第２の左眼用画像と前記第１の右眼用画像の列間の第２の右眼用画像を表示させ、これらの４つの画像によって高精細の三次元画像を表示する。

【０１０２】

すなわち、前記光源３４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と実質的に直交する直線偏光からなる前記第１の照明光を照射させたときは、その第１の照明光のうち、前記位相差素子２８の複数のλ／２位相差部２９を透過して偏光面を９０°回転された光が、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、前記位相差素子２８の複数の無位相差部３０を実質的に偏光状態を変えずに透過した光が、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。

【０１０３】

そのため、前記液晶表示パネル１の前記奇数番の画素列の各画素に左眼用画像データを書込み、偶数番の画素列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３４から前記第１の照明光を照射させたときに、前記位相差素子２８の複数のλ／２位相差部２９を透過した光のうち、前記左眼用画像データを書込んだ前記奇数番の画素列の各画素（図１１において塗りつぶした画素）Ｄａに入射した光が、その画素に表示された左眼用画像Ｌ１として観察者Ｍの左眼に向かって出射し、前記右眼用画像データを書込んだ前記偶数番の画素列の各画素（図１１において白抜きの画素）Ｄｂに入射した光が、その画素より表示された右眼用画像Ｒ１として観察者Ｍの右眼に向かって出射する。したがって、観察者の左眼に、奇数番の画素列毎の左眼用画像を観察させ、右眼に、偶数番の画素列毎の右眼用画像を観察させることができる。

【０１０４】

また、前記光源３４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からなる前記第２の照明光を照射させたときは、その第２の照明光のうち、前記位相差素子２８の複数の無位相差部３０を実質的に偏光状態を変えずに透過した光が、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、前記位相差素子２８の複数のλ／２位相差部２９を透過して偏光面を９０°回転された光が、前記液晶表

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示パネル１の反対側偏光板６により吸収される。

【０１０５】

そのため、前記液晶表示パネル１の前記偶数番の画素列の各画素に左眼用画像データを書込み、前記奇数番の画素列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３４から前記第２の照明光を照射させたときに、前記位相差素子２８の複数の無位相差部３０を透過した光のうち、前記左眼用画像データを書込んだ前記偶数番の画素列の各画素（図１２において塗りつぶした画素）Ｄｂに入射した光が、その画素に表示された左眼用画像Ｌ２として観察者Ｍの左眼に向かって出射し、前記右眼用画像データを書込んだ前記奇数番の画素列の各画素（図１２において白抜きの画素）Ｄａに入射した光が、その画素に表示された右眼用画像Ｒ２として観察者Ｍの右眼に向かって出射する。したがって、観察者の左眼に、偶数番の画素列毎の左眼用画像を観察させ、右眼に、奇数番の画素列毎の右眼用画像を観察させることができる。

【０１０６】

図１３は前記第２の実施例の液晶表示装置における前記液晶表示パネル１の表示画像の模式図であり、（ａ）は、図１１のように前記光源３４から前記第１の照明光を照射させたときの前記奇数番の画素列により表示された左眼用画像Ｌ１と前記偶数番の画素列により表示された右眼用画像Ｒ１を示し、（ｂ）は、図１２のように前記光源３４から前記第２の照明光を照射させたときの前記偶数番の画素列により表示された左眼用画像Ｌ２と前記奇数番の画素列により表示された右眼用画像Ｒ２を示している。

【０１０７】

すなわち、この液晶表示装置は、前記光源３４から前記第１の照明光を照射させたときには、前記位相差素子２８の複数の無位相差部３０がパララックスバリアとして作用し、前記奇数番の画素列により表示された左眼用画像Ｌ１を表示観察者Ｍの左眼に観察させ、前記偶数番の画素列により表示された右眼用画像Ｒ１を表示観察者Ｍの右眼に観察させ、前記光源３４から前記第２の照明光を照射させたときには、前記位相差素子２８の複数のλ／２位相差部２９がパララックスバリアとして作用して、前記偶数番の画素列により表示された左眼用画像Ｌ２を表示観察者Ｍの左眼に観察させ、前記奇数番の画素列により表示された右眼用画像Ｒ２を表示観察者Ｍの左眼に観察させる。

【０１０８】

したがって、前記奇数番の画素列により表示された左眼用画像Ｌ１と偶数番の画素列により表示された左眼用画像Ｌ２とにより解像度の高い左眼用画像（図１３の表示例ではＡの文字画像）を表示観察者Ｍの左眼に観察させ、前記偶数番の画素列により表示された右眼用画像Ｒ１と、前記奇数番の画素列により表示された右眼用画像Ｒ２とにより解像度の高い右眼用画像（図１３の表示例ではＺの文字画像）を前記観察者Ｍの右眼に観察させることができる。

【０１０９】

なお、この実施例では、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形成しているが、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複数の画素列、例えば２～１０列程度の画素列毎に分割し、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の前記複数の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形成してもよい。

【０１１０】

このように、この実施例の液晶表示装置は、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を配置し、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

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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複数の無位相差部３０を形成した位相差素子２８を配置し、駆動手段４３により、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、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３４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。

【０１１１】

また、この実施例の液晶表示装置は、前記駆動手段４３により、第１の表示期間に、前記液晶表示パネル１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１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ようにしているため、、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。

【０１１２】

（第３の実施形態）

図１４及び図１５はこの発明の第３の実施例を示す液晶表示装置の斜視図及び平面図である。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。

【０１１３】

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り、且つ前記液晶表示パネル１の法線方向に対して表示観察者Ｍ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ａ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り、且つ前記液晶表示パネル１の法線方向に対して前記観察者Ｍ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ｂとを選択的に照射する光源４４と、前記光源４４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、前記位相差素子２８を前記液晶表示パネル１の画面の上下方向に移動させる位相差素子移動手段５１と、前記液晶表示パネル１と光源４４の駆動手段５２とを備えている。

【０１１４】

前記光源４４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ａと第２の照明光ｂ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の右半分の領域と左半分の領域とにそれぞれ対応する第１と第２の光源部４５ａ，４５ｂと、一方の方向に透過軸４８ａ，４９ａを有し、前記第１と第２の光源部４５ａ，４５ｂの出射側にそれぞれ、各々の透過軸４８ａ，４９ａ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４８，４９と、前記液晶表示パネル１の観察側から見て右側の第１の光源部４５ａから出射し、前記第１の直線偏光素子４８によりその透過軸４８ａに平行な直線偏光とされた第１の照明光ａを表示観察者Ｍの一方の眼の方向、例えば左眼方向に集光させ、前記観察側から見て左側の第２の光源部４５ｂから出射し、前記第２の直線偏光素子４９によりその透過軸４９ａに平行な直線偏光とされた第２の照明光ｂを前記観察者Ｍの他方の眼の方向、つまり右眼方向に集光させるサーキュラフレネルレンズ５０とにより構成されている。

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【０１１５】
この実施例では、図１４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を前記画面の左右方向と平行にし、前記光源４４の第１の光源部４５ａの出射側に配置した第１の直線偏光素子４８の透過軸４８ａを前記液晶表示パネル１の反対側偏光板６の透過軸６ａに対して実質的に直交させ、第２の光源部４５ｂの出射側に配置した第２の直線偏光素子４９の透過軸４９ａ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いる。なお、図１４において、５ａは、前記液晶表示パネル１の観察側偏光板５の透過軸である。

【０１１６】
前記第１と第２の光源部４５ａ，４５ｂはそれぞれ、前記液晶表示パネル１の画面エリア１ａの右半分及び左半分の領域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、その一端面に光を入射させる入射端面が形成され、２つの板面の一方に前記入射部から入射した光を出射する出射面が形成され、他方の板面に前記入射部から入射した光を前記出射面に向けて内面反射する反射面が形成された導光板４６と，前記導光板４６の入射端面に対向させて配置された発光体４７とからなっている。なお、前記発光体４７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４６の入射端面に対向させて配置されている。

【０１１７】
この光源４４は、前記駆動手段５２により前記第１の光源部４５ａの発光体４７と前記第２の光源部４５ｂの発光体４７の両方を点灯され、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り、且つ前記液晶表示パネル１の法線方向に対して表示観察者Ｍの左眼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ａ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り、且つ前記液晶表示パネル１の法線方向に対して前記観察者Ｍ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ｂとを図１５に矢線で示したように前記液晶表示パネル１に向けて照射する。

【０１１８】
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を前記画面の上下方向に予め定めた数の画素毎、例えば１つ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、前記光源４４の第１の光源部４５ａの出射側に配置された第１の直線偏光素子４８の透過軸４８ａ及び第２の光源部４５ｂの出射側に配置された第２の直線偏光素子４９の透過軸４９ａ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。

【０１１９】
この実施例では、前記液晶表示パネル１の画面エリア１ａを前記画面の上下方向に１画素行毎に分割し、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画素行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，前記画面の左右方向に沿った横ストライプ状に形成している。

【０１２０】
前記位相差素子移動手段５１は、その構造は図示しないが、例えばリニアステッピングモータからなっており、前記駆動手段５２から供給されるタイミング信号に応じて、前記位相差素子２８を、前記λ／２位相差部２９と無位相差部３０のピッチに対応するストロークで前記画面の上下方向に移動させ、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の前記第１の領域と第２の領域とに交互に対向させる。

【０１２１】

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また、前記駆動手段５２は、前記位相差素子移動手段５１により前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の前記１つ置きの第１の領域に対向させ、無位相差部３０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１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、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４４から前記第１と第２の照明光ａ，ｂを照射させ，前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の前記第２の領域に対向させ、無位相差部３０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１の前記第１の領域の各画素に右眼用画像データを、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４４から前記第１と第２の照明光ａ，ｂを照射させる駆動回路からなっている。

【０１２２】

さらに、この駆動手段５２は、第１の表示期間に、前記液晶表示パネル１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１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ように構成されている。

【０１２３】

前記位相差素子移動手段５１と駆動手段５２は、前記位相差素子２８の移動と、前記液晶表示パネル１の奇数番の画素行の各画素と偶数番の画素行の各画素への左眼用画像データと右眼用画像データの書込み及び前記奇数番の画素行の各画素と偶数番の画素行の各画素への左眼用画像データと右眼用画像データの書込みとを交互に行なうように構成されており、前記位相差素子移動手段５１は、前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の奇数番の画素行に対向させ、無位相差部３０を偶数番の画素行に対向させた状態を、前記液晶表示パネル１の奇数番の画素行の各画素と偶数番の画素行の各画素に左眼用画像データと右眼用画像データを書込み、前記光源４４から前記第１と第２の照明光ａ，ｂを照射させる表示時間中維持し，前記位相差素子２８のλ／２位相差部２９を前記偶数番の画素行に対向させ、無位相差部３０を前記奇数番の画素行に対向させた状態を、前記偶数番の画素行の各画素と奇数番の画素行の各画素に左眼用画像データと右眼用画像データを書込み、前記光源４４から前記第１と第２の照明光ａ，ｂを照射させる表示時間中維持する。

【０１２４】

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、前記位相差素子移動手段５１と駆動手段５２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、前記位相差素子２８を上下いずれかの方向に移動させ、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、前記奇数番と偶数番の一方の画素行の各画素と他方の画素行の各画素とに書込み，これらの赤、緑、青の各単位色の左眼用及び右眼用画像データの書込みにそれぞれ同期させて、前記光源４４から、赤，緑，青の３色のうちの書込み画像データの色の第１と第２の照明光ａ，ｂを出射させるように構成する。

【０１２５】

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、前記位相差素子移動手段５１と駆動手段５２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つのフィールド毎に、前記位相差素子２８を上下いずれかの方向に移動させ、赤、緑、青の３色の色データからなる左眼用画像データと右眼用画像データとを、前記奇数番と偶数番の一方の画素行の各画素と他方の画素行の各画素とに書込み、それに同期させて前記光源４４から第１と第２の白色照明光ａ，ｂを出射させるように構成する。

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【０１２６】
この液晶表示装置は、前記位相差素子２８を前記位相差素子移動手段５１により前記液晶表示パネル１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２９と無位相差部３０を前記液晶表示パネル１の奇数番の画素行と偶数番の画素行とに交互に対向させ、前記駆動手段５２により、前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の奇数番の画素行に対向させ、無位相差部３０を偶数番の画素行に対向させたときに、前記液晶表示パネル１の複数の画素のうち、前記奇数番の画素行の各画素に左眼用画像データを書込み、前記偶数番の画素行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４４から前記第１と第２の照明光ａ，ｂを照射させ、前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の偶数番の画素行に対向させ、無位相差部３０を奇数番の画素行に対向させたときに、前記液晶表示パネル１の前記偶数番の画素行の各画素に右眼用画像データを書込み、前記奇数番の画素行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ａ，ｂを照射させて三次元画像を表示する。

【０１２７】
すなわち、前記光源４４の第１の光源部３５ａから照射された第１の照明光ａは、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であるため、この第１の照明光ａのうち、前記位相差素子２８の複数のλ／２位相差部２９を透過して偏光面を９０°回転された光が、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、前記位相差素子２８の複数の無位相差部３０を実質的に偏光状態を変えずに透過した光が、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。

【０１２８】
また、前記光源４４の第２の光源部３５ｂから照射された第２の照明光ｂは、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であるため、この第２の照明光ｂのうち、前記位相差素子２８の複数の無位相差部３０を実質的に偏光状態を変えずに透過した光が、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、前記位相差素子２８の複数のλ／２位相差部２９を透過して偏光面を９０°回転された光が、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。

【０１２９】
そのため、前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の奇数番の画素行に対向させ、無位相差部３０を偶数番の画素行に対向させ、前記液晶表示パネル１の奇数番の画素行の各画素に左眼用画像データを書込み、偶数番の画素行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４４から前記第１と第２の照明光ａ，ｂを照射させたときに、前記液晶表示パネル１の左眼用画像データを書込んだ前記奇数番の画素行の各画素により表示された左眼用画像が観察者Ｍの左眼に見え、右眼用画像データを書込んだ前記偶数番の画素行の各画素により表示された右眼用画像が観察者Ｍの右眼に見える。

【０１３０】
また、前記位相差素子２８のλ／２位相差部２９を前記液晶表示パネル１の偶数番の画素行に対向させ、無位相差部３０を奇数番の画素行に対向させ、前記液晶表示パネル１の偶数番の画素行の各画素に左眼用画像データを書込み、奇数番の画素行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４４から前記第１と第２の照明光ａ，ｂを照射させたときに、前記液晶表示パネル１の左眼用画像データを書込んだ前記偶数番の画素行の各画素により表示された左眼用画像が観察者Ｍの左眼に見え、右眼用画像データを書込んだ前記奇数番の画素行の各画素により表示された右眼用画像が観察者Ｍの右眼に見える。

【０１３１】
したがって、この液晶表示装置によれば、前記液晶表示パネル１の奇数番の画素列と偶数番の画素列とにより交互に表示された１画素行置きの２つの左眼用画像からなる解像度の高い左眼用画像を表示観察者Ｍの左眼に観察させ、前記液晶表示パネル１の偶数番の画

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素列と奇数番の画素列とにより交互に表示された１画素行置きの２つの右眼用画像からなる解像度の高い右眼用画像を表示観察者Ｍの左眼に観察させることができる。

【０１３２】

なお、この実施例では、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画素行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形成しているが、前記液晶表示パネル１の画面エリア１ａを前記画面の上下方向に複数の画素行、例えば２～１０行程度の画素行毎に分割し、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の前記複数の画素行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形成してもよい。

【０１３３】

このように、この実施例の液晶表示装置は、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り、且つ前記液晶表示パネル１の法線方向に対して表示観察者Ｍ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ａ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り、且つ前記法線方向に対して前記観察者Ｍ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ｂとを照射する光源４４を配置し、前記光源４４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の画面エリア１ａ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複数の無位相差部３０を形成した位相差素子２８を配置し、前記位相差素子２８を前記位相差素子移動手段５１により前記液晶表示パネル１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２９と無位相差部３０を前記液晶表示パネル１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５２により、前記位相差素子２８の前記λ／２位相差部２９を前記液晶表示パネル１の前記第１の領域に対向させ、前記無位相差部３０を前記第２の領域に対向させたときに、前記液晶表示パネル１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４４から前記第１と第２の照明光ａ，ｂを照射させ、前記位相差素子２８の前記λ／２位相差部２９を前記液晶表示パネル１の前記第２の領域に対向させ、前記無位相差部３０を前記第１の領域に対向する位置に移動させたときに、前記液晶表示パネル１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４４から前記第１と第２の照明光ａ，ｂ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。

【０１３４】

また、この実施例の液晶表示装置は、前記駆動手段５２により、第１の表示期間に、前記液晶表示パネル１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ようにしているため、前記液晶表示パネル１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。

【０１３５】

（第４の実施形態）

図１６はこの発明の第４の実施例を示す液晶表示装置の斜視図である。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。

【０１３６】

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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に向けて照明光を照射する光源５３と、前記液晶表示パネル１の観察側に、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の駆動手段５６と、前記液晶表示パネル１から観察側に出射した画像光を表示観察者の方向に反射する反射型スクリーン５７と、前記観察者に三次元画像を観察させるための観察用偏光眼鏡５８とを備えている。

【０１３７】

なお、前記光源５３は、光源ランプ５４と、前記光源ランプ５４からの放射光を前記液晶表示パネル１に向けて反射するリフレクタ５５とからなっており、前記反射型スクリーン５７は、前記光源５３からの照射光の広がりによる表示画像の歪みを補償する凹曲面スクリーンからなっている。

【０１３８】

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、前記液晶表示パネル１の観察側偏光板の透過軸に対して実質的に４５°傾いた方向に遅相軸を有している。

【０１３９】

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。

【０１４０】

前記液晶表示パネル１の駆動手段５６は、前記液晶表示パネル１の複数の画素のうち、前記位相差素子２８の複数のλ／２位相差部２９に対応する１列置きの複数の画素列の各画素に、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一方の眼用の画像データを書込み、前記位相差素子２８の複数の無位相差部３０に対応する他の１列置きの複数の画素列の各画素に、他方の眼用の画像データを書込を書込む駆動回路からなっている。

【０１４１】

また、前記観察用偏光眼鏡５８は、前記液晶表示パネル１から出射した直線偏光（観察側偏光板の透過軸に平行な直線偏光）からなる画像光のうち、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の一方を透過して観察側に出射し、前記反射型スクリーン５７により反射された光を透過させる左眼用直線偏光素子５９と、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の他方を透過して前記観察側に出射し、前記反射型スクリーン５７により反射された光を透過させる右眼用直線偏光素子６０とを有している。

【０１４２】

この観察用偏光眼鏡５８の左眼用と右眼用の直線偏光素子５９，６０は、一方の方向に透過軸５９ａ，６０ａを有しており、眼鏡フレーム５８ａに、それぞれの直線偏光素子５９，６０の透過軸５９ａ，６０ａを実質的に直交させて固定されている。

【０１４３】

なお、この実施例では、前記駆動手段５６を、前記液晶表示パネル１の前記位相差素子２８の複数のλ／２位相差部２９に対応する１列置きの複数の画素列の各画素に左眼用画像データを書込み、前記位相差素子２８の複数の無位相差部３０に対応する他の１列置きの複数の画素列の各画素に右眼用画像データを書込を書込むように構成し、前記観察用偏

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光眼鏡５８の左眼用直線偏光素子５９の透過軸５９ａを、前記液晶表示パネル１の前記左眼用画像データを書込んだ１列置きの画素列に対応する領域から出射し、前記位相差素子２８の複数の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°回転されて透過して前記反射型スクリーン５７により反射された左眼用の画像光の偏光面と実質的に平行にし、前記観察用偏光眼鏡５８の右眼用直線偏光素子６０の透過軸６０ａを、前記液晶表示パネル１の前記右眼用画像データを書込んだ他の１列置きの画素列に対応する領域から出射し、前記位相差素子２８の複数の無位相差部３０を実質的に偏光状態を変えずに透過して前記反射型スクリーン５７により反射された右眼用の画像光の偏光面と実質的に平行にしている。

【０１４４】

すなわち、この実施例の液晶表示装置は、前記液晶表示パネル１の観察側とは反対側に、前記液晶表示パネル１に向けて照明光を照射する光源５３を配置し、前記液晶表示パネル１の観察側に、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複数の無位相差部３０を形成した位相差素子２８を配置し、前記駆動手段５６により、前記液晶表示パネル１の複数の画素のうち、前記位相差素子２８の複数のλ／２位相差部２９に対応する各画素に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２８の複数の無位相差部３０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１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２８の複数のλ／２位相差部２９と無位相差部３０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５９と、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６０とを有する観察用偏光眼鏡５８により観察させるようにしたものである。

【０１４５】

そのため、この液晶表示装置によれば、前記液晶表示パネル１の画面エリア１ａのうち、前記位相差素子２８の複数のλ／２位相差部２９に対応する領域に表示させた一方の眼用の画像と、前記位相差素子２８の複数の無位相差部３０に対応する領域に表示させた他方の眼用の画像データとを表示観察者Ｍの左右の眼にそれぞれ観察させ、三次元画像を表示することができる。

【０１４６】

また、この実施例の液晶表示装置は、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の画面エリア１ａ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しているため、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。

【０１４７】

なお、この実施例の液晶表示装置は、液晶表示パネル１から観察側に出射した画像光を表示観察者の方向に反射する反射型スクリーン５７を備えたものであるが、前記反射型スクリーン５７を透過型スクリーンに変更し、この透過型スクリーンを透過した左右の眼用の画像光を前記観察用偏光眼鏡５８により観察させるようにしても、あるいは、スクリーンを備えずに、液晶表示パネル１から観察側に出射した左右の眼用の画像光を前記直接観察用偏光眼鏡５８により観察させるようにしてもよい。

【０１４８】

（他の実施形態）

上述した各実施例では、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、液晶表示パネル１の画面の上下方向または左右方向に沿ったストライプ状に形成しているが、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は、例えば前記画面の上下方向と左右方向とに交互に並んだ市松状に形成してもよく、第１の実施例において前記位相差素子２８の複数のλ／２位相差部２９と無位相差部３０を市松状に形成

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する場合は、レンズアレイ３１の各レンズ３２も前記λ／２位相差部２９及び無位相差部３０に対応する市松状に形成すればよい。

【０１４９】

また、上述した各実施例の液晶表示装置はＴＮ型の液晶表示パネル１を備えたものであるが、液晶表示パネルは、ＳＴＮ型、非ツイストの水平配向型、垂直配向型、ベント配向型の液晶表示パネル、あるいは強誘電性または反強誘電性液晶表示パネル等でもよい。

【図面の簡単な説明】

【０１５０】

【図１】この発明の第１の実施例を示す液晶表示装置の分解斜視図。

【図２】前記液晶表示装置の平面図。

【図３】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。

【図４】前記液晶表示装置の面光源からの第１の発光体を点灯させたときの出射光線図。

【図５】前記液晶表示装置の面光源からの第２の発光体を点灯させたときの出射光線図。

【図６】前記面光源からの第１の発光体を点灯させたときの２つの方向の直線偏光の出射光強度分布図。

【図７】前記面光源からの第２の発光体を点灯させたときの２つの方向の直線偏光の出射光強度分布図。

【図８】第１の実施例の変形例を示す液晶表示装置の平面図。

【図９】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。

【図１０】この発明の第２の実施例を示す液晶表示装置の平面図。

【図１１】第２の実施例の液晶表示装置の光源から第１の照明光を照射させたときの左眼用画像と右眼用画像の表示原理図。

【図１２】第２の実施例の液晶表示装置の光源から第２の照明光を照射させたときの左眼用画像と右眼用画像の表示原理図。

【図１３】第２の実施例の液晶表示装置における液晶表示パネルの表示画像の模式図。

【図１４】この発明の第３の実施例を示す液晶表示装置の斜視図。

【図１５】第３の実施例の液晶表示装置の平面図。

【図１６】この発明の第４の実施例を示す液晶表示装置の斜視図。

【符号の説明】

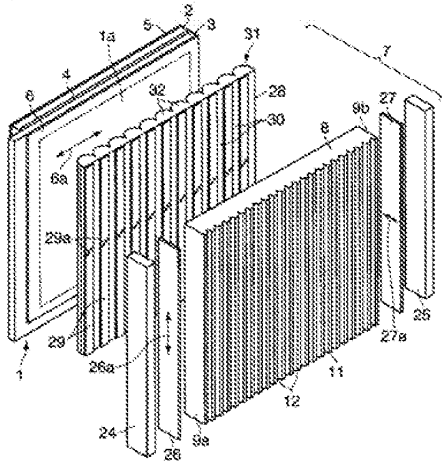
【０１５１】

１…液晶表示パネル、１ａ…画面エリア、７…面光源、８…導光板（導光手段）、９ａ，９ｂ…入射端面（入射部）、１０…出射面、１１…反射面、１３…導光手段、１４…プリズムシート、１６…反射板，１４ａ…出射面、１６ａ…反射面、１８…導光板（導光手段）、１９…入射端面（入射部）、２０…出射面、２１…反射面、２３…拡散板，２４，２５…発光体、２６，２７…直線偏光素子、２６ａ，２７ａ…透過軸、２８…位相差素子、２９…λ／２位相差部、３０…無位相差部、３１…レンズアレイ、３２…レンズ、３３…駆動手段、３４，４４，５３…光源、４３，５２，５６…駆動手段、５１…位相差素子移動手段、５７…反射型スクリーン、５８…観察用偏光眼鏡、５９…左眼用直線偏光素子、６０…右眼用直線偏光素子、５９ａ，６０ａ…透過軸。

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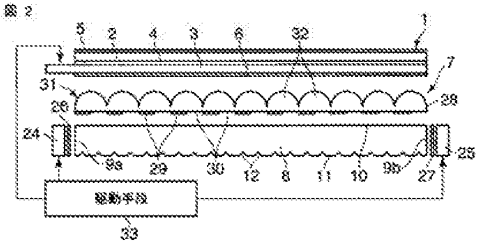
【図１】

図１



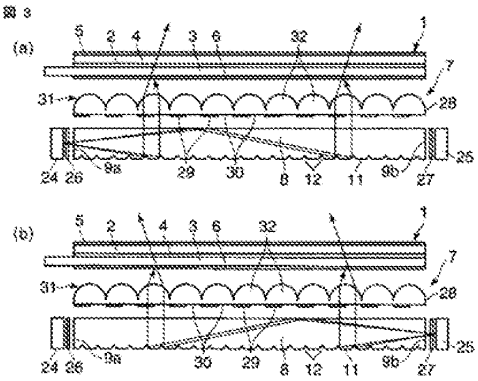
【図２】

図２



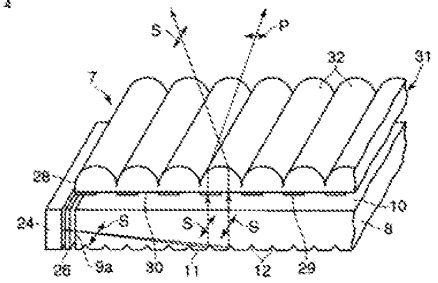
【図３】

図３



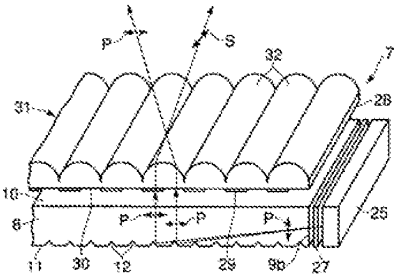
【図４】

図４



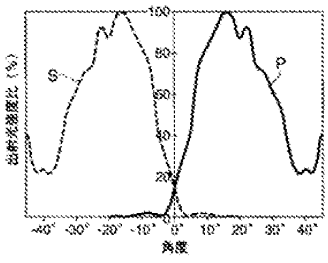
【図５】

図５



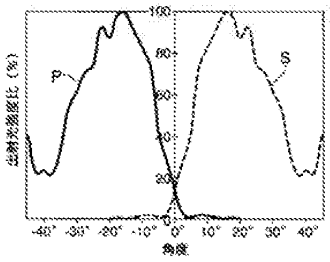
【図６】

図６



【図７】

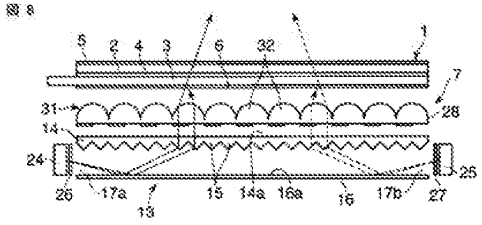
図７



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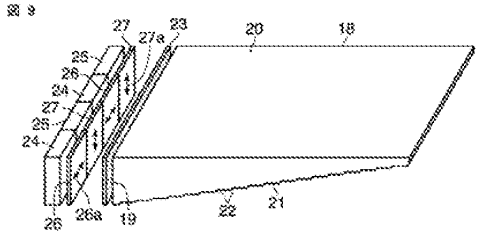
【図８】

図８



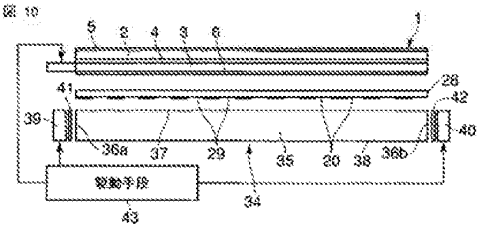
【図９】

図９



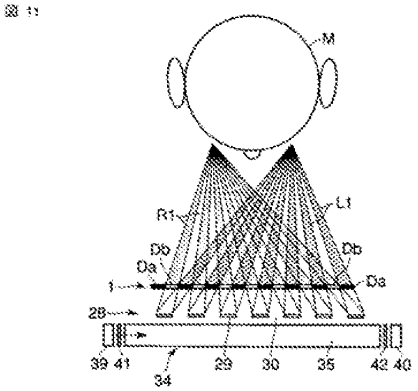
【図１０】

図１０



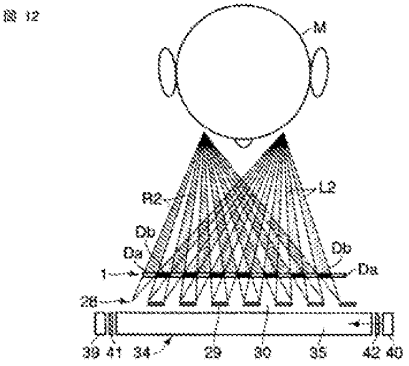
【図１１】

図１１



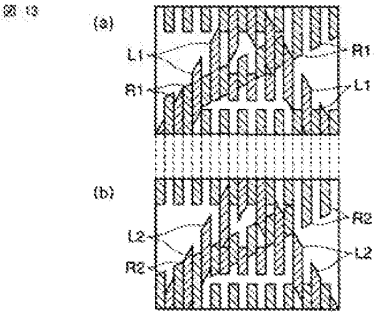
【図１２】

図１２



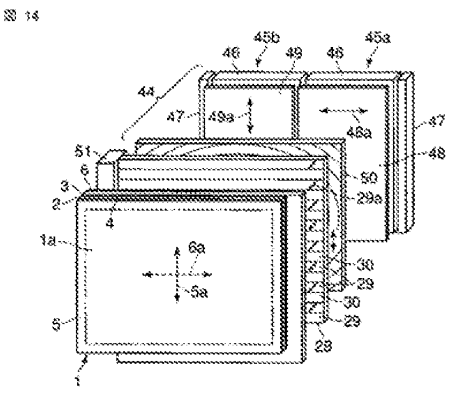
【図１３】

図１３



【図１４】

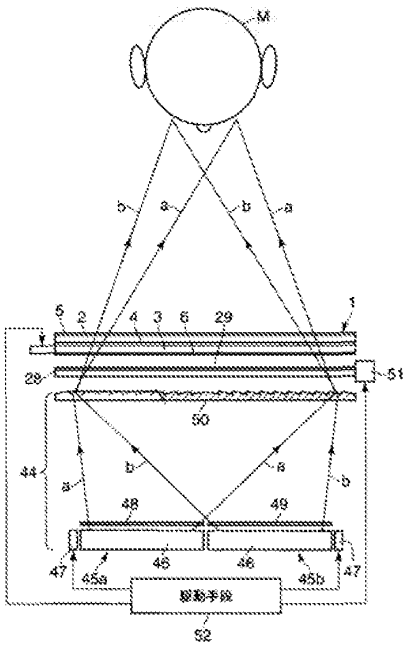
図１４



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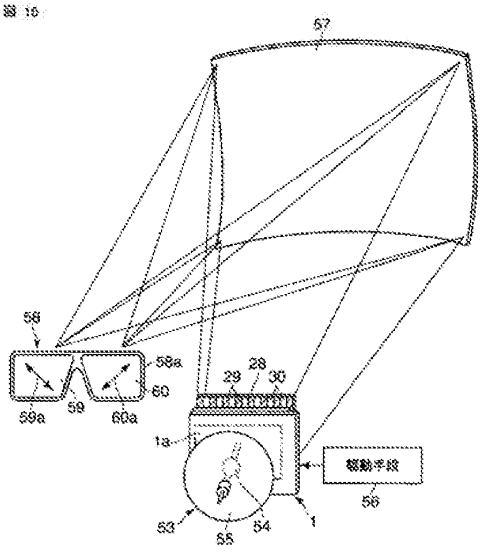
【図１５】

図 15



【図１６】

図 16



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1.This document has been translated by computer. So the translation may not reflect the original precisely.
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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]The present invention relates to the display device and method for detecting the position of the eye of 1 or a plurality of observers, and making 3-dimensional scenography observe with the motion parallax of both eyes, and especially other observers other than the observer of 3-dimensional scenography are related with the image display device and method for enabling observation of a two-dimensional image.

[0002]

[Description of the Prior Art]Conventionally, as a stereoscopic display device, the thing of the 2 eye type is known best. Fig.55 is the conventional 2 eye type stereoscopic display device. The image 206 for right eyes and the image 208 for left eyes are displayed on the screen 202 of the display device 200 like Fig.56, The image 206 for right eyes was shown as the right eye 38 for this image using fill-in flash study systems, such as a polarization eyeglass, the image 208 for left eyes was simultaneously shown as the left eye 40, and the stereoscopic picture 204 is shown with motion parallax of both eyes.

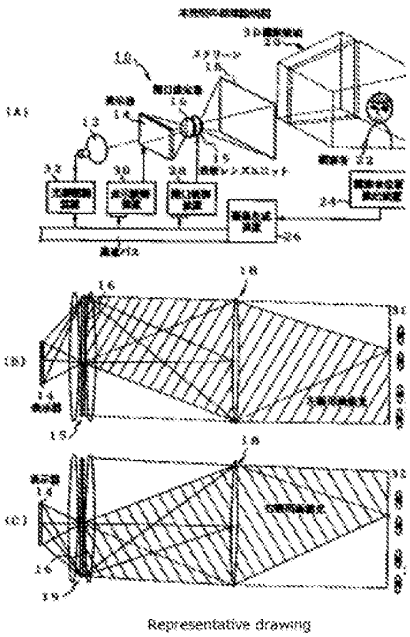
As a stereoscopic display device which does not need fill-in flash study systems, such as a polarization eyeglass, there are a RENTI cura system of Fig.57 and a parallax barrier system of Fig.58.

[0003]The stereoscopic display device of the RENTI cura system of Fig.57 comprises the indicator 210 and the RENTI cura lenses 212, such as a liquid crystal device. Separation arrangement of the display pixel R of a right eye image and the display pixel L of a left eye image is carried out at the indicator 210. The light from the right eye pixel R is projected on the position of the right eye 38 of the observer in the viewing area 214 with the RENTI cura lens 212. Simultaneously, the light from the left eye pixel L is projected on the position of the left eye 40 of the observer in the viewing area 214 with the RENTI cura lens 212, and can see 3-dimensional scenography with the motion parallax of both eyes.

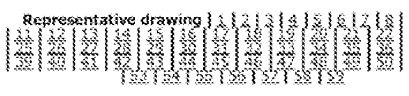
[0004]The stereoscopic display device of the parallax barrier system of Fig.58 comprises the indicator 210 and the slits 216, such as a liquid crystal device. Separation arrangement of the display pixel R of a right eye image and the display pixel L of a left eye image is carried out at the indicator 210. The light from the right eye pixel R is projected on the position of the right eye 38 of the observer in the viewing area 214 by the slit 216. Simultaneously, the light from the left eye pixel L is projected on the position of the left eye 40 of the observer in the viewing area 214 by the slit 216, and can see 3-dimensional scenography from the motion parallax of both eyes.

[0005]However, about both a RENTI cura system and a parallax barrier system. Since would be in the pseudoscopic condition which the image included in a right and left eye replaces, and it would separate or a screen would become dark if it separates like eye 38' and 40' from the viewing area 214 where the position of an observer's eyes 38 and 40 was set up preliminarily, there was a problem to which a solid observation area is limited. There is a stereoscopic display device of the Fig.59 which extended the solid observation area about the RENTI cura system to eliminate this problem. The double RENTI cura lens 220 which equipped the screen with the slit 222 is being used for this stereoscopic display device. To the screen which uses the double RENTI cura lens 220, the indicator 216-1 for right eye images, the projector lens 218-1, and the indicator 216-2 and the projector lens 218-2 for left eye images are independently provided by the projector 215.

[0006]The double RENTI cura lens 220 has a function which transmits light towards the



Representative drawing



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direction by which light came. For this reason, when a screen is seen from the position of the viewing area 214 which faces projector lens 216-1,216-2, the right eye image R and the left eye image L on which it was projected can be seen, the right and left eyes 38 and 40 can be made to perceive an image independently, and it can observe as a solid.
[0007]When an observer moves to the right and left directions 224-1 or the forward/rearward direction 226-1, he is trying not to always separate from an observer's eyes 38 and 40 from the viewing area 214 by moving the position of the projector 215 in accordance with an observer like the right and left directions 224-2 or the forward/rearward direction 226-2.
[0008]
[Problem to be solved by the invention]However, in the case of the stereoscopic display device of the conventional RENTI cura system, to the viewing area 214 followed and set as an observer, If the solid observation area called subprobe spreads also in the right and left directions of the viewing area 214 and the projector 215 is moved in accordance with a one observer, The quality of the very thing of the two-dimensional image which becomes insufficient [the isolation region of an image] and it cannot not only be visible to a solid, but can be seen also had the problem of worsening, to other observers, for example, those who are looking from back.
[0009]Since disturbance of the image by a subprobe would take place between each projector if different movement according to each observer is performed even if it prepares a plurality of projectors 215 corresponding to a plurality of observers, there was a problem that it could respond only to a one observer. The present invention enables solid observation while 1 or a plurality of observers move without fit-in flash study systems, such as glasses, and an object of the present invention is observers other than a solid observation area to provide the image display device and method of having enabled it to observe a clear two-dimensional image further.
[0010]
[Means for solving problem]Fig.1 is a principle explanatory view of the present invention. Like [the present invention is an image display device which makes 3-dimensional scenography recognize with a binocular disparity, and] Fig.1 (A). By setting out of the indicator 14 which displays the right eye image which the position detector 24 and the observer 22 of a detection position who detect the position of the observer 22 who exists in the solid observation area 20 looked at, the right eye image generated by the image generation part 26 which generates a left eye image, and the image generation part 26, and a left eye image, and an opening position. Based on the projected light study unit which projects the display image of the indicator 14 on the observer's 22 detection position, and the observer's 22 detection position, project a right eye image on the position containing the observer's 22 right eye at least, and. It has the opening control part 28 which controls the position and size of an opening of a projected light study unit, and makes a stereoscopic picture observe so that a left eye image may be projected on the position containing the observer's 22 left eye.
[0011]Projection of a parallax image which followed movement of the observer 22 in the solid observation area 20 by this is performed, and a motion of the observer 22 in the wide range is permitted. Since how where an image is in sight with an observer's movement is changed, observation of a stereoscopic picture with motion parallax can be performed. The position detector 24 detects the eyeball position of the right eye 38 and the left eye 40 of the observer 22 specifically. The position detector 24 is provided with the position calculation part which computes the aforementioned observer's position from the image of two sheets photoed by two imaging devices horizontally arranged with a predetermined interval, and imaging devices.
[0012]As another form, the position detector 24 comprises a position calculation part which calculates the aforementioned observer's position from the detecting signal of two sets of the magnet with which the observer was equipped, and the magnetic sensors horizontally arranged with a predetermined interval, and a magnetic sensor. As another form, the position detector 24 can also consist of position calculation parts which calculate an observer's position from the detecting signal of two sets of the ultrasonic sensors horizontally arranged with a predetermined interval, and an ultrasonic sensor.
[0013]The opening control part 28 sets up each of the right eye opening corresponding to the detection position of the observer's 22 right eye 38, and the left eye opening corresponding to the detection position of the left eye 40, projects a right eye image and a left eye image on an observer's detection position, and makes a stereoscopic picture observe with the parallax image of both eyes. In this case, the opening control part 28 sets up the small opening region corresponding to the detection position of the right eye 38 and the left eye 40 of an observer as a right eye opening and a left eye opening.
[0014]The opening control part 28 sets up an opening region to project an image on the prescribed range based on the both-eyes interval (about 32.5 mm - 97.5 mm) of the observer who asked statistically as a right eye opening and a left eye opening. The opening control part 28 sets up an opening to project a right eye image or a left eye image on a different position from the observer's 22 detection position further, shows an identical image as other observers' both eyes, and makes a two-dimensional image observe. For this reason, about other observers other than observer 22 detected as a candidate of solid observation, either one of a right eye image or a left eye image is projected, and a clear two-dimensional image can be observed.
[0015]The display of the stereoscopic picture by the opening control part 28 and a two-dimensional image sets up each of the right eye opening corresponding to the detection position of an observer's right eye, and the left eye opening corresponding to the detection position of the left eye, projects a right eye image and a left eye image, and makes a stereoscopic picture observe with a binocular disparity. An identical image is shown as other observers' both eyes, and a two-dimensional image is made to observe by projecting simultaneously the image which extends either one of a right eye opening or a left eye opening in the position except the other, and corresponds.
[0016]The opening control part 28 projects the image which sets up the right eye opening 130

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and the left eye opening 128, and is equivalent to the center of the detection position of the right eye 38 and the left eye 40 of an observer so that a boundary may come as shown in Fig.1 (B) and (C), An observer is made to observe a stereoscopic picture with a binocular disparity, and an identical image is shown as other observers' both eyes, and a two-dimensional image is made to observe. As a projected light study unit, there is time-division system, a space division system, or a polarization division system. The projected light study unit of time sharing is first premised on use of the single display device which displays a right eye image and a left eye image sequentially as the indicator 14 like Fig.1 (A), It comprises the opening setting device 16 which is installed near the projector lens 15 and the projector lens 15 which carry out enlargement projection of the image from a display device, and sets up the position and size of an opening, and the screen 18 which has been arranged in the focal position of the projector lens 15, and was provided with the image formation function of an aperture image to a solid observation area.

[0017]Synchronizing with the switching display of the right eye image according [the opening control part 28] to the indicator 14, and a left eye image, the position of the right eye opening of the opening setting device 16 and a left eye opening is switched to this projected light study unit. The projected light study unit of a space division system is premised on a pair of display device as the indicator 14 corresponding to a right eye image and a left eye image, The pair of projector lens which carries out enlargement projection of the image from a pair of display device individually, It comprises a pair of opening setting device which is installed near the pair of projector lens and sets up the position and size of an opening, and a screen which has been arranged in the focal position of a pair of projector lens, and was provided with the image formation function of an aperture image to a solid observation area.

[0018]In this case, the opening control part 28 carries out simultaneous setting out of a right eye opening and the left eye opening for the right eye image and left eye image to a display device at a pair of opening setting device at a couple synchronizing with a parallel display. Similarly the projection optical system of a polarization division system is premised on the pair of display device corresponding to a right eye image and a left eye image as the indicator 14, Separate into two lights with a plane of polarization which is different in the light from a light source, and to a pair of display device The incident polarization beam splitter for separation, The polarization beam splitter for a synthesis which synthesizes the image light from which the plane of polarization from a pair of display device differs, The projector lens which carries out enlargement projection of the image light from the polarization beam splitter for a synthesis, It comprises a screen which has been arranged in the polarization control type opening setting device which sets up the opening position which transmits selectively the image light from which it is installed near the projector lens and a plane of polarization differs by the existence of the rotatory polarization of incident light, and the focal position of a projector lens, and was provided with the image formation function of an aperture image to a solid observation area.

[0019]In this case, the opening control part 28 carries out polarization control so that the image light corresponding to each of the position of the right eye opening of a polarization control device and a left eye opening may transmit the right eye image and left eye image to a pair of display device synchronizing with a parallel display. As the opening setting device 16 in the projected light study unit of time sharing and space division, the liquid crystal device which sets up a transmission position arbitrarily by the voltage control of the subdivided liquid crystal segment is used.

[0020]The polarization control type opening setting device in the projected light study unit of polarization division, It constitutes from a liquid crystal device (matrix pi cell) which controls the rotatory polarization of incident light by existence of an application of the drive voltage to the subdivided liquid crystal segment, and a polarizing plate which transmits only image light with the specific plane of polarization outputted from the liquid crystal device. A projected light study unit is provided with the virtual-image generation component to which the caliber of the projector lens 16 is expanded, for example, a concave surface mirror.

[0021]The opening control part 28 controls an opening position right and left by being horizontal and changing the transmission position of the opening setting device 16. By carrying out the movement controls of the projector lens 16 to optical axis direction, an opening position is controlled forward and backward. By changing the focal distance of the projector lens 16, an opening position is also controllable forward and backward. The opening control part 28 controls an opening position forward and backward by controlling the transmission position in the lamination direction of a plurality of opening setting devices 16 by the control before and behind an opening position carrying out the plural laminates of the opening setting device 16 to optical axis direction.

[0022]The control before and behind an opening position arranges an opening setting device aslant by forward/rearward direction to an optic axis, and it provides the diffusion board which makes a vertical direction light diffuse on a screen. In this case, the opening control part 28 controls an opening position by change of the transmission position in the right and left directions of the opening setting device arranged aslant right and left, and controls an opening position by change of the transmission position of the slanting vertical direction of an opening setting device forward and backward.

[0023]The image generation part 26 generates the two-dimensional image data of the right eye image and left eye image which were seen from the observer's 22 detection position based on the three dimensional image data by which modeling was carried out. The two-dimensional image data of the right eye image and left eye image which were seen from the observer's 22 detection position is also generable with interpolation of the two-dimensional image data which looked at the object from a horizontal different position.

[0024]If it is on another form of the present invention, a plurality of observers can also be made to observe a stereoscopic picture. In this case, there are individual projection of an image according to a plurality of observers' position and community projection of an identical image. Two or more observers' individual projection first generates the right eye image and left eye

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image which detected a plurality of observers by the position detector 24, and a plurality of observers' each looked at by the image generation part 26, Display sequentially the right eye image and left eye image which were generated by the indicator 14 for every observers of a plurality of, and the opening control part 28, Based on a plurality of observers' detection position, each observer's right eye image is projected on the position containing a right eye, and the position and size of an opening of a projected light study unit are controlled to project a left eye image on the position containing a left eye.
[0025]Two or more, although a plurality of observers are detected by the position detector 24, an observer's community projection, The image generation part 26 generates the right eye image and left eye image which any one of a plurality of observers looked at, displays a right eye image and a left eye image on the indicator 14, and the opening control part 28, Based on a plurality of observers' detection position, a right eye image is projected on the position containing a plurality of observers' right eye, and the position and size of an opening of a projected light study unit are controlled to project a left eye image on the position containing a plurality of observers' left eye.
[0026]The present invention is an image display method which makes 3-dimensional scenography recognize with a binocular disparity, and is provided with the following process. The position of the observer 22 who exists in the three dimentional display region 20. The detecting position process to detect; the image generation process in which the right eye image which the observer 22 of the detection position looked at, and a left eye image are generated; the image display process in which a right eye image and a left eye image are displayed, based on an observer's detection position, by the position of the opening of a projection optical system, and control of a size, The three-dimensional display process in which project a right eye image on the position containing the observer's 22 right eye, and project a left eye image on the position containing the observer's 22 left eye, and it makes a stereoscopic picture observe with a binocular disparity; by another different opening setting out from the opening position of a projection optical system, The two-dimensional display process which projects either a right eye image or a left eye image on a different position from an observer's detection position, shows an identical image as other observers' eye, and makes a two-dimensional image observe; according to the image display method of such the present invention. A three dimentional display can be seen without glasses, motion parallax from which a display picture changes with an observer's movements can be realized, and further, a two-dimensional image can be vividly displayed so that persons other than a solid observer can understand the contents.
[0027]
[Mode for carrying out the invention]
A <table-of-contents>1. equipment configuration. A display-function 2. observer's detecting position 3. right eye image. The projection display depended comparatively, the projection opening control 1. equipment configuration to opening control 7. two or more observers, and display-function Fig.2 are the embodiments of the image display device by the present invention by the projection display by the generation 4. time sharing of a left eye image, the projection display by opening control 5. space division, and opening control 6. deviation. In Fig.2, the image display device 10 of the present invention is provided with the light source unit 12, the indicator 14, the projection lens unit 15, the opening setting device 16, and the screen 18 provided with the image formation function as a projection optics unit to the 3D observation area 20. The observer position detection device 24 was provided to the 3D observation area 20, and the observer's 22 position is detected.
[0028]The position detection information of the right eye of the observer's 22 detection position, specifically observer 22 **, detected with the observer position detection device 24, and the left eye is given to the image generating device 26. The image generating device 26 generates the image data of the display object seen from each position of the right eye and left eye of the observer 22 which were detected as right eye image data and left eye image data, respectively.
[0029]To the high speed bus 34 of the image generating device 26, the opening control unit 28, the display control 30, and the light source drive 32 are connected. As the image generating device 26, the computer system provided with the graphic function of modeling and a rendering can be used here. The light source drive 32 carries out the lighting drive of the light source of the light source unit 12 by the busy condition of equipment, and generates the light for image projection. The display control 30 displays the right eye image and left eye image corresponding to a detection position of the observer 22 generated with the image generating device 26 on the indicator 14. There are three kinds of display types of the right eye image and left eye image to the indicator 14, time-division system, a space division system, and a polarization division system.
[0030]If it is in time-division system, a single display device is used for the indicator 14. On the other hand, about a space division system and a polarization division system, a display device for exclusive use is used per each of a right eye image and a left eye image. Since the single display device is used as the indicator 14 if it is in the embodiment of Fig.2, it can respond to time-division system.
[0031]The opening control unit 28 corresponds to each detection position of a right eye and a left eye detected about the observer 22, The opening position of the projection optical system which projects an image on the region which contains the observer's 22 right eye to the timing which displayed the right eye image on the indicator 14, and projects an image on the region which contains the observer's 22 left eye to the timing which displayed the left eye image on the indicator 14 is set up. By setting-out control of the opening position of the opening setting device 16 by the opening control unit 28 in sync with the switching display of the right eye image and left eye image of this indicator 14, The observer 22 can observe in response to projection of the parallax image of the same object with azimuth difference which is different in a right eye and a left eye via the screen 18, and can recognize a stereoscopic picture with a

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binocular disparity.
[0032]If shown in the stereoscopic display device 10 of the present invention, from other observers other than observer 22 detected with the observer position detection device 24, Opening setting out in the opening setting device 16 is performed so that the two-dimensional image of either one of a right eye image or a left eye image which is carrying out the switching display to the indicator 14 by time sharing can be observed. Fig.3 is an observation area of screen 18 front face by the image display device of Fig.2. If the 3D observation area 20 is set to the prescribed range used as the front of the screen 18 of the image display device 10 and an observer's right eye 38 and left eye 40 exist in this 3D observation area 20, in response to projection of the image of azimuth difference different, respectively, a stereoscopic picture is observable.
[0033]If an observer is in the 3D observation area 20, in every position, he can observe a three dimentional display. That is, real time has detected the position of the observer who exists in the 3D observation area 20 by the stereoscopic display device 10 side, a right eye image and a left eye image when an object body is seen from each movement zone according to an observer's motion are generated in real time, and it projects on an observer's right eye 38 and left eye 40. For this reason, if an observer moves in the 3D observation area 20, solid observation which had motion parallax in connection with this can be performed.
[0034]The region of the outside of the 3D observation area 20 turns into the 2D observation area 36 which can observe a two-dimensional image. For this reason, since it will exist in the 2D observation area 36 when other observers other than the observer who has been the target of the detecting position in the 3D observation area 20 observe simultaneously from the neighborhood, the clear two-dimensional image by projection of a right eye image or a left eye image is observable.
[0035]Fig.4 is a flow chart of the three dimentional display by the time division processing in the image display device 10 of Fig.2. First, at Step S1, the observer position detection device 24 detects the position of the observer's 22 right and left eye, the image generating device 26 generates the image for left eyes, and the image for right eyes in the following step S2 based on the position of an observer's right and left eye, and it transmits to the frame buffer of the display control 30.
[0036]The display control 30 expresses the image for left eyes to the indicator 14 as Step S3 first. Synchronizing with the display of this image for left eyes, the opening control unit 28 carries out setting-out control of the opening position for left eyes by step S4 at the opening setting device 16. For this reason, the image for left eyes from the indicator 14 is projected on the longwise slit region containing the observer's 22 left eye. Next, at Step S5, the display control 30 displays the image for right eyes on the indicator 14, synchronizing with the display of this image for right eyes, it is Step S6 and the opening control unit 28 performs setting-out control of the opening position for right eyes to the opening setting device 16. For this reason, if shown in the following display timing, the image for right eyes displayed on the indicator 14 is projected on the observer's 22 right eye.
[0037]The processing from such steps S1-S6 is repeated until the display stop of equipment is performed at Step S7. When the switching display cycle of a right eye image and a left eye image by time sharing is made into 1 / cycles of 60 seconds as a display period of the prevention from a flicker per each image, since it is a switching display, the object for right eyes, and the object for left eyes, of two sheets, it should just perform half 1 / cycles of 120 seconds, i e., a 120-Hz change.
2. An observer's detecting position Fig.5 is an embodiment of the observer position detection device 24 of Fig.2, and detected the position of an observer's eye by the image processing by two sets of CCD cameras. In Fig.5, the observer position detection device 24 is provided with two sets of CCD cameras 42 and 44, and to the 3D observation area 20 of Fig.2, CCD cameras 42 and 44 separate a horizontal predetermined interval, and are installed in the equipment side.
[0038]The observer position calculating part 46 calculates the position of the right and left eye of the observer who took a photograph with CCD cameras 42 and 44. The observer position information generating part 48 transmits the three-dimensional-coordinates information on the observer position calculated by the observer position calculating part 46 (X, Y, Z) to the image generating device 26 of Fig.2, and also the opening control unit 28. Fig.6 is an explanatory view of the arithmetic contents in the observer position detection device 24 of Fig.5. Fig.6 (A) is a plan view of the relation of the imaging lenses 52 and 50 installed in the position distant for a prescribed distance to the observer and the imaging surfaces 54 and 56 of two cameras. The side view is expressed for the front view seen from the camera side to Fig.6 (B) to Fig.6 (C).
[0039]To the images 58 and 60 of two sheets imaged with two cameras, the detecting position principle in this case asks for an observer's eyes 38 and 40 with pattern matching, and calculates the position information on an inputted image. Since this position information can be replaced to angle information, the position of an eye can be deduced from two angles to the distance and the camera between cameras by the principle of triangulation.
[0040]If it describes in detail, the z-axis will be set to the center of two cameras, and a x axis and the y-axis will be set up on the lens 50 and 52, respectively. Two cameras are installed so that the optic axis may be made parallel. Distance from the images 58 and 60 and the lenses 52 and 50 to the imaging surfaces 54 and 56 is set to d for the image on the imaging surface 54 and 56 imaged with B and a camera in the interval of the lenses 50 and 52.
[0041]According to this embodiment, the coordinates (x0, y0, z0) of the mid-position P of the right eye 38 and the left eye 40 which were obtained by pattern matching are calculated. The angles theta1 and theta2 of the straight line which connects the center position P of the both eyes of Fig.6 (A) and the position on the imaging surface 54 and 56 of a camera first, and the optic axis of the lenses 50 and 52 to make, and also the angle alpha to the optic axis of the straight line which connects the both-eyes center position P to the image formation face 56 seen from the side surface of Fig.6 (C) have a relation to the position information on a following

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formula.
[0042]
[Mathematical formula 1]

$$\tan\theta 1 = \frac{\frac{B}{2} - x1}{d} = \frac{\frac{B}{2} + x0}{z0} \quad (1)$$

$$\tan\theta 2 = \frac{X2 - \frac{B}{2}}{d} = \frac{\frac{B}{2} - x0}{z0} \quad (2)$$

$$\tan\alpha = \frac{y1}{d} = \frac{y0}{z0} \quad (3)$$

[0043]Then, addition of (1) type and (2) types will compute the coordinate value z0 of the both-eyes center position P from the relation of a following formula.
[0044]
[Mathematical formula 2]

$$\frac{\frac{B}{2} - x1}{d} = \frac{x2 - \frac{B}{2}}{d} = \frac{\frac{B}{2}}{z0}$$

$$\frac{x2 - x1}{d} = \frac{B}{z0}$$

$$z0 = \frac{B - d}{x2 - x1} \quad (4)$$

[0045]If this (4) type is substituted for (1) type, the coordinate value x0 of the both-eyes center position P will be computed as follows.
[0046]
[Mathematical formula 3]

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$$\frac{\frac{B}{2}-x1}{d}=\frac{\frac{B}{2}+x0}{\frac{B\cdot d}{x2-x1}}=\frac{\left(\frac{B}{2}+x0\right)(X2-x1)}{B\cdot d}$$

$$x0=\frac{B\{B-(X2-x1)\}}{2(x2-x1)} \quad (5)$$

[0047]If (4) types are substituted for (3) types, the coordinate value y0 of the both-eyes center position P will be computed as follows.

[0048]

[Mathematical formula 4]

$$y0=\frac{y1}{d}\cdot z0=\frac{B\cdot y1}{x2-x1} \quad (6)$$

[0049]By applying such a (4), (5), and (6) type to each of the right eye 38 by which pattern matching was carried out, and the left eye 40, the coordinates (xr, yr, zr) of right eye position Pr and the coordinates (xl, yl, zl) of the left eye position Pl can be searched for. About right eye position Pr (xr, yr, zr) and the left eye position Pl (xl, yl, zl) of an observer position in actual space, it becomes possible to generate the right eye image and left eye image which were seen from the detection position of an observer's eye by performing scale conversion and carrying out image generation between coordinates space of the computer graphics which performs a three dimentional display, about the display object seen from the coordinate position of the right eye and left eye by which scale conversion was carried out.

[0050]Fig.7 is other embodiments of the observer position detection device 24 used by Fig.2, and used the magnetic sensor. If it is in the observer position detection device 24 of Fig.7, a predetermined interval horizontal to the equipment side is separated, and the pair of magnetic sensor 342,344 is installed. To the magnetic sensor 342,344, the observer 22 side who exists in 3D observation area is equipped with the magnet 350.

[0051]For example, it takes the lead in the observer's 22 both eyes, a frame etc. may be equipped with the magnet 350 in a band, and the mind heart position of the observer's 22 coat may be equipped with it by a pin etc. Each of the magnetic sensor 342,344 detects the magnetic field strength from the magnet 350 which the observer 22 has carried. Since magnetic field strength usually decreases in inverse proportion to the cube of distance, it can deduce the distance from the strength of the detection magnetic field of the magnetic sensor 342,344 to the magnet 350, i.e., the distance R1 and R2 to the center position of the observer's 22 both eyes. Thus, if the distance R1 and R2 from a sensor to the magnet 350 is known, the position of the magnet 350 can be decided as an intersection of the circular arc of the radii R1 and R2 centering on the magnetic sensor 342,344, and the position of right and left directions (x axial direction) and forward/rearward direction (z axial direction) can be detected.

[0052]Here, if shown in the three dimentional display of the present invention, even if an observer moves a face to a vertical direction, detection in particular is unnecessary about a vertical direction (y axial direction), from performing the same image projection. That is, if it is in the observer position detection by the magnetic sensor 342,344, the coordinate value y0 used as a vertical direction uses a fixed value, and calculates the coordinate value x0 of right and left directions, and the coordinate value z0 of forward/rearward direction by the observer position calculating part 346 by an operation.

[0053]About the position of the observer's 22 right and left eye, The coordinate value xr of each eye and xl may be calculated by subtracting and adding W/2 to the coordinate value x0 of the both-eyes center position decided by the magnet 350 which was set, for example as W= 60 mm of intervals of an eye, and was detected from the interval of people's eye being in the range which are 32.5 mm - 97.5 mm statistically. In this case, the coordinate value zr and zl should just use the coordinate value z of a both-eyes center position with the magnet 350.

[0054]Fig.8 is other embodiments of the observer position detection device 24 used by the present invention, and used the ultrasonic sensor. If it is in this observer position detection device 24, a predetermined interval horizontal to the front face on the equipment side is separated, and the pair of ultrasonic sensor 442,444 is installed. The ultrasonic sensor 442,444 has discharged the ultrasonic pulse to 3D observation area with the constant period.

[0055]It is reflected by the observer 22 and this ultrasonic pulse is received by the ultrasonic sensor 442,444 side. Therefore, from the propagation time to the observer 22 of the ultrasonic wave by the ultrasonic sensor 442,444, The distance R1 and R2 from each sensor to the observer 22 can be found, the observer's 22 position information as well as the case where it is a magnetic sensor of Fig.8 can be calculated by the observer position calculating part 446, and it can send to the image generation side from the observer position information generating part 448.

[0056]Detection of the observer position used by the present invention is not limited to the

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above-mentioned embodiment, but can use the position sensing device using a proper sensor.
3. The generation drawing 9 of a right eye image and a left eye image is an embodiment of the image generating device 26 of the Fig 2 which generates a right eye image and a left eye image based on observer position detection information, and this embodiment, Based on observer position information, the right eye image and the left eye image were generated from the modeling data recorded preliminarily.
[0057]In Fig.9, the image generating device 26 comprises the modeling data storage 62 and the rendering processing part 64. The display control 30 has the right eye image frame buffer 66, the left eye image frame buffer 68, the data switching section 70 that performs an image change 1 / in a cycle of 120 seconds, and the display driving part 72 to the single indicator 14 from having taken the time sharing display of a right eye image and a left eye image for the example. As the display driving part 72, when a liquid crystal device is used as the indicator 14, a liquid crystal driver is used.
[0058]The modeling data created by the technique of computer graphics is preliminarily recorded on the modeling data storage 62 of the image generating device 26. Modeling data is generating the object body as a set of some polygon data. If observer position information is given to the rendering processing part 64, each polygon which forms the object body stored in the modeling data storage 62 by making this observation position into a view position will calculate how it is visible from a view position.
[0059]That is, a position, a size, a color, a texture, etc. are calculated, and it develops as right eye image data to the right eye image frame buffer 66 about a right eye, and develops as left eye image data to the left eye image frame buffer 68 about a left eye image. The display control 30 each data of a right eye image and a left eye image developed by the right eye image frame buffer 66 and the left eye image frame buffer 68 from the image generating device 26, For example, it reads sequentially by the switching operation of the data switching section 70 by the change cycle of 1 / 120 seconds, and carries out a switching display to the indicator 14 by the display driving part 72. As a result, from the data switching section 70, like Fig.10, the right eye image data 74 and the left eye image data 76 are outputted alternately, and the switching display by the time sharing of a right eye image and a left eye image is performed.
[0060]Fig.11 is other embodiments of the image generating device 26 of Fig.2, and this embodiment generated the right eye image and left eye image which made detection information of the observer position the view position based on the picture information of two sheets imaged from a position which is different with a camera by interpolation. In Fig.11, the image generating device 26 comprises the camera image data storing part 73 and the interpolation picture generation part 75. The taken image of the object body with at least two cameras horizontally installed via prescribed distance is stored in the camera image data storing part 73. The interpolation picture preparing part 75 generates the right eye image and left eye image which were seen from the observer position by the interpolation of the pair of taken image stored in the camera image data storing part 73 based on observer position information, It stores in the right eye image frame buffer 66 on the display control 30 side, and the left eye image frame buffer 68. The display control 30 performs the same time sharing display control as the embodiment of Fig.9.
[0061]It is as follows when the generation processing by the interpolation picture generation part 75 of Fig.11 is described with reference to Fig.12 - Fig.15 here. If each view information of a right eye position and a left eye position is first given as observer position information to the interpolation picture generation part 75, an interpolation picture will be generated from the image of two sheets stored in the camera image data storing part 73 near the given view position.
[0062]Like Fig.12 now, about the cameras 42 and 44, supposing it is carrying out horizontal arrangement of the optic axis in parallel, the image of the object 78 seen from the two cameras 42 and 44 will become like image 80-1,80-2 of Fig.13. The relation of the line pixel of horizontal line 82-1,82-2 in image 80-1,80-2 is shown in Fig.14 (A) and (B). Each of surface 78-1,78-2 of the object 78 has projected on the horizontal line 82-1 of the image 80-1 with the width of the width a1 and b1 like Fig.14 (A). Surface 78-1,78-2 of the object 78 has projected on the horizontal line 82-2 of the image 80-2 with the width a2 and b2 like Fig.15 (B) similarly.
[0063]The generation of an interpolation picture based on image 80-1,80-2 of Fig.13 is the generation of an image which set up and looked at the new viewpoint between the lenses 50 and 52 here, and surface 78-1,78-2 of an object will move according to a view position. Therefore, if a new viewpoint is set up among the lenses 50 and 52, if distance from alpha and the lens 52 to the view position P is set to beta, the distance from the lens 50 to a viewpoint, The position and width of surface 78-1,78-2 of the object 78 in a new viewpoint can be decided based on split ratio alpha:beta between the lenses 50 and 52.
[0064]The interpolation screen for one screen can be obtained by performing the operation which calculates surface 78-1,78-2 of the object on the line in this new viewpoint P to all the horizontal lines. It is as follows when the generation procedure of the interpolation picture of a horizontal line is described on an intermediary concrete target at Fig.15 (A) - (E).
(I) Find the distance a1 and b1 of surface 78-1,78-2 of the object on the horizontal line 82-1 of the image 80-1.
[0065](II) Find the distance a2 and b2 of surface 78-1,78-2 of the object on the horizontal line 82-2 of the image 80-2.
(III) The distance between the center of gravity of the distance a1 and a2 of the surface 78-1 in the aforementioned (I)(II) is found, The position which divided the distance between this center of gravity by split ratio beta:alpha of the view position for generating an interpolation picture is made into a center of gravity position, and also it is the interpolation distance a3 a3=a1x{beta/(alpha+beta)}+a2x {beta/(alpha+beta)}
It asks by carrying out.
[0066](IV) The distance between each center of gravity of the distance b1 and b2 of the

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surface 78-2 of the object in (I) and (II) is found like the aforementioned (III), The position which divided the distance between this center of gravity by split ratio beta:alpha decided by the viewpoint which generates an interpolation picture is made into the center of gravity position of an interpolation picture, and also it is the distance b3 of an interpolation portion b3=b1x{beta/(alpha+beta)}+b2x {beta/(alpha+beta)}
It asks by carrying out.
[0067](V) Synthesize surface 78-1,78-2 of the interpolation formation object obtained by the aforementioned (III)(IV), and generate the interpolation picture for 1 horizontal line. The interpolation picture 84 of Fig.15 can be obtained by performing generation processing of such a horizontal interpolation picture about all the horizontal lines. Since two, a right eye position and a left eye position, are obtained as observer position information if it is in the present invention, interpolation formation of a right eye image and a left eye image based on an observer detection position can be performed by performing generation processing of the interpolation picture same about each.
4. The projection display and the opening control diagram 16 by time sharing are the opening control unit 28 and the block diagram of the opening setting device 16 in the image display device of Fig.2. The opening control unit 28 is provided with the opening position calculating part 88 and the display controller 90. If the opening setting device 16 is in this embodiment, it is using the matrix liquid crystal shutter 92.
[0068]A transmission type liquid crystal display device can be used specifically, the liquid crystal cell which constitutes the minute display segment by which two-dimensional arrangement was carried out is driven by control of the matrix voltage by the drivers 92 and 96, and opening control by setting out of a transmission state can be performed arbitrarily. The opening position calculating part 88 provided to the opening control unit 28, The opening position and size in a projection optics unit corresponding to the view position set up by observer position detection information are calculated, and opening setting out is performed by controlling the correspondence opening of the matrix liquid crystal shutter 92 to a transmission state via the display controller 90.
[0069]Fig.17 is an embodiment of the projection optics unit provided to the stereoscopic display device 10 of the Fig.2 which performs the three dimentional display by time sharing. A light source unit comprises the light source 98 and the reflector 100 first. As the light source 98, the white light source of a metal hull light lamp etc. is used, for example. It is condensed with the lens 102, converts to a parallel beam with Fresnel lens 104, it is reflected by the mirror 106, and the light from the light source 98 enters into the indicator 14.
[0070]To the indicator 14, a right eye image and a left eye image are sequentially displayed by time-division system. If the indicator 14 is followed, the matrix liquid crystal shutter 92 which functions as an opening setting device is provided. Fig.17 is the timing which displayed the left eye image on the indicator 14, and, for this reason, the opening 128 by setting out of the strip-like transmission region of the vertical direction corresponding to a left eye image is set to the matrix liquid crystal shutter 92.
[0071]If the matrix liquid crystal shutter 92 is followed, if it is in this embodiment, the projector lens 110 is provided as the projection lens unit 15. The projector lens 110 images the image which transmitted the opening 128 of the indicator 14 in the position of convex Fresnel lens 116 which functions as a screen. If the projector lens 110 is followed, the concave surface mirror 112 is provided. Since there is a limit in the caliber of the projector lens 110, the concave surface mirror 112 functions as a virtual-image generator child who expands the caliber of the projector lens 110 so that the size of convex Fresnel lens 116 which functions as a screen may be suited. It is reflected by the back face mirror 114, and the image light expanded by the concave surface mirror 112 enters so that image light may be imaged to convex Fresnel lens 116 installed as a screen.
[0072]Convex Fresnel lens 116 has a function as a convex lens which images the slit image of the MARITOKUSU liquid crystal shutter 92 to the virtual image formation face of the 3D observation area 20. That is, convex Fresnel lens 116 images the slit image 118 used as the enlarged image of the opening 128 set as the matrix liquid crystal shutter 92 in this state to the 3D observation area 20, and this forms the left eye observation area 20-1.
[0073]The left eye observation area 20-1 by image formation of the slit image 118 is performed by setting out of the opening 128 based on the detection result of the position an observer's left eye 40. For this reason, since the observer can observe the left eye image currently displayed on the indicator 14 at this time only by the left eye 40 and projection of the image lights from the indicator 14 is not performed before the right eye 38, the left eye image of the indicator 14 cannot be seen by the right eye 38 side.
[0074]Fig.18 is in the state which displayed the right eye image on the indicator 14, and set the opening 130 corresponding to the detection position of an observer's right eye 38 to the matrix liquid crystal shutter 92 synchronizing with this in the projection optics unit of Fig.17. In this case, convex Fresnel lens 116 images the slit image 120 of the opening 130 set up as a transmission region of the matrix liquid crystal shutter 92 to the 3D observation area 20.
[0075]This serves as the right eye observation area 20-2, and since the image light of the right eye image simultaneously displayed on the indicator 14 via the opening 130 with the projector lens 110 is projected, the observer can observe the right eye image of the indicator 14 only by the right eye 38. Since the projection display of the left eye image of Fig.17 and the projection display of the right eye image of Fig.18 are repeated by time sharing for example, 1 / in a cycle of 120 seconds, an observer will look at the parallax image seen from each view position which is simultaneously different by the right and left eyes 38 and 40, and can observe a stereoscopic picture with a binocular disparity.
[0076]Fig.19 is an equalization optical system of Fig.17 and the projection optics unit corresponding to the display timing of the right eye image and left eye image of Fig.18. Fig.20 (A) is an equalization optical system corresponding to the image display for left eyes of Fig.17, the left eye image is displayed on the indicator 14, and drive setting out of the transmission

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region for setting up the opening 128 is performed to the matrix liquid crystal shutter 92 synchronizing with this.
[0077]The projection lens unit 15 arranges the pair of projection lens 109,110 here in the form which sandwiches the matrix liquid crystal shutter 92. In the screen position, the convex lens 117 is arranged as an equalization optical system of a convex Fresnel lens. The image lights from the indicator 14 pass the opening 128 set as the matrix liquid crystal shutter 92, and image it to the convex lens 117 used as a screen position. The convex lens 117 is imaged as the slit image 118 to the surface of the viewing area 115 set as the observation area of the opening 128 of the matrix liquid crystal shutter 92. At this time, the opening 128 is set up based on the detection position of an observer's left eye 40.
[0078]For this reason, setting out of the opening 128 is performed so that it may be placed before the left eye 40 about the slit image 118. Therefore, the observer can observe the left eye image of the indicator 14 only by the left eye 40. Fig.19 (B) is a displaying condition of the equalization optical system corresponding to the projection optics unit of the image display state for right eyes of Fig.18. In this case, the right eye image is displayed on the indicator 14, and the opening 130 is set to the matrix liquid crystal shutter 92 by drive setting out of the transmission region synchronizing with this.
[0079]For this reason, corresponding to the position of the opening 130 of the matrix liquid crystal shutter 92, it is imaged by the viewing area 115 of an observation area in the slit image 120. Since the opening 130 is set up corresponding to the detection position of an observer's right eye 38, the slit image 120 of the opening 130 will be imaged in front of an observer's right eye 38. For this reason, the observer can observe the right eye image of the indicator 14 only by the right eye 38.
[0080]Since a high-speed indication of the right eye image and left eye image of such Fig.19 (A) and (B) is given by time sharing, an observer will observe the image from which a view position differs simultaneously by the right eye 38 and the left eye 40, and can observe a stereoscopic picture with a binocular disparity. If an observer moves the position of an eye within the scope of the 3D display region 20, the position of an observer's eye will be detected in real time, The setting-out position of the opening 128,130 of the matrix liquid crystal shutter 92 moves, The slit image 118,120 is always imaged just before an observer's right eye 38 and the left eye 40, and also the time sharing display of a right eye image and a left eye image which adopts the way of being visible which responded to movement of the position of an observer's eye to the indicator 14 is performed. For this reason, the observation of 3-dimensional scenography which had motion parallax to the display object is realizable.
[0081]Having realized the equivalent three dimentional display function understands that it carried out the projection display of the equalization optical system in the three dimentional display of the present invention shown in Fig.19 (A) and (B) by two sets of projectors like Fig.20. Fig.20 provides the indicator 14-1, the projector provided with the projection lens 110-1 for right eyes, and the projector provided with the indicator 14-2 and the projection lens 110-2 for left eyes, and moves each projector to right and left directions and forward/rearward direction according to the detection position of the right eye 38 and the left eye 40 of an observer.
[0082]For this reason, a right eye image can always be projected on the position of an observer's right eye 38, a left eye image can be projected on the position of the left eye 40, and a three dimentional display can be realized. The function using two sets of such projectors is easily realizable like Fig.19 using a fixed optical system, if it is in the present invention. Fig.21 is an explanatory view of setting-out control of the opening in the matrix liquid crystal shutter 92 corresponding to the detection position of an observer's eye in the projection optics unit of the present invention. Fig.21 has taken for the example the case where the opening 130 corresponding to the detection position of an observer's right eye 38 is set as the matrix liquid crystal shutter 92.
[0083]According to the projection optics unit of the present invention, the opening 130 of the matrix liquid crystal shutter 92 images the slit image 120 like a graphic display on the viewing area 115 which is the virtual plane set as the observation area. The width of this slit image 120 is decided by the magnifying power K of the opening 130. That is, if width of the viewing area K115 of 1 and an observation area is set to K for the lateral width of the slit 92, the opening 130 will be imaged as the slit image 120 which has one K times the width of this in the viewing area 115.
[0084]In order for the width of this slit image 120 to project image light, for example on the right eye 38, not to project image light on the left eye 40 and to carry out reliably visual recognition of the stereoscopic model by motion of the eye of some an observer's right and left directions, it needs to have a certain amount of width. Fig.22 is an example of the lateral width of the slit image 120. It turns out first that the intervals W of the right eye 38 and the left eye 40 of an observer are W= 32.5 mm - 97.5 mm statistically. Therefore, let width of the slit image 12 be the right eye observation area 20-2 which had W/2 of width in right and left from the center of the right eye 38. The left eye observation area 20-1 which had W/2 of width in right and left from the center of a left eye about the left eye 40 similarly is set up like a dashed line.
[0085]Thus, by giving the width of the slit image over a right and left eye, even if an observer moves an eye in **W/2, he can observe a stereoscopic model within the limits of this, without needing the detecting position of an eye. W/2 can be satisfied as detection power of the observer position detection device of the present invention, and this can raise the margin of observer position detection. Of course, by not being limited to W/2, for example, raising detection accuracy, the width of a slit image is good also considering an opening as setting out so that it may be considered as the narrow range of the width degree of an eye.
[0086]Fig.23 is a displaying condition of the left eye image by other opening setting out in the projection optics unit of the present invention which performs a time sharing three dimentional display. If it is in this embodiment, the opening 128 is set to the matrix liquid crystal shutter 92

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to make the whole region on the left-hand side of both an observer's eye center position 126 in the 3D observation area 20 into the left eye observation area 20-1. Fig.24 is the timing switched to the displaying condition of the right eye image about the embodiment of Fig.23, and has set the opening 130 to the matrix liquid crystal shutter 92 to make the right-hand side whole region of the both-eyes center position 126 in the observer of 3D observation area into the right eye observation area 20-2 in this case.

[0087]Fig.25 is an equalization optical system corresponding to Fig.23 and Fig.24. Namely, Fig.25 (A) is an image display state for left eyes, and has set up the opening 128 by making a left-hand side whole region into a transmission state toward the screen side of the corresponding points 127 of the matrix liquid crystal shutter 92 based on the detection information of the both-eyes center position 126 of the observer who becomes a detection target of the 3D observation area 20.

[0088]For this reason, also in the 2D observation area 36 of not only the 3D observation area 20 but its left-hand side, the left eye image of the indicator 14 is observable by receiving the image light 120 for left eyes. Fig.25 (B) is an equalization optical system corresponding to the image display state for right eyes of Fig.24, and has set up the opening 130 by making the right-hand side whole region into a transmission state toward the screen of the corresponding points 127 of the matrix liquid crystal shutter 92 corresponding to the both-eyes center position 126 used as the observation object of a three dimentional display.

[0089]The image light 122 for right eyes is projected on the whole region on the right-hand side of the both-eyes center position 126 by setting out of such an opening 130, and the right eye image by projection of the image light 122 for right eyes can be observed also on the right-hand side beyond the 3D observation area 20. The observer who becomes a detection target of the observer position which is placed at the 3D observation area 20 by setting out of the opening 128 of a right eye image and the opening 130 of a left eye image as shown in this Fig.25 (A) and (B) is observing the image the object for right eyes, and for left eyes simultaneously by a right and left eye, and can observe a stereoscopic model with a binocular disparity.

[0090]About other observers other than the observer who is observing the three dimentional display, For example, if it observes on the left-hand side of the 3D observation area 20, only the image light 120 for left eyes from the indicator 14 by setting out of the opening 128 will be observed like Fig.25 (A), and the two-dimensional image by the image for left eyes can be observed. When other observers are observing on the right-hand side of the 3D observation area 20, like Fig.25 (B), projection of the image light 122 for right eyes can be received, and only the two-dimensional image by the right eye image currently displayed on the indicator 14 can be observed. That is, about other observers other than the observer who has been the target of observer position detection of the present invention which exists in the 3D observation area 20, the two-dimensional image by the right eye image or a left eye image is vividly observable by seeing the same screen.

[0091]Fig.26 and 27 are other displaying conditions by the projection optical system which carries out simultaneous observation of a stereoscopic picture and the two-dimensional image. If shown in the displaying condition of the left eye image of Fig.26, the opening 128 is set to the position corresponding to the observer's left eye 40, the left eye observation area 20-1 is set up by narrow width, and it enables it to observe the left eye image of the indicator 14 only by the left eye 40 of the observer of 3D observation area.

[0092]On the other hand, about the display of the right eye image of Fig.27, the opening 130 is set to the matrix liquid crystal shutter 92 to make the whole region except the left eye observation area 20-1 of Fig.26 into the right eye observation area 20-2. It enables it to observe [observers / other than the observer who can do solid observation which serves as a detection target of the observer position by this in 3D observation area / other] only the two-dimensional image by the right eye image by the displaying condition of Fig.27 also about which position.

[0093]Fig.28 is an equalization optical system in Fig.26 and the projection optics unit of Fig.27, Fig.28 (A) is an image display state for left eyes, and Fig.28 (B) is an image display state for right eyes. That is, about the image display state for left eyes of Fig.28 (A), the slit image 118 is projected on the position of the left eye of the observer of the 3D observation area 20 by setting out of the opening 128. On the other hand, if shown in the image display state for right eyes of Fig.28 (B), the opening 130 is set up by setting out of the transmission state of the matrix liquid crystal shutter 92 so that the slit image 120,120 for right eyes may be imaged by the whole region except the slit image 118 for left eyes.

[0094]Fig.29 is an embodiment of the projection optics unit of the present invention which enables opening setting-out control which followed movement of an observer's forward/rearward direction in the three dimentional display by time sharing. If it is in this projection optics unit, the lamination shutter 134 which carried out the plural laminates of the matrix liquid crystal shutter 92 used as an opening setting device by Fig.16 to optical axis direction is used as an opening setting device provided before the projector lens 110.

[0095]The specific matrix liquid crystal shutter to which opening setting out of the lamination shutter 134 corresponds based on the position of an observer's forward/rearward direction, i.e., the detection position of the coordinate value z, is chosen, and opening setting out corresponding to the observer detection position of the right and left directions at that time is performed. The whole region is controlled by the transmission state about other other matrix liquid crystal shutters of a plurality of.

[0096]Fig.30 is an equalization optical system of Fig.29, and if it is in this equalization optical system, it has laminated the matrix liquid crystal shutter 92-1 to 92-5 of five sheets as the lamination shutter 134. Corresponding to the position of the forward/rearward direction of the matrix liquid crystal shutter 92-1 to 92-5 of such a lamination shutter 134, the slit image formation face 132-1 to 132-5 is set to 3D observation area in forward/rearward direction.

[0097]Between the matrix liquid crystal shutter 92-1 to 92-5 by the convex lens 117 provided

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in the screen position, and the slit image formation face 132-1 to 132-5, it is decided that a slit image formation face always makes image formation distance the same to change of the opening position of forward/rearward direction. That is, corresponding to the matrix liquid crystal shutter 92-1 of most this side, the slit image formation face 132-1 exists, and the slit image formation face 132-5 at the very back exists most corresponding to the previous matrix liquid crystal shutter 92-5.

[0098]For this reason, based on the observer's position, i.e., coordinate value z, of forward/rearward direction which exist in the 3D observation area 20, Any one [92-3] of the matrix liquid crystal shutters 92-1 to 92-5 in the lamination shutter 134, for example, a matrix liquid crystal shutter, is chosen, The slit image of an opening can be imaged to the slit image formation face 132-3, and the stereoscopic picture by a binocular disparity can be made to observe to an observer by similarly carrying out opening setting out in the position of right and left directions corresponding to the detection position of a right eye or a left eye based on observer position detection of right and left directions.

[0099]Fig.19, Fig.25 and also the object for one right eyes of the Fig.28, and the time division processing of the image display for left eyes are applicable to the opening setting-out control according to the detection position of this observer's depth direction. When display processing of Fig.25 or Fig.28 is applied, a two-dimensional image can be observed in the 2D observation areas 36 other than solid observation area 20.

[0100]Fig.31 is other embodiments of the projection optics unit which opening setting out according to the detecting position of an observer's forward/rearward direction realizes, and if it is in this embodiment, the three dimentional display according to a motion of an observer's depth direction is made possible by providing a moving lens to a projector lens and changing a focal distance into it. As the projection lens unit 15 in Fig.31, the moving lens 182 which can move to optical axis direction freely is provided with the actuator 186 between the fixing projector lenses 180,184. By moving this moving lens 182 to optical axis direction with the actuator 186, the slit image formation face 132-1 - forward/rearward direction like 132-n can be set up in 3D observation area. Fig.32 used for the actuator VCM which is an embodiment of the projection lens unit 15 which changes the focal distance of Fig.31, and has linear motor structure. In Fig.32, the opening side of the lens accommodation cylinder 188 is equipped with the fixing lens 180,184, and the moving lens 182 is slidably poured into optical axis direction between them.

[0101]The arm 192 is equipped with the moving lens 182, and the VCM coil 194 of the actuator 186 is equipped with the arm 192 via the guide slit 190 which carried out the opening to the axial direction. Optical axis direction is slidably equipped with the VCM coil 194 to the yoke 196 which carried out fixed installation. For this reason, by energizing in the VCM coil 194, a real circuit is formed between the yokes 196, the VCM coil 94 can be moved in forward/rearward direction, by this, the moving lens 182 can be moved to optical axis direction within the lens accommodation cylinder 188, and a focal distance can be changed.

[0102]Fig.32 is other embodiments of the projection lens unit 15 of Fig.31. If it is in this embodiment, the lens accommodation cylinder 188 provided with the fixing lens 180,184 and the moving lens 182 is stored into the outer cylinder 198 like Fig.33 (A). The pin 242,246 is fixed to the radial object position, for example, and the pin 242,246 is inserted in the moving lens 182 at the slit of the outer cylinder 198 which is placed outside via the slit 240,244 formed in the optical axis direction of the lens accommodation cylinder 188.

[0103]The slit of the outer cylinder 198 is the slit 260 aslant formed to the optic axis like Fig.33 (B). Outer NARUGIA 248 is formed in the periphery of the end of the outer cylinder 198, and outer NARUGIA 248 meshes with the drive gear 252 of the motor 254 via the intermediate gear 250. If the drive gear 252 is rotated by the motor 254, rotation will be transmited to outer NARUGIA 248 via the intermediate gear 250, and the outer cylinder 198 will rotate. Although the lens accommodation cylinder 188 stored in the outer cylinder 198 moves to an axial direction, the motion of a hand of cut is restricted.

[0104]For this reason, with rotation of the outer cylinder 198, for example, it is fixing to the moving lens 182, the pin 246 of Fig.33 (B) moves to an axial direction along with the slit 244 by the motion by rotation of the slit 260, and moves the moving lens 182. By movement of such optical axis direction of the moving lens 182, a focal distance is changeable. Fig.34 is other embodiments of the opening setting-out control by the detecting position of an observer's forward/rearward direction, the equalization optical system of the actual projection optics unit shows, and this equalization optical system is in the state seen from the side surface. If it was in this embodiment, the matrix liquid crystal shutter 92 has been arranged among the projector lenses 109 and 110 so that it may become in forward/rearward direction slanting to an optic axis.

[0105]Fig.35 is a front view of the matrix liquid crystal shutter 92 of Fig.34, and divides the opening set area into the level stripe opening region 135-1 - 135-n from the bottom. This level stripe opening region differs in the distance of optical axis direction to the convex lens 117 of a screen position. For this reason, the slit imaging area 131-1 which has a position which is different in optical axis direction in an observation area - 131-n will be set up.

[0106]Fig.36 is an explanatory view on the screen side in a actual projection optics unit, and the slit image imaging area 136-1 located in a line across forward/rearward direction to optical axis direction - 136-n are formed in the image formation position of convex Fresnel lens 116 which realizes the convex lens 117 of Fig.34. However, the slit image imaging area 136-1 of Fig.36 - each of 136-n are perpendicularly very narrow ranges, and solid observation becomes impossible [each] when it separates from this range.

[0107]Then, if it is in actual equipment, like Fig.78, the convex lens 117 is approached, the vertical diffusion board 140 is provided, the slit image imaging area 136-1 - 136-n are expanded perpendicularly, and the effective area 144 is formed in it. Fig.38 is the convex Fresnel lens 116 side of the actual projection optics unit of Fig.37, and is providing the vertical diffusion board 140 in accordance with convex Fresnel lens 116.

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[0108]By having provided, this vertical diffusion board 140 each narrow slanting slit image set area 136-1 - 136-n of Fig.36, it can convert to the vertical enlarged area 142-1 expanded perpendicularly - 142-n, and can realize solid observation which made the vertical required region the effective area to movement of an observer's forward/rearward direction.
5. The projection opening control diagram 39 by space division is a block diagram of the image generating device 26 in the image display device of Fig.2 for projecting the right eye image and left eye image which were generated based on observer position detection on 3D observation area by space division, and the display control 28. If it is in the image projection of space division, two, the indicator 14-1 for left eyes and the indicator 14-2 for right eyes, are used as the indicator 14.
[0109]As this object for left eyes, and indicator 14-1,14-2 for right eyes, a transmission type liquid crystal display device is used. Display driving part 72-1,72-2 is provided by the display control 28 corresponding to indicator 14-1,14-2 for the object for left eyes, and right eyes. The image generating device 26 is the same as the case of the time sharing of ****, and it comprises the modeling data storage 62 and the rendering processing part 64, Based on observer position information, the right eye image and left eye image based on modeling data are generated by the RENRINGU processing part 64, and it writes in the right eye image frame buffer 66 and the left eye image frame buffer 68 of the display control 28. As the image generating device 26, the camera image data storing part 73 and the interpolation picture generation part 75 of Fig.11 may be used.
[0110]Fig.40 is the read operation of right eye image data and left eye image data by the display control 28 of Fig.39, The image data 74 for right eyes and the image data 76 for left eyes are read from each of the right eye image frame buffer 66 where two display driving part 72-1,72-2 corresponds, and the left eye image frame buffer 68 in parallel, The image corresponding to the display part 14-2 for right eyes and the indicator 14-1 for left eyes is displayed simultaneously.
[0111]Fig.41 is an embodiment of the projection optics unit for performing the projection display of the right eye image by space division, and a left eye image. In Fig.41, the indicator 14-1 for left eyes and the indicator 14-2 for right eyes are arranged individually, and MARITOKUSU liquid crystal shutter 92-1,92-2 and projector lens 110-1,110-2 which perform opening setting out are installed corresponding to each indicator 14-1,14-2.
[0112]The concave surface mirror 112 and the back face mirror 114 which were provided following the projector lens serve as a community optical system, and are installing convex Fresnel lens 116 which has an image formation function in a screen position in the 3D observation area 20. On the other hand, although the light source unit side is omitting, The light source 98, the reflector 100, the lens 102, and Fresnel lens 104 are provided like the embodiment of the space division of Fig.17, A half mirror is used instead of the mirror 106, and the reflected light of a half mirror is entered into the indicator 14-2 for right eyes of Fig.41, and he reflects further the light which transmitted the half mirror by a mirror, and is trying to enter into the indicator 14-1 for left eyes of Fig.41.
[0113]If it is in the projection optics unit by such space division, The display of the right eye image and left eye image which correspond to each of the indicator 14-2 for right eyes and the indicator 14-1 for left eyes in parallel is performed, and the opening 130,128 is set to each of matrix liquid crystal shutter 92-2,92-1 synchronizing with this. Opening setting out in this case is the same as the case of the space division of Fig.26 and Fig.27.
[0114]Namely, the slit shape opening 128 with small width corresponding to the detection position of the left eye 40 of the observer who exists in the 3D observation area 20 is set as the matrix liquid crystal shutter 92-2 corresponding to the indicator 14-2 for right eyes, The slit image 118 is imaged to the 3D observation area 20, and this is made into the left eye observation area 20-1. The opening 130 which made the transmission state the whole region except the opening 128 set as the matrix liquid crystal shutter 92-1 for left eyes is simultaneously set to the matrix liquid crystal shutter 92-2 corresponding to the indicator 14-2 for right eyes. For this reason, the slit image 120 of the opening 130 is imaged by the 3D observation area 20 to the region except the left eye observation area 20-1, and this forms the right eye observation area 20-2.
[0115]Fig.42 is the block diagram of matrix liquid crystal shutter 92-1,92-2 and an opening control unit provided to the projection optics unit of the space division of Fig.41. As the opening setting device 16, two matrices liquid crystal shutter 92-1,92-2, each driver 94-1,94-2, and 96-1,96-2 are provided. Display controller 90-1,90-2 is provided by the opening control unit 30 corresponding to two-set liquid crystal shutter [of matrices] 92-1,92-2, and opening setting-out control is performed to it in parallel. The opening position calculating part 88 is the same as the case of the time sharing of Fig.16, calculates the opening position for a right eye and left eyes based on observer position detection information, and instructs it to the display controller 90.
[0116]Fig.43 is a flow chart of the projection opening control in the projection optics unit by the space division of Fig.41. The position of an observer's right and left eye is first detected at Step S1, and the image for left eyes and the image for right eyes are generated at Step S2. Then, the image for left eyes and the image for right eyes are expressed to each indicator provided independently as Step S3 in parallel. Setting-out control of the opening position for left eyes and the opening position for right eyes is simultaneously performed to each of matrix liquid crystal shutter 92-1,92-2 provided as the object for left eyes, and an opening setting device for right eyes by step S4, and it repeats until a display stop has the above Step S1 - S4 processed at Step S5. If shown in Fig.41, opening setting out of the Fig 26 in time sharing and Fig.27 is taken for the example, but it may be made to perform opening setting out of Fig.17, opening setting out of Fig.18 or Fig.23, and Fig.24 in addition to this.
[0117]Fig.44 is an embodiment for control of the depth direction of the opening in the projection optics unit of space division. If it is in this embodiment, lamination shutter 134-1,134-2 which carried out the plural laminates of matrix liquid crystal shutter 92-1,92-2 of

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Fig.42 to optical axis direction following the indicator 14-1 for left eyes and the indicator 14-2 for right eyes is set up. Corresponding to each matrix liquid crystal shutter of these lamination shutter 134-1,134-2, the slit image formation face 132-1 - 132-n will be formed in the 3D observation area 20 ahead of convex Fresnel lens 116 used as a screen position by shutter number of sheets in forward/rearward direction.

[0118]By for this reason, the thing which the corresponding matrix liquid crystal shutter in lamination shutter 134-1,134-2 is chosen, and is done for opening setting out based on the detection position of the forward/rearward direction of the observer position of the 3D observation area 20, A slit image formation face is formed in the position of the depth direction corresponding to the detection position of 3D observation direction, and projection of the image light by formation of the slit image for observing the object for right eyes and the image for left eyes here can be performed.

[0119]As an embodiment of opening control of the forward/rearward direction in space division, What changes a focal distance by movement of the optical axis direction of the moving lens 162 provided to the projection lens unit 15 shown in the time sharing of Fig.31 besides the lamination shutter of Fig.45, It is good for convex Fresnel lens 116 which an optic axis arranges aslant the matrix liquid crystal shutter shown in Fig.37 in forward/rearward direction, and serves as a screen position also as what provided the vertical diffusion board 140.

6. As for the projection opening control diagram 45 by polarization division, a polarized part is an embodiment of the projection optics unit of the Fig.2 realized comparatively more about the projection of a right eye and a left eye image and opening setting out to 3D observation area.

[0120]In Fig.45, if it is in polarization division, the indicator 14-1 for left eyes and the indicator 14-2 for right eyes are independently provided as an indicator. For this reason, as a display control, the thing of the same Fig.39 as space division can be used. After the light source side condenses the light by the light source 98 and the reflector 100 with the lens 102, Fresnel lens 104 has converted and separated it into S polarization component which serves as P polarization component used as the transmitted light, and a reflected light by the polarization beam splitter (PBS) 144 for beams to the parallel beam continuously. It is reflected by the mirror 146 and S polarization component reflected by the polarization beam splitter 144 for separation enters into the indicator 14-1 for left eyes.

[0121]On the other hand, P polarization component which transmitted the polarization beam splitter 144 for separation enters into the indicator 14-2 for right eyes, after being reflected by the mirror 148. S polarization component used as the image lights which passed the indicator 14-1 for left eyes, and P polarization component which passed the indicator 14-2 for right eyes, and became image lights are given to the polarization beam splitter 150 for a synthesis. After the polarization beam splitter 150 for a synthesis synthesizes S polarization component and P polarization component, it is given to the matrix pi cell 152 which functions as an opening setting device in polarization division. If the matrix pi cell 152 is followed, the projector lens 110 is provided, and the optical system after it comprises convex Fresnel lens 116 which has an image formation function in the concave surface mirror 112, the back face mirror 114, and the 3D observation area 20 like the case of time sharing and space division.

[0122]Fig.46 has taken out the portions of the indicator 14-1 for left eyes in Fig.45, the indicator 14-2 for right eyes, the polarization beam splitter 150 for a synthesis, and the matrix pi cell 152. The matrix pi cell 152 which functions as an opening setting device comprises TN liquid crystal 158 and the polarizing plate 160, as shown in Fig.47. TN liquid crystal 158 makes the rotatory polarization and non rotating state of incident light by electrolysis turning on and off by the application of the drive voltage to between the electrodes which have laminated the liquid crystal.

[0123]That is, Fig.47 (A) is the electrolysis OFF state which turned off the drive voltage between the electrodes of TN liquid crystal 158. In this electrolysis OFF state, when P polarization component used as the right eye image light 124 passes TN liquid crystal 158, a plane of polarization rotates 90 degree and it is converted to S polarization component. On the other hand, it rotates 90 degree similarly and S polarization component used as the left eye image light 122 also turns into P polarization component. The polarizing plate 160 transmitted only S polarization component, for example, and is provided with the polarization characteristic which intercepts P polarization component.

[0124]For this reason, the polarizing plate 160 is passed, the S polarization component, i.e., right eye image light 124, which were outputted from TN liquid crystal 158, and it is projected on the right eye 38 side. Therefore, in the matrix pi cell 152 of Fig.46, the electrolysis OFF region 154 which turned off electrolysis of TN liquid crystal 158 may be set up about a region to set the opening for right eyes. On the other hand, about the electrolysis ON state which applied the drive voltage to the electrode of TN liquid crystal 158, it becomes like Fig.47 (B). If it is in the electrolysis ON state which applied the drive voltage between the electrodes of TN liquid crystal 158, the rotatory polarization function by TN liquid crystal 158 will be lost, it will be in a transmission state, and P polarization component which is the right eye image light 124, and S polarization component which is the left eye image light 122 pass TN liquid crystal 158 as it is.

[0125]At this time, since the polarizing plate 160 has the penetration characteristic of only S polarization component, S component used as the left eye image light 122 is outputted, and it is projected on the left eye 40. Therefore, in the matrix pi cell 152 of Fig.46, the electrolysis ON region 156 may be set up about a region to set the opening for left eyes. By setting out of the electrolysis ON region 156 corresponding to the opening for left eyes in such a matrix pi cell 152, and the electrolysis OFF region 154 corresponding to the opening for right eyes. The left eye observation area 20-1 and the right eye observation area 20-2 are set to the 3D observation area 20 ahead of convex Fresnel lens 116 used as a screen position like Fig.45, and the observer can observe a stereoscopic model with a binocular disparity by projection of a right eye image and a left eye image to each region.

[0126]About observers other than the observer who is a detecting position object, in the case

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of this embodiment, since it will observe from the right eye observation area 20-2, the right eye image by the indicator 14-2 for right eyes is vividly observable as a two-dimensional image. As for Fig.48, a polarized part of Fig.45 is a flow chart of the projection control depended comparatively and opening control. The position of an observer's right and left eye is first detected at Step S1, and the image for left eyes and the image for right eyes are generated at Step S2. Then, the image for left eyes and the image for right eyes are expressed to each indicator 14-1,14-2 as Step S3. The electrolysis turning-on-and-off region which determines the existence of polarization rotation according to the opening position for right eyes and the opening position for left eyes is controlled by step S4.

[0127]The projection and opening control by polarization division of such a step S1 - S4 are repeated until a display stop is performed at Step S5. Here, although opening setting out of the matrix pi cell 152 in polarization division of Fig.45 has taken the Fig.26 by time sharing, and the same opening setting out as 27 for the example, it is natural. [of opening setting out of Fig.17, opening setting out of Fig.18 or Fig.23, and Fig.24 being performed in addition to this]

[0128]As for Fig.49, a polarized part is an embodiment of the projection optics unit which controls the forward/rearward direction of the opening which can be set comparatively. If it is in this embodiment, the lamination matrix pi cell 161 is provided following the polarization beam splitter 150 for a synthesis. The lamination matrix pi cell 161 has laminated the matrix pi cell 152 used by Fig.45 on two or more sheets and optical axis direction.

[0129]Along with the forward/rearward direction in alignment with an optic axis, a plurality of slit imaging areas 162-1 - 162-n are formed in the 3D observation area 20 ahead of convex Fresnel lens 116 which serves as a screen position by such a lamination matrix pi cell 161. For this reason, corresponding to the detection position of an observer's forward/rearward direction in the 3D observation area 20, the corresponding matrix pi cell in the lamination matrix pi cell 161 is chosen, By performing opening setting out the object for right eyes by setting out of the electrolysis OFF region 154 like Fig.46, and the electrolysis ON region 156, and for left eyes, the slit image of a matrix pi cell is imaged to the slit image formation position in front of the detection position of the observer of the 3D observation area 20, and solid observation by an observer is enabled.

[0130]Fig.50 is other embodiments of control of the forward/rearward direction of the opening in the projection optics unit of polarization division, and installed the matrix pi cell aslant in forward/rearward direction to the optic axis. That is, following the polarization beam splitter 150 for a synthesis, the matrix pi cell 152 is arranged so that it may become in forward/rearward direction slanting to an optic axis. The matrix pi cell 152 arranged aslant performs opening setting out in the position where the optical axis direction by a plurality of level stripe openings differed like the case of the matrix liquid crystal shutter of the Fig.34 in space division.

[0131]For this reason, the level stripe slit image 164-1 corresponding to each level stripe opening of the matrix pi cell 152 arranged aslant - 164-n are formed in 3D observation space 20 ahead of convex Fresnel lens 116 used as a screen position. In this case, a stereoscopic model is unobservable in the width of each level stripe slit image 164-1 - the vertical direction of 164-n being very narrow, and an observer's eye separating from this width.

[0132]Then, like Fig.51, the vertical diffusion board 166 is provided to convex Fresnel lens 116, and it is referred to as the vertical enlarged area 170-1 - 170-n which expanded each level stripe slit image 164-1 - 164-n perpendicularly. The projector lens in the time sharing of Fig.31 is moved to optical axis direction, and, of course, it may be made to change a focal distance about control of the forward/rearward direction of the opening by polarization division in addition to this.

7. The projection opening control diagrams 52 to two or more observers are other embodiments of the image display device of the present invention, a plurality of observer positions which exist in 3D observation area are detected, and each observer could be made to do solid observation individually.

[0133]In Fig.52, the equipment configuration of the image display device 10 of the present invention which enables two or more observers' solid observation, Each of a plurality of observer [to whom it is fundamentally / as the embodiment of Fig.2 / the same, and the observer position detection device 24 exists in the 3D observation area 20], for example, two observer 22-1,22-, 2 is detectable. For example, the image generating device 26 is based on the observer position detection device 24, it performs image generation according to the following mode based on the detection information of two observer 22-1,22-2.

[0134]Mode 1: Generate the right eye image and left eye image which saw the right eye and left eye of the one specific person 22-1 of a plurality of observer 22-1,22-2, for example, an observer, as a view position.

Mode 2: Generate the right eye image and left eye image which saw each right eye and left eye of observer 22-1,22-2 as a view position.

[0135]For this reason, if it is in the mode 1, the image display to the indicator 14 by the same image generation and the display control 30 as the case where it is targeted at one observer in the already described working example from it being an observer's one right eye image and left eye image corresponding to a detection position may be sufficient. On the other hand, in generating each right eye image and left eye image every observer 22-1,22-2 in the mode 2, For example, since it is necessary to display the right eye image for 2 persons, and a left eye image using the single indicator 14 if it is in time sharing, it is the display period which multiplied severalN of the observer made into a displaying object, the display period, for example (1/120), the second cycle, which are a part for one person, For example, it is necessary to carry out the switching display of the case of the observer of a non-side at high speed a second (1/240) cycle.

[0136]On the other hand, about the opening control by the opening control unit 32 to the opening setting device 16, opening setting out corresponding to the position of each right eye and each left eye of two observer 22-1,22-2 is performed. If it is in the illustrated 3D

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observation area 20, it is in the state which set up right eye observation area 20-21,20-22 of observer 22-1,22-2, and two opening setting out for right eyes is performed to the opening setting device 16 corresponding to this.
[0137]Fig.53 is an embodiment of the projection optics unit of the equipment [/ time sharing] for two or more observers of Fig.52. If shown in Fig.53, opening 128-1,128-2 corresponding to the detection position of left eye 40-1,40-2 of two observers who exist in the 3D observation area 20 is set up to the matrix liquid crystal shutter 92. The slit image of each left eye observation area 20-11,20-12 is formed in the 3D observation area 20 by this, and two observers can observe the left eye image displayed on the same indicator 14 by each left eye 40-1,40-2.
[0138]Fig.54 is in the state switched to the display of a right eye image, and opening setting out, and is setting up opening 130-1,130-2 corresponding to the detection position of right eye 38-1,38-2 of two observers who exist in the 3D observation area 20 to the matrix liquid crystal shutter 92. For this reason, right eye observation area 20-21,20-22 to each observer is formed in the 3D observation area 20, and two observers can observe the right eye image of the indicator 14 by each right eye 38-1,38-2.
[0139]Since the display of Fig.53 and Fig.54 is alternately switched if it is in time sharing, two observers will look at a parallax image which is simultaneously different by the right eye and a left eye, and can observe a solid by this. If shown in the display control of the indicator 14 by the mode 1 at this time, two observers will observe the same stereoscopic picture. On the other hand, if it is in the mode 2, corresponding to each position of an observer, a right eye image and a left eye image are formed individually, for example, if there are two observers like Fig.52, The observer's 22-1 right eye image and left eye image are displayed first, the opening for right eyes and the opening for left eyes are set to the matrix liquid crystal shutter 92 synchronizing with this, and the projection display for the solid observation to the observer 22-1 is performed.
[0140]Then, the stereoscopic picture by the observer 22-2 is made to observe by performing sequentially the display of the right eye image and left eye image which were generated from the next observer's 22-2 detection position to the indicator 14, and performing sequentially opening setting out corresponding to the observer's 22-2 right eye position and left eye position synchronizing with this. For this reason, if it is in the projection display in the mode 2, and opening control, observer 22-1,22-2 can observe the stereoscopic picture of how corresponding to each position to be visible, even if it is the same display picture.
[0141]Although the projection optics unit of the equipment for two or more observers of Fig.53 is based on what is depended on space division, and polarization division like the embodiment of the projection optics unit for the single observer of Fig.2 in addition to the space division of Fig.53 and Fig.54, all can be used for it as it is. Proper deformation is possible for the present invention in the range which does not deviate from the object of invention. The limitation by the numerical value by which the present invention was described in the working example is not received again.
[0142]
[Effect of the Invention]A stereoscopic picture can be seen vividly, without using fill-in flash study systems, such as glasses, according to the present invention, as described above, Motion parallax from which an observer's movement is followed and 3-dimensional scenography changes can be realized, and also a two-dimensional image with the same contents can be vividly shown about observers other than a solid observer.

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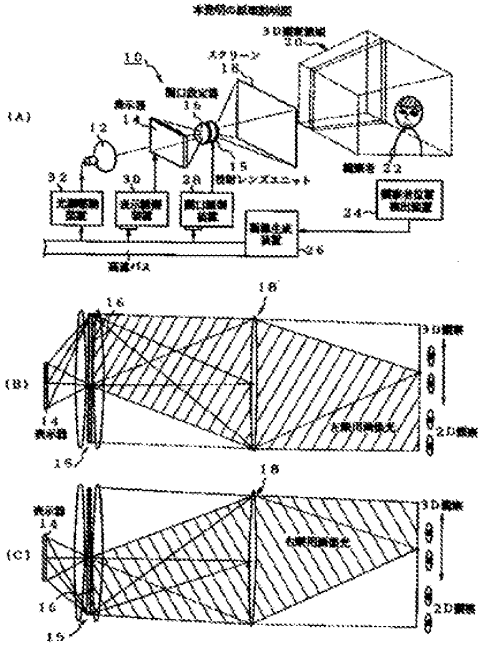
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(54)【発明の名称】画像表示装置及び方法

(57)【要約】

【課題】　眼鏡等の補助光学系なしで１又は複数の観察者の移動しながらの立体観察を可能とし、立体観察領域以外の観察者は鮮明な二次元画像を観察させる。

【解決手段】　立体観察領域２０の観察者２２の位置を位置検出部２４で検出して画像生成部２６で検出位置から見た右眼画像と左眼画像を生成して表示器１４に表示し、投映光学系の開口位置の設定により右眼画像を観察者２２の左眼位置に、左眼画像を左眼位置に投映して立体画像を観察させ、更に、観察者２２の検出位置とは異なる位置に右眼画像又は左眼画像を投映するように開口を設定し、他の観察者の両眼に同一画像を見せて二次元画像を観察させる。



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【特許請求の範囲】

【請求項１】両眼視差により立体映像を認識させる画像表示装置に於いて，

立体観察領域に存在する観察者の位置を検出する位置検出部と，

前記観察者の検出位置から見た右眼画像と左眼画像を生成する画像生成部と，

前記画像生成装置で生成した右眼画像と左眼画像を表示する表示器と，

開口位置の設定により前記表示器の表示画像を前記観察者の検出位置に投映する投映光学ユニットと，

前記観察者の検出位置に基づいて，少なくとも前記右眼画像を前記観察者の右眼を含む位置に投映すると共に前記左眼画像を前記観察者の左眼を含む位置に投映するように前記投映光学ユニットの開口の位置と大きさを制御して前記観察者に立体画像を観察させる開口制御部と，

を備えたことを特徴とする画像表示装置。

【請求項２】請求項１記載の画像表示装置に於いて，前記位置検出部は，観察者の眼球位置を検出することを特徴とする画像表示装置。

【請求項３】請求項２記載の画像表示装置に於いて，前記位置検出部は，

水平方向に所定間隔で配置された２台の撮像装置と，

該撮像装置により撮影された２枚の画像から前記観察者の位置を算出する位置演算部と，を備えたことを特徴とする画像表示装置。

【請求項４】請求項２記載の画像表示装置に於いて，前記位置検出部は，

前記観察者に装着された磁石と，

水平方向に所定間隔で配置された２台の磁気センサと，

前記磁気センサの検出信号から前記観察者の位置を演算する位置演算部と，を備えたことを特徴とする画像表示装置。

【請求項５】請求項２記載の画像表示装置に於いて，前記位置検出部は，

水平方向に所定間隔で配置された２台の超音波センサと，

前記超音波センサの検出信号から前記観察者の位置を演算する位置演算部と，を備えたことを特徴とする画像表示装置。

【請求項６】請求項１記載の画像表示装置に於いて，前記開口制御部は，前記観察者の右眼の検出位置に対応した右眼開口と左眼の検出位置に対応した左眼開口の各々を設定して，前記右眼画像と前記左眼画像を前記観察者に投映して両眼の視差画像により立体画像を観察させることを特徴とする画像表示装置。

【請求項７】請求項１記載の画像表示装置に於いて，前記開口制御部は，前記右眼開口と左眼開口として，前記観察者の右眼と左眼の検出位置に対応した小さな開口領域を設定することを特徴とする画像表示装置。

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【請求項８】請求項１記載の画像表示装置に於いて，前記開口制御部は，前記右眼開口と左眼開口として，統計的に求めた観察者の両眼間隔に基づいて定めた所定範囲に画像を投映するように開口を設定したことを特徴とする画像表示装置。

【請求項９】請求項１記載の画像表示装置に於いて，前記開口制御部は，更に，前記観察者の検出位置とは異なる位置に，前記右眼画像または左眼画像を投映するように開口を設定することにより，他の観察者の両眼に同一画像を見せて二次元画像を観察させることを特徴とする画像表示装置。

【請求項１０】請求項９記載の画像表示装置に於いて，前記開口制御部は，前記観察者の右眼の検出位置に対応した右眼開口と左眼の検出位置に対応した左眼開口の各々を設定して両眼視差により立体画像を観察させ，更に，前記右眼開口と左眼開口のいずれか一方を，他方の開口を除く位置に広げて対応する画像を投映して，他の観察者の両眼に同一画像を見せて二次元画像を観察させることを特徴とする画像表示装置。

【請求項１１】請求項９記載の画像表示装置に於いて，前記開口位置制御部は，前記観察者の右眼と左眼の検出位置の中心に境界がくるように右眼開口と左眼開口を設定して各々対応する画像を投映し，前記検出位置の観察者に両眼の視差画像により立体画像を観察させると共に，他の観察者の両眼に同一画像を見せて二次元画像を観察させることを特徴とする画像表示装置。

【請求項１２】請求項１記載の画像表示装置に於いて，前記表示器は，前記右眼画像と左眼画像を順次表示する単一の表示デバイスを備え，

前記投映光学ユニットは，

前記表示デバイスからの画像を拡大投射する投射レンズと，

前記投射レンズの近傍に設置され，前記開口の位置と大きさを設定する開口設定器と，

前記投射レンズの焦点位置に配置され，前記立体観察領域に対する開口像の結像機能を備えたスクリーンと，とを備え，

前記開口制御部は，前記表示器による右眼画像と左眼画像の切替表示に同期して前記開口設定器の右眼開口と左眼開口の位置とを切り替えることを特徴とする画像表示装置。

【請求項１３】請求項１２記載の画像表示装置に於いて，

前記表示器は，前記右眼画像と左眼画像に対応して一対の表示デバイスを備え，

前記投映光学ユニットは，

前記一対の表示デバイスからの画像を個別に拡大投射する一対の投射レンズと，

前記一対の投射レンズの近傍に設置され，前記開口の位置と大きさを設定する一対の開口設定器と，

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前記一対の投射レンズの焦点位置に配置され、前記立体観察領域に対する開口像の結像機能を備えたスクリーンと、を備え、

前記開口制御部は、前記一対の表示器に対する右眼画像と左眼画像を並列表示に同期して前記一対の開口設定器に右眼開口と左眼開口の位置を同時設定することを特徴とする画像表示装置。

【請求項１４】請求項１２記載の画像表示装置に於いて、

前記表示器は、前記右眼画像と左眼画像に対応して一対の表示デバイスを備え、

前記投映光学ユニットは、

光源からの光を異なる偏光面をもつ２つの光に分離して前記一対の表示デバイスに入射する分離用偏光ビームスプリッタと、

前記一対の表示デバイスからの偏光面の異なる画像光を合成する合成用偏向ビームスプリッタと、

前記合成用偏光ビームスプリッタからの画像光を拡大投射する投射レンズと、

前記投射レンズの近傍に配置され、入射光の偏光面の回転の有無により偏向面の異なる画像光を選択的に透過する開口位置を設定する偏光制御型の開口設定器と、

前記投射レンズの焦点位置に配置され、前記立体観察領域に対する開口像の結像機能を備えたスクリーンと、を備え、

前記開口制御部は、前記一対の表示デバイスに対する右眼画像と左眼画像を並列表示に同期して、前記偏光制御デバイスの右眼開口と左眼開口の位置の各々に対応する画像光が透過するように偏光制御することを特徴とする画像表示装置。

【請求項１５】請求項１２又は１３記載の画像表示装置に於いて、前記開口設定器は、細分化された液晶セグメントの電圧制御により透過位置を任意に設定する液晶デバイスであることを特徴とする画像表示装置。

【請求項１６】請求項１４記載の画像表示装置に於いて、前記偏光制御型の開口設定器は、

細分化された液晶セグメントに対する駆動電圧の印加の有無により入射光の偏光面の回転を制御する液晶デバイスと、

前記液晶デバイスから出力された特定の偏光面をもつ画像光のみを透過する偏光板と、を備えたことを特徴とする画像表示装置。

【請求項１７】請求項１２乃至１４のいずれかに記載の画像表示装置に於いて、前記投映光学ユニットは、前記投射レンズの口径を拡大する虚像生成部材を備えたことを特徴とする画像表示装置。

【請求項１８】請求項１２乃至１４記載の画像表示装置に於いて、前記開口制御部は、前記開口設定器の透過位置を水平方向で変化させることにより、前記開口位置を左右に制御することを特徴とする画像表示装置。

【請求項１９】請求項１８記載の画像表示装置に於いて、前記開口制御部は、前記投射レンズを光軸方向に移動制御することにより、前記開口位置を前後に制御することを特徴とする画像表示装置。

【請求項２０】請求項１８記載の画像表示装置に於いて、前記開口制御部は、前記投射レンズの焦点距離を変化させることにより、前記開口位置を前後に制御することを特徴とする画像表示装置。

【請求項２１】請求項１８記載の画像表示装置に於いて、前記開口設定器を光軸方向に複数積層し、前記開口制御部は、前記複数の開口設定器の積層方向での透過位置を制御することにより、前記開口位置を前後に制御することを特徴とする画像表示装置。

【請求項２２】請求項１２乃至１４のいずれかに記載の画像表示装置に於いて、

前記開口設定器を光軸に対し前後方向で斜めに配置すると共に前記スクリーンに光を上下方向に拡散させる拡散板を設け、

前記開口制御部は、前記開口設定器の左右方向での透過位置の変化により前記開口位置を左右に制御し、且つ前記開口設定器の斜め上下方向の透過位置の変化により前記開口位置を前後に制御することを特徴とする画像表示装置。

【請求項２３】請求項１記載の画像表示装置に於いて、前記画像生成部は、前記観察者の検出位置から見た右眼画像と左眼画像の二次元画像データを、モデリングされた三次元画像データに基づいて生成することを特徴とする画像表示装置。

【請求項２４】請求項１記載の画像表示装置に於いて、前記画像生成部は、前記観察者の検出位置から見た右眼画像と左眼画像の二次元画像データを、物体を水平方向の異なる位置から見た二次元画像データの補間により生成することを特徴とする画像表示装置。

【請求項２５】請求項１記載の画像表示装置に於いて、前記位置検出部は、複数の観察者を検出し、

前記画像生成部は、前記複数の観察者の各々から見た右眼画像と左眼画像を生成し、

前記表示器は、前記複数の観察者毎に生成された右眼画像と左眼画像を順次表示し、

前記開口制御部は、前記複数の観察者の検出位置に基づいて、各観察者の右眼画像を右眼を含む位置に投映すると共に、前記左眼画像を左眼を含む位置に投映するように、前記投映光学ユニットの開口の位置と大きさを制御し、前記複数の観察者に各位置から見た固有の立体画像を観察させることを特徴とする画像表示装置。

【請求項２６】請求項１記載の画像表示装置に於いて、前記位置検出部は、複数の観察者を検出し、

前記画像生成部は、前記複数の観察者のいずれか一人が見た右眼画像と左眼画像を生成し、

前記表示器は、前記右眼画像と左眼画像を表示し、

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前記開口制御部は、前記複数の観察者の検出位置に基づいて、前記右眼画像を前記複数の観察者の右眼を含む位置に投映すると共に、前記左眼画像を複数の観察者の左眼を含む位置に投映するように前記投映光学系の開口の位置と大きさを制御し、前記複数の観察者に同じ立体画像を観察させることを特徴とする画像表示装置。

【請求項２７】両眼視差により立体映像を認識させる画像表示方法に於いて、

観察領域に存在する観察者の位置を検出する位置検出過程と、

前記検出位置の観察者が見た右眼画像と左眼画像を生成する画像生成過程と、

前記右眼画像と左眼画像を表示する画像表示過程と、

前記観察者の検出位置に基づいて投映光学系の開口の位置と大きさの制御により、前記右眼画像を前記観察者の右眼を含む位置に投映すると共に、前記左眼画像を前記観察者の左眼を含む位置に投映して両眼視差により立体画像を観察させる三次元表示過程と、

前記投映光学系の開口位置とは異なる別の開口設定により、前記右眼画像又は左眼画像のいずれかを前記観察者の検出位置とは異なる位置に投映して，他の観察者の両眼に同一画像を見せて二次元画像を観察させる二次元表示過程と、を備えたことを特徴とする画像表示方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、１又は複数の観察者の眼の位置を検出して両眼の運動視差により立体映像を観察させるための表示装置及び方法に関し、特に、立体映像の観察者以外の他の観察者は二次元映像を観察可能とするための画像表示装置及び方法に関する。

【０００２】

【従来の技術】従来，立体表示装置としては二眼式のものが最も良く知られている。図５５は、従来の二眼式立体表示装置であり、表示装置２００のスクリーン２０２に、図５６のように右眼用画像２０６と左眼用画像２０８を表示し、この映像を偏光眼鏡などの補助光学系を用いて右眼３８に右眼用画像２０６を見せ、同時に左眼４０に左眼用画像２０８を見せ、両眼の運動視差によって立体画像２０４を見せている。また偏光眼鏡等の補助光学系を必要としない立体表示装置としては，図５７のレンティキュラ方式や、図５８のパララックスバリア方式がある。

【０００３】図５７のレンティキュラ方式の立体表示装置は、液晶デバイス等の表示器２１０とレンティキュラレンズ２１２で構成される。表示器２１０には右眼画像の表示画素Ｒと左眼画像の表示画素Ｌが分離配置される。右眼画素Ｒからの光はレンティキュラレンズ２１２により視域２１４内の観察者の右眼３８の位置に投映される。同時に左眼画素Ｌからの光はレンティキュラレンズ２１２により視域２１４内の観察者の左眼４０の位置に投映され、両眼の運動視差により立体映像を見ることができる。

【０００４】図５８のパララックスバリア方式の立体表示装置は、液晶デバイス等の表示器２１０とスリット２１６で構成される。表示器２１０には右眼画像の表示画素Ｒと左眼画像の表示画素Ｌが分離配置される。右眼画素Ｒからの光はスリット２１６により視域２１４内の観察者の右眼３８の位置に投映される。同時に左眼画素Ｌからの光はスリット２１６により視域２１４内の観察者の左眼４０の位置に投映され、両眼の運動視差より立体映像を見ることができる。

【０００５】しかし、レンティキュラ方式及びパララックスバリア方式のいずれについても、観察者の眼３８，４０の位置が予め設定された視域２１４から眼３８´，４０´のように外れると、左右の眼に入る映像が入れ替わる逆視状態となって分離したり、画面が暗くなったりするため、立体観察領域が限定される問題があった。この問題を解消するものとして、レンティキュラ方式について立体観察領域を拡げた図５９の立体表示装置がある。この立体表示装置は、スクリーンにスリット２２２を備えたダブルレンティキュラレンズ２２０を使用している。ダブルレンティキュラレンズ２２０を使用したスクリーンに対してはプロジェクタ２１５には、右眼画像用の表示器２１６－１と投射レンズ２１８－１、及び左眼画像用の表示器２１６－２と投射レンズ２１８－２が独立に設けられる。

【０００６】ダブルレンティキュラレンズ２２０は、光の来た方向に向けて光を透過する機能がある。このため投射レンズ２１８－１，２１８－２に相対する視域２１４の位置からスクリーンを見たとき，投射された右眼映像Ｒと左眼映像Ｌを見ることができ，左右の眼３８，４０に独立して映像を知覚させることができ、立体として観察することができる。

【０００７】観察者が左右方向２２４－１や前後方向２２６－１に移動した場合は、プロジェクタ２１５の位置を左右方向２２４－２や前後方向２２６－２のように観察者に合わせて移動することにより、観察者の眼３８，４０を常に視域２１４から外れないようにしている。

【０００８】

【発明が解決しようとする課題】しかしながら、従来のレンティキュラ方式の立体表示装置の場合，観察者に追従して設定する視域２１４に対し、副プローブといわれる立体観察範囲が視域２１４の左右方向にも拡がり、一人の観察者に合わせてプロジェクタ２１５を移動させると、他の観察者、例えば後ろから見ている別の人には、映像の分離領域が不十分となって立体に見えないだけでなく、見ることのできる二次元画像のそのものの品質も悪くなるという問題があった。

【０００９】また、複数の観察者に対応して複数のプロジェクタ２１５を用意しても、各観察者に応じて異なっ

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た移動を行うと、各プロジェクタ間で副プローブによる映像の妨害が起こるため、一人の観察者にしか対応できないという問題があった。本発明は、眼鏡等の補助光学系なしで１又は複数の観察者の移動しながらの立体観察を可能とし、更に、立体観察領域以外の観察者は鮮明な二次元画像が観察できるようにした画像表示装置及び方法を提供することを目的とする。

【００１０】

【課題を解決するための手段】図１は本発明の原理説明図である。本発明は、両眼視差により立体映像を認識させる画像表示装置であり、図１（Ａ）のように、立体観察領域２０に存在する観察者２２の位置を検出する位置検出部２４、検出位置の観察者２２が見た右眼画像と左眼画像を生成する画像生成部２６、画像生成部２６で生成した右眼画像と左眼画像を表示する表示器１４、開口位置の設定により表示器１４の表示画像を観察者２２の検出位置に投映する投映光学ユニット、及び観察者２２の検出位置に基づいて、少なくとも右眼画像を観察者２２の右眼を含む位置に投映すると共に、左眼画像を観察者２２の左眼を含む位置に投映するように投映光学ユニットの開口の位置と大きさを制御して立体画像を観察させる開口制御部２８を備える。

【００１１】これにより立体観察領域２０内での観察者２２の移動に追従した視差画像の投映が行われ、広い範囲での観察者２２の動きを許容する。また観察者の移動に伴なって画像の見え方を変化するので、運動視差のある立体画像の観察ができる。位置検出部２４は、具体的には観察者２２の右眼３８と左眼４０の眼球位置を検出する。位置検出部２４は、水平方向に所定間隔で配置された２台の撮像装置と、撮像装置により撮影された２枚の画像から前記観察者の位置を算出する位置演算部を備える。

【００１２】また別の形態として、位置検出部２４は、観察者に装着された磁石、水平方向に所定間隔で配置された２台の磁気センサ、及び磁気センサの検出信号から前記観察者の位置を演算する位置演算部で構成される。更に別の形態として、位置検出部２４は、水平方向に所定間隔で配置された２台の超音波センサと、超音波センサの検出信号から観察者の位置を演算する位置演算部からも構成できる。

【００１３】開口制御部２８は、観察者２２の右眼３８の検出位置に対応した右眼開口と左眼４０の検出位置に対応した左眼開口の各々を設定して、右眼画像と左眼画像を観察者の検出位置に投映して両眼の視差画像により立体画像を観察させる。この場合、開口制御部２８は、右眼開口と左眼開口として、観察者の右眼３８と左眼４０の検出位置に対応した小さな開口領域を設定する。

【００１４】また開口制御部２８は、右眼開口と左眼開口として、統計的に求めた観察者の両眼間隔（約３２．５ｍｍ～９７．５ｍｍ）に基づいた所定範囲に画像を投映するように開口領域を設定する。開口制御部２８は、更に、観察者２２の検出位置とは異なる位置に右眼画像又は左眼画像を投映するように開口を設定し、他の観察者の両眼に同一画像を見せて二次元画像を観察させる。このため立体観察の対象者として検出している観察者２２以外の他の観察者については、右眼画像または左眼画像のいずれか一方が投映され、鮮明な二次元画像を観察することができる。

【００１５】開口制御部２８による立体画像と二次元画像の表示は、観察者の右眼の検出位置に対応した右眼開口と左眼の検出位置に対応した左眼開口の各々を設定し、右眼画像と左眼画像を投映して両眼視差により立体画像を観察させる。同時に右眼開口と左眼開口のいずれか一方を、他方を除く位置に広げて対応する画像を投映することにより、他の観察者の両眼に同一画像を見せて二次元画像を観察させる。

【００１６】また開口制御部２８は、図１（Ｂ）（Ｃ）のように、観察者の右眼３８と左眼４０の検出位置の中心に境界がくるように右眼開口１３０と左眼開口１２８を設定して対応する画像を投映し、観察者に両眼視差により立体画像を観察させると共に、他の観察者の両眼に同一画像を見せて二次元画像を観察させる。投映光学ユニットとしては、時分割方式、空間分割方式又は偏光分割方式がある。まず時分割の投映光学ユニットは、図１（Ａ）のように、表示器１４として右眼画像と左眼画像を順次表示する単一の表示デバイスの使用を前提とし、表示デバイスからの画像を拡大投射する投射レンズ１５、投射レンズ１５の近傍に設置され開口の位置と大きさを設定する開口設定器１６、投射レンズ１５の焦点位置に配置され立体観察領域に対する開口像の結像機能を備えたスクリーン１８で構成される。

【００１７】この投映光学ユニットに対し開口制御部２８は、表示器１４による右眼画像と左眼画像の切替表示に同期して開口設定器１６の右眼開口と左眼開口の位置を切り替える。空間分割方式の投映光学ユニットは、表示器１４として右眼画像と左眼画像に対応して一対の表示デバイスを前提とし、一対の表示デバイスからの画像を個別に拡大投射する一対の投射レンズ、一対の投射レンズの近傍に設置され開口の位置と大きさを設定する一対の開口設定器、及び一対の投射レンズの焦点位置に配置され立体観察領域に対する開口像の結像機能を備えたスクリーンで構成される。

【００１８】この場合、開口制御部２８は、一対に表示デバイスに対する右眼画像と左眼画像を並列表示に同期して、一対の開口設定器に右眼開口と左眼開口を同時設定する。偏光分割方式の投映光学系は、同じく表示器１４として右眼画像と左眼画像に対応した一対の表示デバイスを前提とし、光源からの光を異なる偏光面をもつ２つの光に分離して一対の表示デバイスに入射する分離用偏光ビームスプリッタ、一対の表示デバイスからの偏光

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面の異なる画像光を合成する合成用偏光ビームスプリッタ、合成用偏光ビームスプリッタからの画像光を拡大投射する投射レンズ，投射レンズの近傍に設置され入射光の偏光面の回転の有無により偏光面の異なる画像光を選択的に透過する開口位置を設定する偏光制御型の開口設定器、及び投射レンズの焦点位置に配置され立体観察領域に対する開口像の結像機能を備えたスクリーンで構成される。

【００１９】この場合、開口制御部２８は、一対の表示デバイスに対する右眼画像と左眼画像を並列表示に同期して、偏光制御デバイスの右眼開口と左眼開口の位置の各々に対応する画像光が透過するように偏光制御する。時分割および空間分割の投映光学ユニットにおける開口設定器１６としては，細分化された液晶セグメントの電圧制御により透過位置を任意に設定する液晶デバイスを使用する。

【００２０】偏光分割の投映光学ユニットにおける偏光制御型の開口設定器は、細分化された液晶セグメントに対する駆動電圧の印加の有無により入射光の偏光面の回転を制御する液晶デバイス（マトリックスｱｸｾﾙ）と、液晶デバイスから出力された特定偏光面をもつ画像光のみを透過する偏光板で構成する。投映光学ユニットは、投射レンズ１６の口径を拡大する虚像生成部材，例えば凹面ミラーを備える。

【００２１】開口制御部２８は、開口設定器１６の透過位置を水平方向で変化させることにより、開口位置を左右に制御する。また投射レンズ１６を光軸方向に移動制御することにより、開口位置を前後に制御する。投射レンズ１６の焦点距離を変化させることにより、開口位置を前後に制御することもできる。また開口位置の前後の制御は、開口設定器１６を光軸方向に複数積層し、開口制御部２８は、複数の開口設定器１６の積層方向での透過位置を制御することにより、開口位置を前後に制御する。

【００２２】更に開口位置の前後の制御は、開口設定器を光軸に対し前後方向で斜めに配置すると共にスクリーンに光を上下方向に拡散させる拡散板を設ける。この場合、開口制御部２８は、斜めに配置した開口設定器の左右方向での透過位置の変化により開口位置を左右に制御し、且つ開口設定器の斜め上下方向の透過位置の変化により開口位置を前後に制御する。

【００２３】画像生成部２６は、観察者２２の検出位置から見た右眼画像と左眼画像の二次元画像データを、モデリングされた三次元画像データに基づいて生成する。また観察者２２の検出位置から見た右眼画像と左眼画像の二次元画像データを、物体を水平方向の異なる位置から見た二次元画像データの補間により生成することもできる。

【００２４】本発明の別の形態にあっては、複数の観察者に立体画像を観察させることもできる。この場合、複数の観察者の位置に応じた画像の個別投映と、同一画像の共通投映がある。まず複数観察者の個別投映は、位置検出部２４で複数の観察者を検出して画像生成部２６により複数の観察者の各々が見た右眼画像と左眼画像を生成し、表示器１４に複数の観察者毎に生成された右眼画像と左眼画像を順次表示し、開口制御部２８は、複数の観察者の検出位置に基づいて、各観察者の右眼画像を右眼を含む位置に投映すると共に、左眼画像を左眼を含む位置に投映するように投映光学ユニットの開口の位置と大きさを制御する。

【００２５】複数観察者の共通投映は、位置検出部２４で複数の観察者を検出するが、画像生成部２６は複数の観察者のいずれか一人が見た右眼画像と左眼画像を生成して表示器１４に右眼画像と左眼画像を表示し、開口制御部２８は、複数の観察者の検出位置に基づいて右眼画像を複数の観察者の右眼を含む位置に投映すると共に、左眼画像を複数の観察者の左眼を含む位置に投映するように投映光学ユニットの開口の位置と大きさを制御する。

【００２６】また本発明は、両眼視差により立体映像を認識させる画像表示方法であり、次の過程を備える。立体表示領域２０に存在する観察者２２の位置を検出する位置検出過程；検出位置の観察者２２が見た右眼画像と左眼画像を生成する画像生成過程；右眼画像と左眼画像を表示する画像表示過程；観察者の検出位置に基づいて投映光学系の開口の位置と大きさの制御により，右眼画像を観察者２２の右眼を含む位置に投映すると共に、左眼画像を観察者２２の左眼を含む位置に投映し、両眼視差により立体画像を観察させる三次元表示過程；投映光学系の開口位置と異なる別の開口設定により、右眼画像又は左眼画像のいずれかを観察者の検出位置とは異なる位置に投映して，他の観察者の眼に同一画像を見せて２次元画像を観察させる二次元表示過程；このような本発明の画像表示方法によれば、眼鏡なしで立体表示を見ることができ、観察者の移動により表示映像が変化する運動視差を実現することができ，さらに、立体観察者以外の人が内容を理解できるように二次元画像を鮮明に表示できる。

【００２７】

【発明の実施の形態】

＜目次＞

１．装置構成と表示機能
２．観察者の位置検出
３．右眼画像と左眼画像の生成
４．時分割による投映表示と開口制御
５．空間分割による投映表示と開口制御
６．傾向分割による投映表示と開口制御
７．複数観察者に対する投映開口制御

１．装置構成と表示機能

図２は本発明による画像表示装置の実施形態である。図

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２において、本発明の画像表示装置１０は、３Ｄ観察領域２０に対する投影光学ユニットとして光源ユニット１２、表示器１４、投射レンズユニット１５、開口設定器１６、結像機能を備えたスクリーン１８を備えている。３Ｄ観察領域２０に対しては観察者位置検出装置２４が設けられ、観察者２２の位置を検出している。

【００２８】観察者位置検出装置２４で検出された観察者２２の検出位置、具体的には観察者２２のの右眼及び左眼の位置検出情報は、画像生成装置２６に与えられている。画像生成装置２６は、検出された観察者２２の右眼と左眼の各位置から見た表示対象物の画像データを、それぞれ右眼画像データ及び左眼画像データとして生成する。

【００２９】画像生成装置２６の高速バス３４に対しては、開口制御装置２８、表示制御装置３０及び光源駆動装置３２が接続されている。ここで画像生成装置２６としては、モデリング及びレンダリングのグラフィック機能を備えた計算機装置を使用することができる。光源駆動装置３２は、装置の使用状態で光源ユニット１２の光源を点灯駆動し、画像投影のための光を発生する。表示制御装置３０は、画像生成装置２６で生成された観察者２２の検出位置に対応した右眼画像と左眼画像を表示器１４に表示する。表示器１４に対する右眼画像と左眼画像の表示方式には、時分割方式、空間分割方式及び偏光分割方式の３種類がある。

【００３０】時分割方式にあっては、表示器１４には単一の表示デバイスが使用される。これに対し空間分割方式及び偏光分割方式については、右眼画像と左眼画像のそれぞれにつき専用の表示デバイスが使用される。図２の実施形態にあっては、表示器１４としては単一の表示デバイスを使用していることから、時分割方式に対応することができる。

【００３１】開口制御装置２８は、観察者２２について検出した右眼と左眼の各検出位置に対応し、表示器１４に右眼画像を表示したタイミングで観察者２２の右眼を含む領域に画像を投影し、表示器１４に左眼画像を表示したタイミングで観察者２２の左眼を含む領域に画像を投影する投影光学系の開口位置の設定を行う。この表示器１４の右眼画像と左眼画像の切替表示に同期した開口制御装置２８による開口設定器１６の開口位置の設定制御により、観察者２２はスクリーン１８を介して右眼と左眼に異なった視差をもつ同じ物体の視差画像の投影を受けて観察することができ、両眼視差によって立体画像を認識することができる。

【００３２】更に本発明の立体表示装置１０にあっては、観察者位置検出装置２４で検出している観察者２２以外の他の観察者からは、表示器１４に時分割で切替表示している右眼画像または左眼画像のいずれか一方の二次元画像が観察できるように開口設定器１６における開口設定を行っている。図３は図２の画像表示装置によるスクリーン１８前面の観察領域である。画像表示装置１０のスクリーン１８の前方となる所定範囲に３Ｄ観察領域２０が設定され、この３Ｄ観察領域２０内に観察者の右眼３８と左眼４０が存在すると、それぞれ異なった視差の画像の投影を受けて立体画像を観察することができる。

【００３３】観察者は３Ｄ観察領域２０内であれば、どの位置においても立体表示を観察することができる。即ち、３Ｄ観察領域２０内に存在する観察者の位置を立体表示装置１０側でリアルタイムで検出しており、観察者の動きに応じて各移動位置から対象物体を見たときの右眼画像と左眼画像をリアルタイムで生成して、観察者の右眼３８と左眼４０に投射する。このため、３Ｄ観察領域２０内で観察者が移動すると、これに伴って運動視差をもった立体観察ができる。

【００３４】３Ｄ観察領域２０の外側の領域は、二次元画像を観察できる２Ｄ観察領域３６となる。このため３Ｄ観察領域２０で位置検出の対象となっている観察者以外の他の観察者が近くから同時に観察する場合には、２Ｄ観察領域３６に存在することになるため、右眼画像または左眼画像の投影による鮮明な二次元画像を観察することができる。

【００３５】図４は図２の画像表示装置１０における時分割処理による立体表示のフローチャートである。まずステップＳ１で、観察者位置検出装置２４により観察者２２の左右の眼の位置を検出し、次のステップＳ２において、画像生成装置２６が観察者の左右の眼の位置に基づいて左眼用画像と右眼用画像を生成し、表示制御装置３０のフレームバッファに転送する。

【００３６】表示制御装置３０は、ステップＳ３でまず左眼用画像を表示器１４に表示する。この左眼用画像の表示に同期して開口制御装置２８が、ステップＳ４で開口設定器１６に左眼用の開口位置を設定制御する。このため、観察者２２の左眼を含む縦長のスリット領域に表示器１４からの左眼用画像が投影される。次にステップＳ５で、表示制御装置３０は表示器１４に右眼用画像を表示し、この右眼用画像の表示に同期してステップＳ６で、開口制御装置２８が開口設定器１６に右眼用の開口位置の設定制御を行う。このため次の表示タイミングにあっては、観察者２２の右眼に表示器１４に表示した右眼用画像が投影される。

【００３７】このようなステップＳ１～Ｓ６からの処理を、ステップＳ７で装置の表示停止が行われるまで繰り返す。時分割による右眼画像と左眼画像の切替表示周期は、各画像当たりのチラツキ防止の表示周期として１／６０秒周期とすると、右眼用と左眼用の２枚の切替表示であることから半分の１／１２０秒周期、即ち１２０Ｈｚの切り替えを行えばよい。

２．観察者の位置検出

図５は図２の観察者位置検出装置２４の実施形態であ

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り、２台のＣＣＤカメラによる画像処理で観察者の眼の位置を検出するようにしたことを特徴とする。図５において、観察者位置検出装置２４は、２台のＣＣＤカメラ４２，４４を備えており、ＣＣＤカメラ４２，４４は図２の３Ｄ観察領域２０に対し、水平方向の所定間隔を隔てて装置側に設置されている。

【００３８】観察者位置演算部４６は、ＣＣＤカメラ４２，４４で撮影した観察者の左右の眼の位置を演算する。観察者位置情報発生部４８は、観察者位置演算部４６で演算した観察者位置の三次元座標情報（Ｘ，Ｙ，Ｚ）を、図２の画像生成装置２６、更には開口制御装置２８に転送する。図６は図５の観察者位置検出装置２４における演算内容の説明図である。図６（Ａ）は、観察者に対し所定距離離れた位置に設置している２台のカメラの撮像レンズ５２，５０とその撮像面５４，５６との関係の平面図である。図６（Ｂ）にカメラ側から見た正面図を、図６（Ｃ）に側面図を表わしている。

【００３９】この場合の位置検出原理は、２台のカメラで撮像された２枚の画像５８，６０に対し、観察者の眼３８，４０をパターンマッチングにより求め、入力画像上での位置情報を計算する。この位置情報は角度情報に置き換えることができるので，カメラ間の距離とカメラに対する２つの角度から三角測量の原理により眼の位置を割り出すことができる。

【００４０】更に詳細に説明すると、２台のカメラの中心にｚ軸を設定し，レンズ５０，５２上にそれぞれｘ軸とｙ軸を設定する。また２台のカメラはその光軸を平行とするように設置されている。更にレンズ５０，５２の間隔をＢ、カメラにより撮像される撮像面５４，５６上の画像を画像５８，６０、レンズ５２，５０から撮像面５４，５６までの距離をｄとする。

【００４１】この実施形態では，パターンマッチングにより得られた右眼３８と左眼４０の中間位置Ｐの座標（ｘ０，ｙ０，ｚ０）を演算する。まず図６（Ａ）の両眼の中心位置Ｐとカメラの撮像面５４，５６上の位置を結ぶ直線とレンズ５０，５２の光軸とのなす角度θ１，θ２，更に図６（Ｃ）の側面から見た結像面５６と両眼中心位置Ｐを結ぶ直線の光軸に対する角度αは、次式の位置情報に対する関係をもつ。

【００４２】

【数１】

$$\tan\theta 1 = \frac{\frac{B}{2} - x1}{d} = \frac{\frac{B}{2} + x0}{z0} \qquad (1)$$

$$\tan\theta 2 = \frac{X2 - \frac{B}{2}}{d} = \frac{\frac{B}{2} - x0}{z0} \qquad (2)$$

$$\tan\alpha = \frac{y1}{d} = \frac{y0}{zo} \qquad (3)$$

【００４３】そこで（１）式と（２）式を加算すると、次式の関係から、両眼中心位置Ｐの座標値ｚ０が算出される。

【００４４】

【数２】

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$$\frac{\frac{B}{2}-x1}{d}=\frac{x2-\frac{B}{2}}{d}=\frac{B}{z0}$$

$$\frac{x2-x1}{d}=\frac{B}{z0}$$

$$z0=\frac{B-d}{x2-x1} \qquad (4)$$

【００４５】この（４）式を（１）式に代入すると、次のようにして両眼中心位置Ｐの座標値ｘ０が算出される。

【００４６】
【数３】

$$\frac{\frac{B}{2}-x1}{d}=\frac{\frac{B}{2}+x0}{\frac{B\cdot d}{x2-x1}}=\frac{(\frac{B}{2}+x0)\ (X2-x1)}{B\cdot d}$$

$$x0=\frac{B\ \{B-(X2-x1)\}}{2\ (x2-x1)} \qquad (5)$$

【００４７】更に（４）式を（３）式に代入すると、両眼中心位置Ｐの座標値ｙ０が次のように算出される。

【００４８】
【数４】

$$y0=\frac{y1}{d}\cdot z0=\frac{B\cdot y1}{x2-x1} \qquad (6)$$

【００４９】このような（４）（５）（６）式をパターンマッチングされた右眼３８及び左眼４０の各々について適用することで、右眼位置Ｐｒの座標（ｘｒ，ｙｒ，ｚｒ）と左眼位置Ｐｌの座標（ｘｌ，ｙｌ，ｚｌ）を求めることができる。実際の空間における観察者位置の右眼位置Ｐｒ（ｘｒ，ｙｒ，ｚｒ）と左眼位置Ｐｌ（ｘｌ，ｙｌ，ｚｌ）については、立体表示を行うコンピュータグラフィックスの座標空間との間でスケール変換を行い、スケール変換された右眼及び左眼の座標位置から見た表示対象物について画像生成することで、観察者の眼の検出位置から見た右眼画像及び左眼画像を生成することが可能となる。

【００５０】図７は図２で使用する観察者位置検出装置２４の他の実施形態であり、磁気センサを用いたことを特徴とする。図７の観察者位置検出装置２４にあっては、装置側に水平方向の所定間隔を隔てて一対の磁気センサ３４２，３４４が設置されている。磁気センサ３４２，３４４に対しては、３Ｄ観察領域に存在する観察者２２側にマグネット３５０を装着している。

【００５１】マグネット３５０は、観察者２２の両眼の中心となる例えば額などにバンドで装着してもよいし、観察者２２の上着の胸中心位置にピン等により装着してもよい。磁気センサ３４２，３４４のそれぞれは、観察者２２が装着しているマグネット３５０からの磁界の強さを検出する。磁界の強さは通常距離の３乗に反比例して減少することから、磁気センサ３４２，３４４の検出磁界の強さからマグネット３５０までの距離、即ち観察者２２の両眼の中心位置までの距離Ｒ１，Ｒ２を割り出すことができる。このようにセンサからマグネット３５０までの距離Ｒ１，Ｒ２が分かれば、磁気センサ３４２，３４４を中心とした半径Ｒ１，Ｒ２の円弧の交点としてマグネット３５０の位置が決まり、左右方向（ｘ軸方向）と前後方向（ｚ軸方向）の位置を検出することができる。

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【００５２】ここで、上下方向（ｙ軸方向）については、本発明の立体表示にあっては、観察者が上下方向に顔を動かしても同じ画像投射を行うことから、特に検出は必要ない。即ち、磁気センサ３４２，３４４による観察者位置検出にあっては、上下方向となる座標値ｙ０は固定値を使用し、左右方向の座標値ｘ０と前後方向の座標値ｚ０を演算により観察者位置演算部３４６で求める。

【００５３】更に観察者２２の左右の眼の位置については、統計的に人の眼の間隔が３２．５ｍｍ～９７．５ｍｍの範囲にあることから、例えば眼の間隔Ｗ＝６０ｍｍに設定し、検出したマグネット３５０で決まる両眼中心位置の座標値ｘ０にＷ／２を加減算することで、各眼の座標値ｘｒ，ｘｌを求めればよい。この場合、座標値ｚｒ，ｚｌは、マグネット３５０による両眼中心位置の座標値ｚを使用すればよい。

【００５４】図８は本発明で用いる観察者位置検出装置２４の他の実施形態であり、超音波センサを用いたことを特徴とする。この観察者位置検出装置２４にあっては、装置側の前面に水平方向の所定間隔を隔てて一対の超音波センサ４４２，４４４を設置している。超音波センサ４４２，４４４は、一定周期で超音波パルスを３Ｄ観察領域に発射している。

【００５５】この超音波パルスは観察者２２で反射され、超音波センサ４４２，４４４側で受信される。したがって超音波センサ４４２，４４４による超音波の観察者２２に対する伝播時間から、観察者２２に対する各センサからの距離Ｒ１，Ｒ２を求めることができ、図８の磁気センサの場合と同様にして観察者２２の位置情報を観察者位置演算部４４６で演算し、観察者位置情報発生部４４８より画像生成側に送ることができる。

【００５６】尚，本発明で用いる観察者位置の検出は、上記の実施形態に限定されず、適宜のセンサを用いた位置検出装置を使用することができる。

３．右眼画像と左眼画像の生成

図９は観察者位置検出情報に基づいて右眼画像と左眼画像を生成する図２の画像生成装置２６の実施形態であり、この実施形態は、予め記録されたモデリングデータから観察者位置情報に基づいて右眼画像と左眼画像を生成するようにしたことを特徴とする。

【００５７】図９において、画像生成装置２６は、モデリングデータ格納部６２とレンダリング処理部６４で構成される。また表示制御装置３０は、右眼画像と左眼画像の時分割表示を例にとっていることから、単一の表示器１４に対し右眼画像フレームバッファ６６、左眼画像フレームバッファ６８、１／１２０秒周期で画像切替えを行うデータ切替部７０、及び表示駆動部７２を有する。表示駆動部７２としては、表示器１４として例えば液晶デバイスを用いた場合には、液晶ドライバが使用される。

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【００５８】画像生成装置２６のモデリングデータ格納部６２には、コンピュータグラフィックスの手法により作成されたモデリングデータが予め記録されている。モデリングデータは対象物体をいくつかのポリゴンデータの集合として生成している。レンダリング処理部６４に観察者位置情報が与えられると、この観察位置を視点位置としてモデリングデータ格納部６２に格納された対象物体を形成する各ポリゴンが視点位置からどのように見えるかを計算する。

【００５９】即ち、位置、大きさ、色、テクスチャ等を計算し、右眼については右眼画像フレームバッファ６６に右眼画像データとして展開し、左眼画像については左眼画像フレームバッファ６８に左眼画像データとして展開する。表示制御装置３０は、右眼画像フレームバッファ６６と左眼画像フレームバッファ６８に画像生成装置２６より展開された右眼画像と左眼画像の各データを、例えば１／１２０秒の切替周期によるデータ切替部７０の切替動作で順次読み出し、表示駆動部７２により表示器１４に切替表示する。この結果，データ切替部７０からは図１０のように、右眼画像データ７４と左眼画像データ７６が交互に出力され、右眼画像と左眼画像の時分割による切替表示が行われる。

【００６０】図１１は図２の画像生成装置２６の他の実施形態であり、この実施形態はカメラで異なる位置から撮像した２枚の画像情報に基づいて観察者位置の検出情報を視点位置とした右眼画像と左眼画像を補間処理により生成するようにしたことを特徴とする。図１１において、画像生成装置２６はカメラ画像データ格納部７３と補間画像生成部７５で構成される。カメラ画像データ格納部７３には、水平方向に所定距離を介して設置された少なくとも２台のカメラによる対象物体の撮影画像が格納されている。補間画像作成部７５は、観察者位置情報に基づいてカメラ画像データ格納部７３に格納されている一対の撮影画像の補間処理により観察者位置から見た右眼画像と左眼画像を生成して、表示制御装置３０側の右眼画像フレームバッファ６６，左眼画像フレームバッファ６８に格納する。表示制御装置３０は、図９の実施形態と同じ時分割表示制御を行う。

【００６１】ここで図１１の補間画像生成部７５による生成処理を図１２～図１５を参照して説明すると次のようになる。まず補間画像生成部７５に対し，観察者位置情報として右眼位置及び左眼位置の各視点情報が与えられたならば、与えられた視点位置に近いカメラ画像データ格納部７３に格納されている２枚の画像から補間画像を生成する。

【００６２】いま図１２のようにカメラ４２，４４を光軸を平行に水平配置していたとすると、２つのカメラ４２，４４から見た物体７８の画像は、図１３の画像８０－１，８０－２のようになる。画像８０－１，８０－２における水平ライン８２－１，８２－２のライン画素の

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関係を図14（A）（B）に示す。画像80－1の水平ライン82－1には、図14（A）のように、物体78の表面78－1，78－2の各々が幅a1，b1の幅をもって映し出されている。同様に画像80－2の水平ライン82－2には，図15（B）のように，物体78の表面78－1，78－2が幅a2，b2をもって映し出されている。

【0063】ここで図13の画像80－1，80－2に基づく補間画像の生成は、レンズ50と52の間の新たな視点を設定して見た画像の生成であり、物体の表面78－1，78－2は視点位置に応じて移動することになる。したがって，レンズ50、52の間に新しい視点を設定したならば，レンズ50から視点までの距離をα、レンズ52から視点位置Pまでの距離をβとすると、新視点における物体78の表面78－1，78－2の位置と幅は、レンズ50，52間の分割比α：βに基づいて決めることができる。

【0064】この新視点Pでのライン上の物体の表面78－1，78－2を求める演算を全水平ラインに対し行うことで、1画面分の補間画面を得ることができる。水平ラインの補間画像の生成手順を図15（A）～（E）につて具体的に説明すると次のようになる。

（I）画像80－1の水平ライン82－1上での物体の面78－1，78－2の距離a1，b1を求める。

【0065】（II）画像80－2の水平ライン82－2上での物体の面78－1，78－2の距離a2，b2を求める。

（III）前記（I）（II）における面78－1の距離a1，a2の重心間の距離を求め，この重心間距離を補間画像を生成するための視点位置の分割比β：αで分割した位置を重心位置とし、更に補間距離a3を

$a3 = a1 \times \{\beta/(\alpha+\beta)\} + a2 \times \{\beta/(\alpha+\beta)\}$

として求める。

【0066】（IV）前記（III）と同様にして，（I）と（II）における物体の面78－2の距離b1，b2の各重心間の距離を求め、この重心間距離を補間画像を生成する視点で決まる分割比β：αで分割した位置を補間画像の重心位置とし，更に補間部分の距離b3を

$b3 = b1 \times \{\beta/(\alpha+\beta)\} + b2 \times \{\beta/(\alpha+\beta)\}$

として求める。

【0067】（V）前記（III）（IV）で得た補間生成物体の面78－1，78－2を合成し、1水平ライン分の補間画像を生成する。このような水平方向の補間画像の生成処理を全ての水平ラインについて行うことで、図15の補間画像84を得ることができる。本発明にあっては、観察者位置情報として右眼位置及び左眼位置の2つが得られることから、それぞれについて同様な補間画像の生成処理を行うことで、観察者検出位置に基づいた右眼画像と左眼画像の補間生成を行うことができる。

4．時分割による投影表示と開口制御

図16は図2の画像表示装置における開口制御装置28と開口設定器16のブロック図である。開口制御装置28は、開口位置演算部88と表示コントローラ90を備える。開口設定器16は、この実施形態にあっては、マトリクス液晶シャッター92を使用している。

【0068】具体的には透過型の液晶表示デバイスを使用することができ、二次元配置された微細な表示セグメントを構成する液晶セルをドライバ92，96によるマトリクス電圧の制御で駆動して，透過状態の設定による開口制御が任意にできる。開口制御装置28に設けた開口位置演算部88は、観察者位置検出情報で設定される視点位置に対応した投影光学ユニットにおける開口位置と大きさを演算し、表示コントローラ90を介してマトリクス液晶シャッタ92の対応開口部を透過状態に制御することで開口設定を行う。

【0069】図17は時分割による立体表示を行う図2の立体表示装置10に設ける投影光学ユニットの実施形態である。まず光源ユニットは、光源98とリフレクタ100で構成される。光源98としては、例えばメタルハルライトランプ等の白色光源を使用する。光源98からの光はレンズ102で集光され、フレネルレンズ104により平行光に変換され、ミラー106で反射されて表示器14に入射する。

【0070】表示器14に対しては、時分割方式により右眼画像と左眼画像が順次表示される。表示器14に続いては、開口設定器として機能するマトリクス液晶シャッタ92が設けられる。図17は表示器14に左眼画像を表示したタイミングであり、このためマトリクス液晶シャッタ92には左眼画像に対応した上下方向の帯状の透過領域の設定による開口128が設定されている。

【0071】マトリクス液晶シャッタ92に続いては、投射レンズユニット15として、この実施形態にあっては投射レンズ110を設けている。投射レンズ110は、スクリーンとして機能する凸フレネルレンズ116の位置に表示器14の開口128を透過した画像を結像する。投射レンズ110に続いては、凹面ミラー112が設けられる。凹面ミラー112は、投射レンズ110の口径には限界があることから、投射レンズ110の口径をスクリーンとして機能する凸フレネルレンズ116のサイズに適合するように拡大する虚像生成素子として機能する。凹面ミラー112で拡大された画像光は背面ミラー114で反射され、スクリーンとして設置された凸フレネルレンズ116に画像光を結像するように入射する。

【0072】凸フレネルレンズ116は、マリトクス液晶シャッタ92のスリット像を3D観察領域20の仮想的な結像面に結像する凸レンズとしての機能をもつ。即ち、凸フレネルレンズ116は、この状態でマトリクス

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液晶シャッタ９２に設定された開口１２８の拡大像となるスリット像１１８を３Ｄ観察領域２０に結像し、これが左眼観察領域２０－１を形成している。

【００７３】スリット像１１８の結像による左眼観察領域２０－１は、観察者の左眼４０の位置の検出結果に基づいた開口１２８の設定により行われている。このため観察者は左眼４０によってのみ、このとき表示器１４に表示されている左眼画像を観察することができ、右眼３８の前には表示器１４からの映像光の投射が行われていないため、右眼３８側で表示器１４の左眼画像を見ることができない。

【００７４】図１８は図１７の投影光学ユニットにおいて、表示器１４に右眼画像を表示し、これに同期してマトリクス液晶シャッタ９２に観察者の右眼３８の検出位置に対応する開口１３０を設定した状態である。この場合、凸フレネルレンズ１１６は、マトリクス液晶シャッタ９２の透過領域として設定した開口１３０のスリット像１２０を３Ｄ観察領域２０に結像する。

【００７５】これが右眼観察領域２０－２となり、同時に投射レンズ１１０によって開口１３０を介して表示器１４に表示した右眼画像の画像光が投影されているため、観察者は右眼３８によってのみ表示器１４の右眼画像を観察することができる。図１７の左眼画像の投影表示と図１８の右眼画像の投影表示は、時分割により例えば１／１２０秒周期で繰り返されるため、観察者は左右の眼３８，４０で同時に異なった各視点位置から見た視差画像を見ることになり、両眼視差により立体画像を観察することができる。

【００７６】図１９は、図１７，図１８の右眼画像と左眼画像の表示タイミングに対応した投影光学ユニットの等化光学系である。図２０（Ａ）は，図１７の左眼用画像表示に対応した等化光学系であり、表示器１４には左眼画像が表示されており、これに同期してマトリクス液晶シャッタ９２には開口１２８を設定するための透過領域の駆動設定が行われている。

【００７７】ここで投影レンズユニット１５は、マトリクス液晶シャッタ９２を挟む形で一対の投影レンズ１０９，１１０を配置している。またスクリーン位置には凸フレネルレンズの等化光学系として凸レンズ１１７を配置している。表示器１４からの映像光は、マトリクス液晶シャッタ９２に設定した開口１２８を通過し、スクリーン位置となる凸レンズ１１７に結像する。凸レンズ１１７は、マトリクス液晶シャッタ９２の開口１２８の観察領域に設定した視域１１５の面にスリット像１１８として結像する。このとき開口１２８は、観察者の左眼４０の検出位置に基づいて設定されている。

【００７８】このため、スリット像１１８を左眼４０の前に位置するように開口１２８の設定が行われる。したがって観察者は，左眼４０のみにより表示器１４の左眼画像を観察することができる。図１９（Ｂ）は、図１８の右眼用画像表示状態の投影光学ユニットに対応した等化光学系の表示状態である。この場合、表示器１４には右眼画像が表示されており、これに同期してマトリクス液晶シャッタ９２には開口１３０が透過領域の駆動設定により設定されている。

【００７９】このため，観察領域の視域１１５にはマトリクス液晶シャッタ９２の開口１３０の位置に対応してスリット像１２０が結像される。開口１３０は、観察者の右眼３８の検出位置に対応して設定されているため、観察者の右眼３８の前に開口１３０のスリット像１２０が結像されることになる。このため観察者は、右眼３８のみによって表示器１４の右眼画像を観察することができる。

【００８０】このような図１９（Ａ）（Ｂ）の右眼画像と左眼画像が時分割で高速表示されるため、観察者は右眼３８と左眼４０で同時に視点位置の異なる画像を観察することとなり、両眼視差により立体画像を観察することができる。また観察者は３Ｄ表示領域２０の範囲内で眼の位置を移動すると、観察者の眼の位置がリアルタイムで検出され，マトリクス液晶シャッタ９２の開口１２８，１３０の設定位置が移動し、常に観察者の右眼３８，左眼４０の各々の直前にスリット像１１８，１２０が結像され、更に表示器１４には観察者の眼の位置の移動に応じた見え方をする右眼画像及び左眼画像の時分割表示が行われる。このため，表示物体に対し運動視差をもった立体映像の観察が実現できる。

【００８１】図１９（Ａ）（Ｂ）に示した本発明の立体表示における等化光学系は，図２０のような２台のプロジェクタで投影表示したと同等の立体表示機能を実現していることが分かる。図２０は，表示器１４－１と投写レンズ１１０－１を備えた右眼用のプロジェクタと、表示器１４－２と投写レンズ１１０－２を備えた左眼用のプロジェクタを設け，各プロジェクタを観察者の右眼３８と左眼４０の検出位置に応じて左右方向及び前後方向に移動する。

【００８２】このため、常に観察者の右眼３８の位置に右眼画像を投影し、左眼４０の位置に左眼画像を投影して、立体表示を実現することができる。このような２台のプロジェクタを用いた機能を、本発明にあっては、図１９のように固定光学系を使用して簡単に実現することができる。図２１は、本発明の投影光学ユニットにおける観察者の眼の検出位置に対応したマトリクス液晶シャッタ９２における開口の設定制御の説明図である。図２１は、観察者の右眼３８の検出位置に対応した開口１３０をマトリクス液晶シャッタ９２に設定した場合を例にとっている。

【００８３】本発明の投影光学ユニットによれば、マトリクス液晶シャッタ９２の開口１３０は観察領域に設定した仮想平面である視域１１５上に図示のようにスリット像１２０を結像する。このスリット像１２０の幅は、

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開口１３０の拡大倍率Ｋで決まる。即ち、スリット９２の横幅を１、観察領域の視域ｋ１１５の幅をＫとすると、開口１３０は視域１１５においてＫ倍の幅をもつスリット像１２０として結像する。

【００８４】このスリット像１２０の幅は，例えば右眼３８に画像光を投影し、左眼４０には画像光を投影しない必要があり、観察者の左右方向の若干の眼の動きによる立体像の視認を確実にするため、ある程度の幅をもつ必要がある。図２２はスリット像１２０の横幅の一例である。まず観察者の右眼３８と左眼４０の間隔Ｗは、統計的にＷ＝３２．５ｍｍ～９７．５ｍｍであることが分かっている。したがって、スリット像１２の幅は、右眼３８の中心から左右にＷ／２の幅をもった右眼観察領域２０－２とする。同様にして左眼４０についても、左眼の中心から左右にＷ／２の幅をもった左眼観察領域２０－１を破線のように設定する。

【００８５】このように左右の眼に対するスリット像の幅をもたせることで，観察者は眼を±Ｗ／２の範囲で動かしても、この範囲内では眼の位置検出を必要とすることなく立体像を観察することができる。また本発明の観察者位置検出装置の検出分解能としてＷ／２を満足できればよく、これによって観察者位置検出のマージンを高めることができる。もちろん、スリット像の幅はＷ／２に限定されず、例えば検出精度を高めることにより眼の幅程度の狭い範囲とするように開口を設定としてもよい。

【００８６】図２３は、時分割立体表示を行う本発明の投影光学ユニットにおける他の開口設定による左眼画像の表示状態である。この実施形態にあっては、３Ｄ観察領域２０における観察者の両目中心位置１２６の左側の全領域を左眼観察領域２０－１とするように、マトリクス液晶シャッタ９２に開口１２８を設定している。図２４は図２３の実施形態について右眼画像の表示状態に切り替えたタイミングであり、この場合には３Ｄ観察領域の観察者における両眼中心位置１２６の右側全域を右眼観察領域２０－２とするように、マトリクス液晶シャッタ９２に開口１３０を設定している。

【００８７】図２５は図２３及び図２４に対応する等化光学系である。即ち、図２５（Ａ）は左眼用画像表示状態であり、３Ｄ観察領域２０の検出対象となる観察者の両眼中心位置１２６の検出情報に基づき、マトリクス液晶シャッタ９２の対応点１２７のスクリーン側に向かって左側の全領域を透過状態として開口１２８を設定している。

【００８８】このため３Ｄ観察領域２０のみならず、その左側の２Ｄ観察領域３６においても、左眼用画像光１２０を受けることによって表示器１４の左眼画像を観察することができる。図２５（Ｂ）は，図２４の右眼用画像表示状態に対応した等化光学系であり、立体表示の観察対象物となる両眼中心位置１２６に対応したマトリクス液晶シャッタ９２の対応点１２７のスクリーンに向かって右側全域を透過状態として開口１３０を設定している。

【００８９】このような開口１３０の設定により、両眼中心位置１２６の右側の全領域に右眼用画像光１２２が投影され、３Ｄ観察領域２０を超えた右側においても右眼用画像光１２２の投影による右眼画像を観察することができる。この図２５（Ａ）（Ｂ）のような右眼画像の開口１２８及び左眼画像の開口１３０の設定により、３Ｄ観察領域２０に位置する観察者位置の検出対象となる観察者は、左右の眼により同時に右眼用と左眼用の画像を観察することで、両眼視差により立体像を観察できる。

【００９０】また立体表示の観察を行っている観察者以外の他の観察者については、例えば３Ｄ観察領域２０の左側において観察すると、図２５（Ａ）のように開口１２８の設定による表示器１４からの左眼用画像光１２０のみを観察することとなり、左眼用画像による二次元画像を観察することができる。また３Ｄ観察領域２０の右側で他の観察者が観察している場合には、図２５（Ｂ）のように、右眼用画像光１２２の投影を受け、表示器１４に表示されている右眼画像による二次元画像のみを観察することができる。即ち、３Ｄ観察領域２０に存在する本発明の観察者位置検出の対象となっている観察者以外の他の観察者については、同じスクリーンを見ることで右眼画像または左眼画像による二次元画像を鮮明に観察することができる。

【００９１】図２６、２７は立体画像と二次元画像を同時観察する投影光学系による他の表示状態である。図２６の左眼画像の表示状態にあっては，観察者の左眼４０に対応した位置に開口１２８を設定して左眼観察領域２０－１を狭い幅で設定し、３Ｄ観察領域の観察者の左眼４０のみによって表示器１４の左眼画像を観察できるようにする。

【００９２】一方、図２７の右眼画像の表示については、図２６の左眼観察領域２０－１を除く全領域を右眼観察領域２０－２とするようにマトリクス液晶シャッタ９２に開口１３０を設定している。これによって３Ｄ観察領域で観察者位置の検出対象となっている立体観察ができる観察者以外の他の観察者については，いずれの位置についても図２７の表示状態による右眼画像による二次元画像のみを観察できるようにしている。

【００９３】図２８は図２６及び図２７の投影光学ユニットにおける等化光学系であり、図２８（Ａ）は左眼用画像表示状態、図２８（Ｂ）は右眼用画像表示状態である。即ち、図２８（Ａ）の左眼用画像表示状態については、開口１２８の設定により３Ｄ観察領域２０の観察者の左眼の位置にスリット像１１８を投影している。これに対し図２８（Ｂ）の右眼用画像表示状態にあっては、左眼用のスリット像１１８を除く全領域に右眼用のスリ

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ット像１２０，１２０が結像されるように、マトリクス液晶シャッタ９２の透過状態の設定により開口１３０を設定している。

【００９４】図２９は時分割により立体表示において、観察者の前後方向の移動に追従した開口設定制御を可能とする本発明の投影光学ユニットの実施形態である。この投影光学ユニットにあっては、投射レンズ１１０の手前に設ける開口設定器として、図１６で開口設定器として使用したマトリクス液晶シャッタ９２を光軸方向に複数積層した積層シャッタ１３４を使用している。

【００９５】積層シャッタ１３４の開口設定は、観察者の前後方向の位置、即ち座標値ｚの検出位置に基づき、対応する特定のマトリクス液晶シャッタが選択されて、そのときの左右方向の観察者検出位置に対応した開口設定が行われる。それ以外の他の複数のマトリクス液晶シャッタについては、全領域が透過状態に制御されている。

【００９６】図３０は図２９の等化光学系であり、この等化光学系にあっては、積層シャッタ１３４として例えば５枚のマトリクス液晶シャッタ９２－１～９２－５を積層している。このような積層シャッタ１３４のマトリクス液晶シャッタ９２－１～９２－５の前後方向の位置に対応して、３Ｄ観察領域にはスリット結像面１３２－１～１３２－５が前後方向に設定される。

【００９７】スクリーン位置に設けた凸レンズ１１７によるマトリクス液晶シャッタ９２－１～９２－５とスリット結像面１３２－１～１３２－５の間には、前後方向の開口位置の変化に対し常に結像距離を同一とするようにスリット結像面が決まる。即ち、一番手前のマトリクス液晶シャッタ９２－１に対応してスリット結像面１３２－１が存在し、一番先のマトリクス液晶シャッタ９２－５に対応して最も奥のスリット結像面１３２－５が存在する。

【００９８】このため、３Ｄ観察領域２０に存在する観察者の前後方向の位置即ち座標値ｚに基づいて、積層シャッタ１３４の中のマトリクス液晶シャッタ９２－１～９２－５のいずれか１つ例えばマトリクス液晶シャッタ９２－３を選択し、同じく左右方向の観察者位置検出に基づく右眼または左眼の検出位置に対応して左右方向の位置に開口設定することで、スリット結像面１３２－３に開口のスリット像を結像して、観察者に両眼視差による立体画像の観察を行わせることができる。

【００９９】この観察者の奥行方向の検出位置に応じた開口設定制御については、図１９，図２５、更には図２８のいずれかの右眼用及び左眼用画像表示の時分割処理を適用することができる。図２５または図２８の表示処理を適用した場合には、立体観察領域２０以外の２Ｄ観察領域３６においては二次元画像を観察することができる。

【０１００】図３１は観察者の前後方向の位置検出に応じた開口設定の実現する投影光学ユニットの他の実施形態であり、この実施形態にあっては、投射レンズに可動レンズを設けて焦点距離を変えることで観察者の奥行方向の動きに応じた立体表示を可能とする。図３１における投射レンズユニット１５としては、固定投射レンズ１８０，１８４の間に、アクチュエータ１８６により光軸方向に移動自在な可動レンズ１８２を設けている。この可動レンズ１８２をアクチュエータ１８６により光軸方向に移動することで、３Ｄ観察領域においてスリット結像面１３２－１～１３２－ｎのような前後方向の設定を行うことができる。図３２は図３１の焦点距離を可変できる投射レンズユニット１５の実施形態であり、リニアモータ構造をもつＶＣＭをアクチュエータに用いたことを特徴とする。図３２において、レンズ収納筒１８８の開口部側には固定レンズ１８０，１８４が装着され、その間に可動レンズ１８２を光軸方向に摺動自在に設み込んでいる。

【０１０１】可動レンズ１８２はアーム１９２に装着され、アーム１９２は軸方向に開口したガイドスリット１９０を介してアクチュエータ１８６のＶＣＭコイル１９４に装着されている。ＶＣＭコイル１９４は、光軸方向に固定設置したヨーク１９６に対し摺動自在に装着されている。このため、ＶＣＭコイル１９４に通電することによりヨーク１９６との間に実回路を形成し、ＶＣＭコイル９４を前後方向に移動でき、これによって可動レンズ１８２をレンズ収納筒１８８内で光軸方向に移動して焦点距離を変化させることができる。

【０１０２】図３２は図３１の投射レンズユニット１５の他の実施形態である。この実施形態にあっては、図３３（Ａ）のように、固定レンズ１８０，１８４、及び可動レンズ１８２を備えたレンズ収納筒１８８を外筒１９８の中に収めている。可動レンズ１８２には例えば半径方向の対象位置に、例えばピン２４２，２４６を固定しており、ピン２４２，２４６はレンズ収納筒１８８の光軸方向に形成したスリット２４０，２４４を介し、外側に位置する外筒１９８のスリットに嵌め込まれている。

【０１０３】外筒１９８のスリットは、図３３（Ｂ）のように、光軸に対し斜めに形成されたスリット２６０となっている。更に外筒１９８の一端の外周にはアウターナルギア２４８が形成されており、アウターナルギア２４８は中間ギア２５０を介してモータ２５４のドライブギア２５２に噛み合っている。モータ２５４によりドライブギア２５２を回転すると、中間ギア２５０を介してアウターナルギア２４８に回転が伝達され、外筒１９８が回転する。外筒１９８の中に収納されたレンズ収納筒１８８は、軸方向には移動するが回転方向の動きは規制されている。

【０１０４】このため外筒１９８の回転に伴い、可動レンズ１８２に固定している例えば図３３（Ｂ）のピン２４６がスリット２６０の回転による動きでスリット２４

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4に沿って軸方向に移動し、可動レンズ182を移動する。このような可動レンズ182の光軸方向の移動により、焦点距離を変えることができる。図34は観察者の前後方向の位置検出による開口設定制御の他の実施形態であり、実際の投影光学ユニットの等化光学系で示しており、また、この等化光学系は側面から見た状態である。この実施形態にあっては、投射レンズ109と110の間にマトリクス液晶シャッタ92を光軸に対し前後方向に斜めとなるように配置したことを特徴とする。

【0105】図35は図34のマトリクス液晶シャッタ92の正面図であり、下側から水平ストライプ開口領域135－1～135－nに開口設定領域を分けている。この水平ストライプ開口領域は、スクリーン位置の凸レンズ117に対し光軸方向の距離が異なっている。このため観察領域に、光軸方向に異なった位置をもつスリット結像領域131－1～131－nを設定することになる。

【0106】図36は実際の投影光学ユニットにおけるスクリーン側の説明図であり、図34の凸レンズ117を実現する凸フレネルレンズ116の結像位置に光軸方向に対し前後方向の斜めに並んだスリット像結像領域136－1～136－nが形成される。しかしながら、図36のスリット像結像領域136－1～136－nのそれぞれは、垂直方向については極めて狭い範囲であり、この範囲を外れると立体観察ができなくなる。

【0107】そこで実際の装置にあっては、図78のように、凸レンズ117に近接して垂直拡散板140を設け、垂直方向にスリット像結像領域136－1～136－nを拡大して有効領域144を形成する。図38は図37の実際の投影光学ユニットの凸フレネルレンズ116側であり、凸フレネルレンズ116に合わせて垂直拡散板140を設けている。

【0108】この垂直拡散板140を設けたことで、図36の斜めの狭い各スリット像設定領域136－1～136－nは、垂直方向に拡大された垂直拡大領域142－1～142－nに変換でき、観察者の前後方向の移動に対し、垂直方向の必要領域を有効領域とした立体観察を実現することができる。

5．空間分割による投影開口制御

図39は観察者位置検出に基づいて生成した右眼画像と左眼画像を空間分割により3D観察領域に投射するための、図2の画像表示装置における画像生成装置26及び表示制御装置28のブロック図である。空間分割の画像投影にあっては、表示器14として左眼用表示器14－1と右眼用表示器14－2の2つを使用する。

【0109】この左眼用及び右眼用表示器14－1，14－2としては、透過型の液晶表示デバイスが使用される。左眼用及び右眼用表示器14－1，14－2に対応して、表示制御装置28には表示駆動部72－1，72－2が設けられている。画像生成装置26は、図よの時分割の場合と同じであり、モデリングデータ格納部62とレンダリング処理部64で構成され、観察者位置情報に基づいてレンリング処理部64でモデリングデータに基づいた右眼画像と左眼画像を生成して、表示制御装置28の右眼画像フレームバッファ66及び左眼画像フレームバッファ68に書き込む。尚、画像生成装置26としては、図11のカメラ画像データ格納部73及び補間画像生成部75を用いたものであってもよい。

【0110】図40は図39の表示制御装置28による右眼画像データと左眼画像データの読み出し動作であり、2つの表示駆動部72－1，72－2が対応する右眼画像フレームバッファ66及び左眼画像フレームバッファ68のそれぞれから並列的に右眼用画像データ74と左眼用画像データ76を読み出し、同時に右眼用表示部14－2，左眼用表示器14－1に対応する画像を表示する。

【0111】図41は空間分割による右眼画像と左眼画像の投影表示を行うための投影光学ユニットの実施形態である。図41において、左眼用表示器14－1と右眼用表示器14－2が側別に配置され、それぞれの表示器14－1，14－2に対応して、開口設定を行うマリトクス液晶シャッタ92－1，92－2と投射レンズ110－1，110－2を設置している。

【0112】投射レンズに続いて設けられた凹面ミラー112、背面ミラー114は共通光学系となり、スクリーン位置に3D観察領域20に結像機能をもつ凸フレネルレンズ116を設置している。一方、光源ユニット側は省略しているが、図17の空間分割の実施形態と同様、光源98、リフレクタ100、レンズ102及びフレネルレンズ104が設けられ、ミラー106の代わりにハーフミラーが使用され、ハーフミラーの反射光を図41の右眼用表示器14－2に入射すると共に、ハーフミラーを透過した光を更にミラーで反射して、図41の左眼用表示器14－1に入射するようにしている。

【0113】このような空間分割による投影光学ユニットにあっては、右眼用表示器14－2と左眼用表示器14－1のそれぞれに並列的に対応する右眼画像と左眼画像の表示を行い、これに同期してマトリクス液晶シャッタ92－2，92－1のそれぞれに開口130，128の設定を行っている。この場合の開口設定は、図26，図27の空間分割の場合と同じである。

【0114】即ち、3D観察領域20に存在する観察者の左眼40の検出位置に対応する幅の小さいスリット状の開口128を右眼用表示器14－2に対応したマトリクス液晶シャッタ92－2に設定し、3D観察領域20にスリット像118を結像し、これを左眼観察領域20－1としている。同時に右眼用表示器14－2に対応したマトリクス液晶シャッタ92－2には、左眼用のマトリクス液晶シャッタ92－1に設定した開口128を除く全領域を透過状態とした開口130が設定される。こ

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のため３Ｄ観察領域２０には左眼観察領域２０－１を除く領域に開口１３０のスリット像１２０が結像され、これが右眼観察領域２０－２を形成している。

【０１１５】図４２は、図４１の空間分割の投影光学ユニットに設けたマトリクス液晶シャッタ９２－１，９２－２と開口制御装置のブロック図である。開口設定器１６としては、２つのマトリクス液晶シャッタ９２－１，９２－２とそれぞれのドライバ９４－１，９４－２，９６－１，９６－２が設けられる。開口制御装置３０には、２台のマトリクス液晶シャッタ９２－１，９２－２に対応して表示コントローラ９０－１，９０－２が設けられ、並列的に開口設定制御を行う。開口位置演算部８８は図１６の時分割の場合と同じであり、観察者位置検出情報に基づいて右眼及び左眼用の開口位置を演算して表示コントローラ９０に指示する。

【０１１６】図４３は、図４１の空間分割による投影光学ユニットにおける投影開口制御のフローチャートである。まずステップＳ１で観察者の左右の眼の位置を検出し、ステップＳ２で左眼用画像と右眼用画像を生成する。続いてステップＳ３で、別々に設けられた各表示器に左眼用画像と右眼用画像を並列的に表示する。同時にステップＳ４で、左眼用及び右眼用の開口設定器として設けたマトリクス液晶シャッタ９２－１，９２－２のそれぞれに左眼用開口位置と右眼用開口位置の設定制御を行い、以上のステップＳ１～Ｓ４の処理を、ステップＳ５で表示停止が行われるまで繰り返す。尚、図４１にあっては、時分割における図２６，図２７の開口設定を例にとっているが、これ以外に図１７，図１８の開口設定、あるいは図２３，図２４の開口設定を行うようにしてもよい。

【０１１７】図４４は空間分割の投影光学ユニットにおける開口の奥行き方向の制御のための実施形態である。この実施形態にあっては、左眼用表示器１４－１及び右眼用表示器１４－２に続いて図４２のマトリクス液晶シャッタ９２－１，９２－２を光軸方向に複数積層した積層シャッタ１３４－１，１３４－２を設定している。これら積層シャッタ１３４－１，１３４－２の各マトリクス液晶シャッタに対応して、スクリーン位置となる凸フレネルレンズ１１６の前方の３Ｄ観察領域２０には、前後方向にスリット結像面１３２－１～１３２－ｎがシャッタ枚数分形成されることになる。

【０１１８】このため、３Ｄ観察領域２０の観察者位置の前後方向の検出位置に基づいて、積層シャッタ１３４－１，１３４－２の中の対応するマトリクス液晶シャッタを選択して開口設定することで、３Ｄ観察方向の検出位置に対応する奥行方向の位置にスリット結像面を形成し、ここに右眼用及び左眼用画像を観察するためのスリット像の形成による画像光の投射ができる。

【０１１９】更に、空間分割における前後方向の開口制御の実施形態としては、図４５の積層シャッタ以外にも、図３１の時分割に示した投射レンズユニット１５に設けた可動レンズ１８２の光軸方向の移動により焦点距離を変えるもの、更には図３７に示したマトリクス液晶シャッタを光軸の前後方向に斜めに配置し、且つスクリーン位置となる凸フレネルレンズ１１６に垂直拡散板１４０を設けたものとしてもよい。

６．偏光分割による投影開口制御

図４５は、３Ｄ観察領域に対する右眼及び左眼画像の投影と開口設定を偏光分割により実現する図２の投影光学ユニットの実施形態である。

【０１２０】図４５において、偏光分割にあっては，表示器として左眼用表示器１４－１と右眼用表示器１４－２を別々に設けている。このため表示制御装置としては、空間分割と同じ図３９のものが使用できる。光源側は光源９８とリフレクタ１００による光をレンズ１０２で集光した後にフレネルレンズ１０４で平行光に変換し、続いてビーム用の偏光ビームスプリッタ（ＰＢＳ）１４４により、透過光となるＰ偏光成分と反射光となるＳ偏光成分に分離している。分離用偏光ビームスプリッタ１４４で反射されたＳ偏光成分はミラー１４６で反射され、左眼用表示器１４－１に入射する。

【０１２１】一方、分離用偏光ビームスプリッタ１４４を透過したＰ偏光成分はミラー１４８で反射された後、右眼用表示器１４－２に入射される。左眼用表示器１４－１を通過した映像光となるＳ偏光成分と、右眼用表示器１４－２を通過して映像光となったＰ偏光成分は、合成用偏光ビームスプリッタ１５０に与えられる。合成用偏光ビームスプリッタ１５０は、Ｓ偏光成分とＰ偏光成分を合成した後、偏光分割における開口設定器として機能するマトリクスπセル１５２に与えられる。マトリクスπセル１５２に続いては投射レンズ１１０が設けられ、それ以降の光学系は時分割及び空間分割の場合と同様、凹面ミラー１１２、背面ミラー１１４、３Ｄ観察領域２０に結像機能をもつ凸フレネルレンズ１１６で構成される。

【０１２２】図４６は、図４５における左眼用表示器１４－１，右眼用表示器１４－２，合成用偏光ビームスプリッタ１５０及びマトリクスπセル１５２の部分を取り出している。開口設定器として機能するマトリクスπセル１５２は、図４７に示すように、ＴＮ液晶１５８と偏光板１６０で構成されている。ＴＮ液晶１５８は、液晶を積層している電極間に対する駆動電圧の印加による電解オンオフにより、入射光の偏光面の回転と非回転状態を作り出す。

【０１２３】即ち図４７（Ａ）は、ＴＮ液晶１５８の電極間の駆動電圧をオフした電解オフ状態である。この電解オフ状態では、右眼画像光１２４となるＰ偏光成分はＴＮ液晶１５８を通過する際に偏光面が９０度回転されてＳ偏光成分に変換される。一方、左眼画像光１２２となるＳ偏光成分も同様に９０度回転されてＰ偏光成分と

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なる。偏光板160は、例えばS偏光成分のみを透過し、P偏光成分を遮断する偏光特性を備えている。

【0124】このため、TN液晶158から出力されたS偏光成分即ち右眼画像光124のみが偏光板160を通過して右眼38側に投影される。したがって図46のマトリクスπセル152において、右眼用の開口を設定したい領域についてはTN液晶158の電解をオフした電解オフ領域154を設定すればよい。一方、TN液晶158の電極に駆動電圧を印加した電解オン状態については、図47（B）のようになる。TN液晶158の電極間に駆動電圧を印加した電解オン状態にあっては、TN液晶158による偏光面の回転機能はなくなって透過状態となり、右眼画像光124であるP偏光成分も左眼画像光122であるS偏光成分もそのままTN液晶158を通過する。

【0125】このとき偏光板160はS偏光成分のみの透過特性をもっているため、左眼画像光122となるS成分が出力され、左眼40に投影される。したがって図46のマトリクスπセル152において、左眼用の開口を設定したい領域については電解オン領域156を設定すればよい。このようなマトリクスπセル152における左眼用の開口に対応した電解オン領域156と右眼用の開口に対応した電解オフ領域154の設定により、図45のように、スクリーン位置となる凸フレネルレンズ116の前方の3D観察領域20に左眼観察領域20－1と右眼観察領域20－2が設定され、それぞれの領域に対する右眼画像と左眼画像の投影により、観察者は両眼視差により立体像を観察することができる。

【0126】また位置検出対象となっている観察者以外の観察者については、この実施形態の場合には、右眼観察領域20－2から観察することになるため、右眼用表示器14－2による右眼画像を二次元画像として鮮明に観察することができる。図48は図45の偏光分割による投影制御と開口制御のフローチャートである。まずステップS1で観察者の左右の眼の位置を検出し、ステップS2で左眼用画像と右眼用画像を生成する。続いてステップS3で左眼用画像と右眼用画像をそれぞれの表示器14－1，14－2に表示する。更にステップS4で、右眼用開口位置と左眼用開口位置に応じて偏光回転の有無を決める電解オンオフ領域の制御を行う。

【0127】このようなステップS1～S4の偏光分割による投影及び開口制御を、ステップS5で表示停止が行われるまで繰り返す。ここで、図45の偏光分割におけるマトリクスπセル152の開口設定は、時分割による図26，27と同じ開口設定を例にとっているが、これ以外に図17，図18の開口設定，あるいは図23，図24の開口設定を行ってもよいことはもちろんである。

【0128】図49は偏光分割における開口の前後方向の制御を行う投影光学ユニットの実施形態である。この実施形態にあっては、合成用偏光ビームスプリッタ150に続いて積層マトリクスπセル161を設けている。積層マトリクスπセル161は、図45で使用したマトリクスπセル152を複数枚、光軸方向に積層している。

【0129】このような積層マトリクスπセル161によりスクリーン位置となる凸フレネルレンズ116の前方の3D観察領域20に、光軸に沿った前後方向に並んで複数のスリット結像領域162－1～162－nが形成される。このため、3D観察領域20における観察者の前後方向の検出位置に対応して積層マトリクスπセル161の中の対応するマトリクスπセルを選択して、図46のような電解オフ領域154と電解オン領域156の設定による右眼用及び左眼用の開口設定を行うことで、3D観察領域20の観察者の検出位置の直前のスリット結像位置にマトリクスπセルのスリット像を結像し、観察者による立体観察を可能とする。

【0130】図50は偏光分割の投影光学ユニットにおける開口の前後方向の制御の他の実施形態であり、マトリクスπセルを光軸に対し前後方向に斜めに設置したことを特徴とする。即ち、合成用偏光ビームスプリッタ150に続いてマトリクスπセル152は、光軸に対し前後方向に斜めとなるように配置されている。斜めに配置したマトリクスπセル152は、空間分割における図34のマトリクス液晶シャッタの場合と同様、複数の水平ストライプ開口による光軸方向の異なった位置での開口設定を行う。

【0131】このためスクリーン位置となる凸フレネルレンズ116の前方の3D観察空間20には、斜めに配置したマトリクスπセル152の各水平ストライプ開口に対応する水平ストライプスリット像164－1～164－nが形成される。この場合、1つ1つの水平ストライプスリット像164－1～164－nの垂直方向の幅は極めて狭く、この幅を観察者の眼が外れると立体像を観察することができない。

【0132】そこで図51のように、凸フレネルレンズ116に垂直拡散板166を設け、各水平ストライプスリット像164－1～164－nを垂直方向に拡大した垂直拡大領域170－1～170－nとする。尚、偏光分割による開口の前後方向の制御については、これ以外に図31の時分割における投射レンズを光軸方向に移動して焦点距離を変えるようにしてもよいことはもちろんである。

7．複数観察者に対する投影開口制御

図52は本発明の画像表示装置の他の実施形態であり、3D観察領域に存在する複数の観察者位置を検出し，各観察者が個別に立体観察ができるようにしたことを特徴とする。

【0133】図52において、複数観察者の立体観察を可能とする本発明の画像表示装置10の装置構成は、図

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２の実施形態と基本的に同じであり、観察者位置検出装置２４が３Ｄ観察領域２０に存在する複数の観察者、例えば二人の観察者２２－１，２２－２のそれぞれを検出できることを特徴とする。画像生成装置２６は、観察者位置検出装置２４による例えば二人の観察者２２－１，２２－２の検出情報に基づき、次のモードに従った画像生成を行う。

【０１３４】モード１：複数の観察者２２－１，２２－２の内の特定の一人、例えば観察者２２－１の右眼と左眼を視点位置としてみた右眼画像及び左眼画像を生成する。

モード２：観察者２２－１，２２－２のそれぞれの右眼と左眼を視点位置としてみた右眼画像及び左眼画像を生成する。

【０１３５】このため、モード１にあっては、一人の観察者の検出位置に対応した右眼画像と左眼画像であることから、既に説明した実施例における観察者一人を対象とした場合と同じ画像生成と表示制御装置３０による表示器１４に対する画像表示でよい。これに対しモード２の観察者２２－１，２２－２ごとにそれぞれの右眼画像と左眼画像を生成する場合には、例えば時分割にあっては単一の表示器１４を使用して二人分の右眼画像と左眼画像を表示する必要があるため、一人分の表示周期例えば（１／１２０）秒周期で表示対象とする観察者の数Ｎを掛け合わせた表示周期で、例えば不辺の観察者の場合は（１／２４９）秒周期で高速に切替表示する必要がある。

【０１３６】一方、開口設定器１６に対する開口制御装置３２による開口制御については、二人の観察者２２－１，２２－２のそれぞれの右眼とそれぞれの左眼の位置に対応した開口設定を行う。図示の３Ｄ観察領域２０にあっては、観察者２２－１，２２－２の右眼観察領域２０－２１，２０－２２を設定した状態であり、これに対応して開口設定器１６には２つの右眼用の開口設定が行われている。

【０１３７】図５３は時分割を例にとって図５２の複数観察者を対象とした装置の投影光学ユニットの実施形態である。図５３にあっては、３Ｄ観察領域２０に存在する二人の観察者の左眼４０－１，４０－２の検出位置に対応した開口１２８－１，１２８－２の設定をマトリクス液晶シャッタ９２に対し行っている。これにより３Ｄ観察領域２０にそれぞれの左眼観察領域２０－１１，２０－１２のスリット像が形成され、二人の観察者はそれぞれの左眼４０－１，４０－２によって同じ表示器１４に表示された左眼画像を観察することができる。

【０１３８】図５４は右眼画像の表示と開口設定に切り替えた状態であり、３Ｄ観察領域２０に存在する二人の観察者の右眼３８－１，３８－２の検出位置に対応した開口１３０－１，１３０－２の設定をマトリクス液晶シャッタ９２に対し行っている。このため３Ｄ観察領域２０にはそれぞれの観察者に対する右眼観察領域２０－２１，２０－２２が形成され、二人の観察者はそれぞれの右眼３８－１，３８－２により表示器１４の右眼画像を観察することができる。

【０１３９】時分割にあっては、図５３と図５４の表示が交互に切り替えられるため、二人の観察者は同時に右眼と左眼で異なった視差画像を見ることになり，これによって立体を観察することができる。このときモード１による表示器１４の表示制御にあっては、二人の観察者は同じ立体画像を観察することになる。これに対しモード２にあっては、観察者の各位置に対応して個別に右眼画像と左眼画像が形成され、例えば観察者が図５２のように二人であれば、まず観察者２２－１の右眼画像と左眼画像が表示され、これに同期してマトリクス液晶シャッタ９２に右眼用開口と左眼用開口が設定され、観察者２２－１に対する立体観察のための投影表示が行われる。

【０１４０】続いて次の観察者２２－２の検出位置から生成した右眼画像と左眼画像の表示を表示器１４に対し順次行い、これに同期して観察者２２－２の右眼位置と左眼位置に対応した開口設定を順次行うことで、観察者２２－２による立体画像の観察を行わせる。このためモード２の投影表示と開口制御にあっては、観察者２２－１，２２－２は同じ表示映像であっても、それぞれの位置に対応した見え方の立体画像を観察することができる。

【０１４１】尚、図５３の複数観察者を対象とした装置の投影光学ユニットは、図５３、図５４の空間分割以外に図２の単一の観察者を対象とした投影光学ユニットの実施形態と同様，空間分割によるもの、偏光分割によるものの全てをそのまま使用することができる。更に本発明は発明の目的を逸脱しない範囲で適宜の変形が可能である。更にまた本発明は、実施例に記載された数値による限定は受けない。

【０１４２】

【発明の効果】以上説明してきたように本発明によれば、眼鏡などの補助光学系を使用することなく立体画像を鮮明に見ることができ、観察者の移動に追従して立体映像が変化する運動視差を実現でき、更に立体観察者以外の観察者については同じ内容をもつ二次元画像を鮮明に見せることができる。

【図面の簡単な説明】

【図１】本発明の原理説明図

【図２】本発明の装置構成の説明図

【図３】本発明による観察領域の説明図

【図４】本発明の時分割処理による立体表示のフローチャート

【図５】画像を用いた図３の観察者位置検出装置のブロック図

【図６】図５の装置による画像を用いた観察者位置の検

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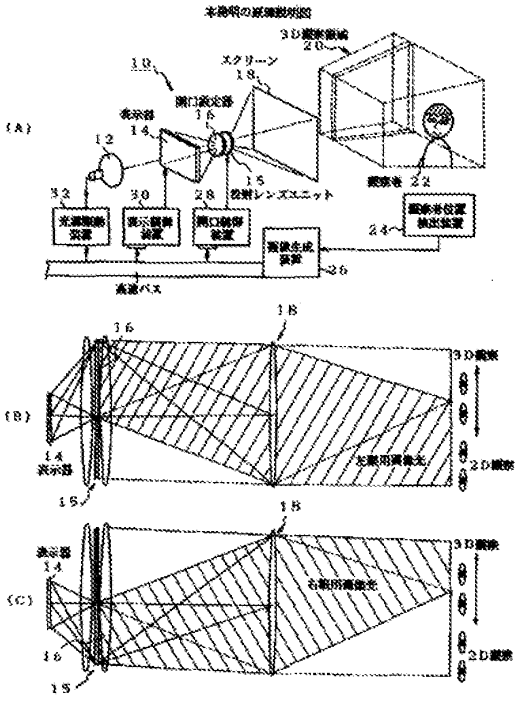
算処理の説明図
【図７】磁気センサを用いた図３の観察者位置検出装置のブロック図
【図８】超音波センサを用いた図３の観察者位置検出装置のブロック図
【図９】図３の画像生成装置と表示制御装置のブロック図
【図１０】時分割による右眼用と左眼用の画像データの転送表示の説明図
【図１１】画像補間を行う図３の画像生成装置と表示制御装置のブロック図
【図１２】図１１におけるカメラ配置の説明図
【図１３】２台のカメラによる撮影画像の説明図
【図１４】図１１の装置による水平方向での画像補間の説明図
【図１５】図１４の補間処理で生成した画像の説明図
【図１６】図２の開口設定器と開口制御装置のブロック図
【図１７】時分割による右眼画像投映状態での図２の投映光学ユニットの説明図
【図１８】時分割による左眼画像投射状態での図２の投映光学ユニットの説明図
【図１９】図１７，図１８の等化光学系による時分割画像投映の説明図
【図２０】図１９の等化光学系に相当するプロジェクタ２台を用いた投映光学系の説明図
【図２１】観察者の検出位置の開口位置の相関関係の説明図
【図２２】観察者の眼の間隔に対する投映領域の説明図
【図２３】立体画像と二次元画像の観察を可能とする時分割による左眼画像投映状態での図２の投映光学ユニットの説明図
【図２４】立体画像と二次元画像の観察を可能とする時分割による右眼画像投射状態での図２の投映光学ユニットの説明図
【図２５】図２３，図２４の等化光学系による空間分割画像投映の説明図
【図２６】立体画像の観察を可能とする時分割による右眼画像投映状態での図２の投映光学ユニットの説明図
【図２７】立体画像と二次元画像の観察を可能とする時分割による左眼画像投射状態での図２の投映光学ユニットの説明図
【図２８】図２６，図２７の等化光学系による空間分割画像投映の説明図
【図２９】積層シャッタを用いた前後方向に開口位置を制御する時分割による図２の投映光学ユニットの説明図
【図３０】図２９の等化光学系による開口位置の前後方向の制御の説明図
【図３１】投射レンズの駆動により前後方向に開口位置を制御する時分割による図２の投映光学ユニットの説明図
【図３２】図３１の投射レンズの駆動機構の説明図
【図３３】図３１の投射レンズの他の駆動機構の説明図
【図３４】積層シャッタを斜めに配置して前後方向に開口位置を制御する時分割による図２の投映光学ユニットの等化光学系の説明図
【図３５】図３４のシャッタの正面図
【図３６】図３４のスクリーン位置に凸フレネルレンズを用いた実際の光学系における観察領域でのスリット像の前後移動の説明図
【図３７】図３４の凸レンズに垂直拡散板を設けて観察領域で垂直方向に視野を拡大した説明図
【図３８】図３７を実際の光学系に適用した場合の垂直方向での視野の拡大の説明図
【図３９】空間分割による図２の画像生成装置と表示制御装置のブロック図
【図４０】空間分割による右眼用と左眼用の画像データの転送表示の説明図
【図４１】空間分割による図２の投映光学ユニットの説明図
【図４２】空間分割による開口制御装置と開口設定器のブロック図
【図４３】空間分割による表示制御と開口制御のフローチャート
【図４４】開口位置を前後に制御する空間分割による図２の投映光学ユニットの説明図
【図４５】偏光分割による図２の投映光学ユニットの説明図
【図４６】図４５の偏光制御型開口設定器の部分を取り出した説明図
【図４７】図４６の開口設定器の構造と開口設定の説明図
【図４８】偏光分割による画像投映と開口制御のフローチャート
【図４９】開口設定器の積層により開口位置を前後に制御する図２の投映光学ユニットの説明図
【図５０】開口設定器の斜め配置により開口位置を前後に制御する図２の投映光学ユニットの説明図
【図５１】図５０の凸フレネルレンズに垂直拡散板を配置した投映光学ユニットの説明図
【図５２】複数の観察者による立体画像を観察可能とする本発明の装置構成の説明図
【図５３】複数観察者による左眼画像投映状態での図５２の投映光学ユニットの説明図
【図５４】複数観察者による右眼画像投映状態での図５２の投映光学ユニットの説明図
【図５５】偏光眼鏡を使用する従来の立体表示装置の説明図
【図５６】図５５で表示する右眼用と左眼用の画像説明図

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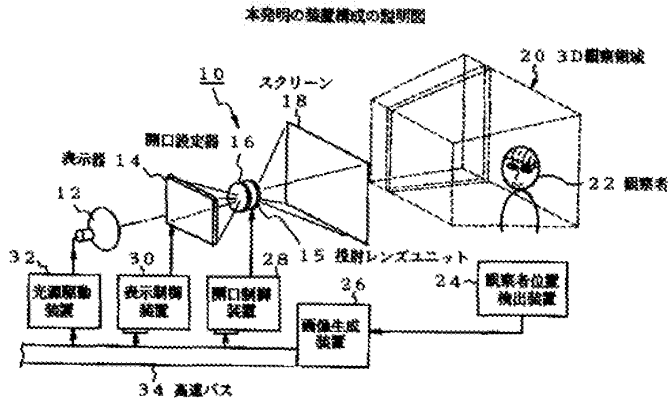
【図57】レンティキュラ方式による従来の立体表示装置の説明図
【図58】パララックスバリア方式による従来の立体表示装置の説明図
【図59】観察領域を拡大したレンティキュラ方式による従来の立体表示装置の説明図
【符号の説明】
10：立体表示装置
12：光源ユニット
14：表示器
16：開口設定器
15：投射レンズユニット
18：スクリーン
20：3D観察領域（立体観察領域）
22：観察者
24：観察者位置検出装置（観察者位置検出部）
26：画像生成装置（画像生成部）
28：開口制御装置（開口制御部）
30：表示制御装置
32：光源駆動装置
34：高速バス
36：2D観察領域（二次元観察領域）
38：右眼
40：左眼
42，44：CCDカメラ
46，346，446：観察位置演算部
48，48，348，448：観察者位置情報発生部
50，52：撮像レンズ
54，56：結像面
58，60：画像
62：モデリングデータ格納部
64：レンダリング処理部
66：右眼画像フレームバッファ
68：左眼画像フレームバッファ
70：データ切替部
72：表示駆動部
73：カメラ画像データ格納部
75：補間画像生成部
74－1～74－4：右眼画像データ
76－1～76－4：左眼画像データ
78：物体
80－1，80－2：画像
84：補間画像
88：開口位置演算部
90：表示コントローラ
92，92－1，92－2：マトリクス液晶シャッタ
94，96：ドライバ
98：光源
100：リフレクタ
102：レンズ
104：フレネルレンズ
106，146，148：ミラー
110：投射レンズ
112：凹面ミラー（虚像拡大素子）
114：背面ミラー
115：視域
116：スクリーン用凸フレネルレンズ
118：スリット像（左眼観察領域）
120：スリット像（右眼観察領域）
122：左眼用画像光
124：右眼用画像光
126：両眼中心位置
128：開口（左眼画像用開口）
130：開口（右眼画像用開口）
132－1～132－5：スリット像
134：積層シャッタ
135－1～135－n：水平ストライプ開口
136－1～136－n：水平スリット像
140：垂直拡散板
142－1～142－n：垂直拡大領域
144：分離用偏光ビームスプリッタ（PBS）
150：合成用偏光ビームスプリッタ（PBS）
152：マトリクスπセル（偏光制御型開口設定器）
154：電界オフ領域（偏光回転あり）
156：電界オン領域（偏光回転なし）
158：TN液晶
160：偏光板
161：積層マトリクスπセル
162－1～162－n：3D観察領域
164－1～164－n：スリット像
170－1～170－n：垂直拡大領域
180，184：固定レンズ
182：可動レンズ
186：アクチュエータ
188：レンズ収納筒
190，260：ガイドスリット
192：アーム
194：VCMコイル
196：ヨーク
198：外筒
242，246：ピン
248：アウターナルギア
250：中間ギア
252：ドライブギア
254：モータ

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【図１】

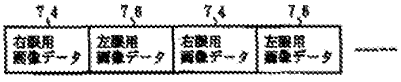


【図２】



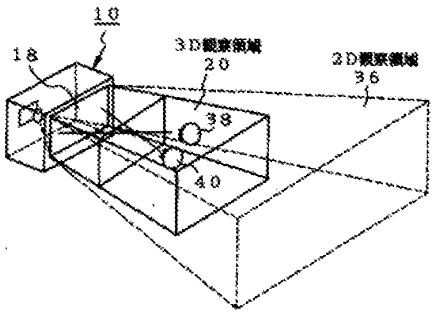
【図１０】

時分割による右眼用と左眼用の画像データの転送表示の説明図



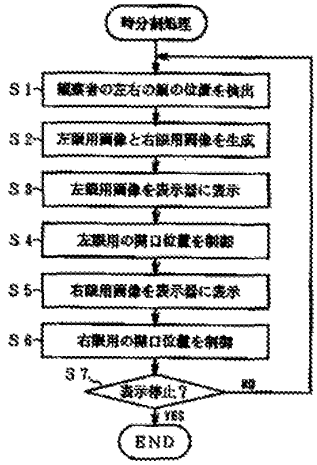
【図３】

本発明による観察領域の説明図



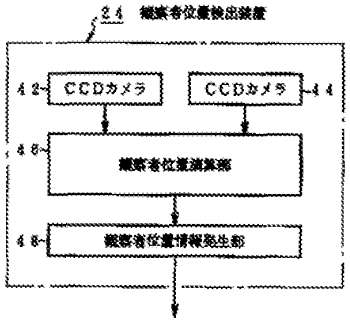
【図４】

本発明の時分割処理による立体表示のフローチャート



【図５】

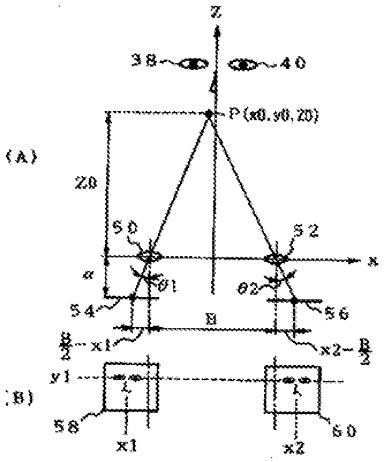
画像を用いた図３の観察者位置検出装置のブロック図



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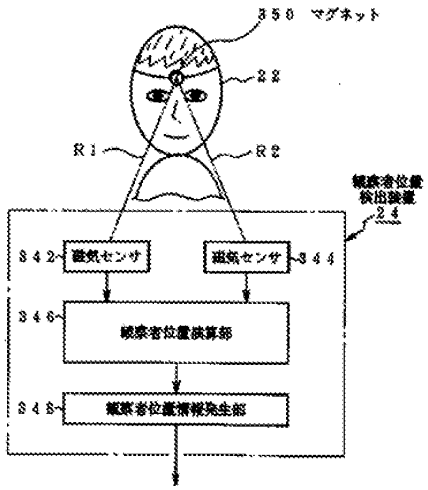
【図6】

図5の装置による画像を用いた観察者位置の演算処理の説明図



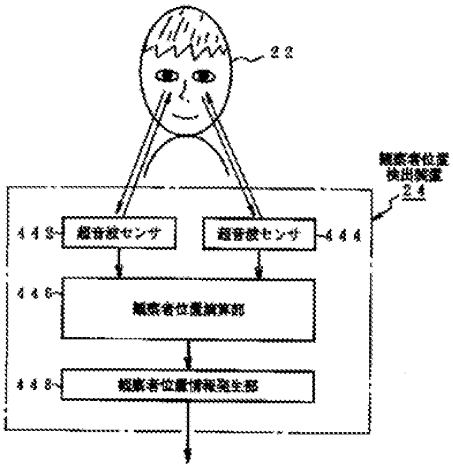
【図7】

磁気センサを用いた図3の観察者位置検出装置のブロック図



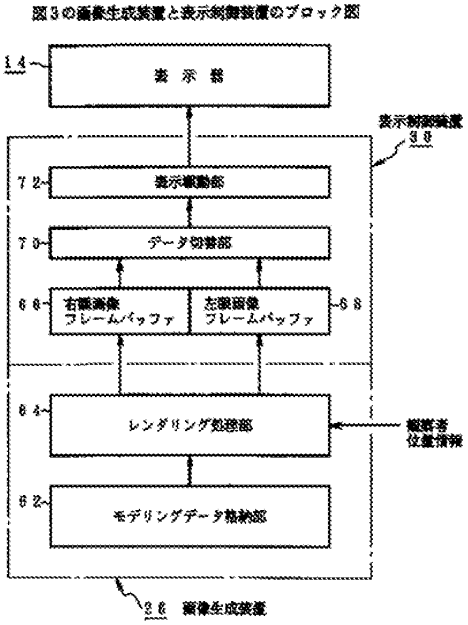
【図8】

超音波センサを用いた図3の観察者位置検出装置のブロック図



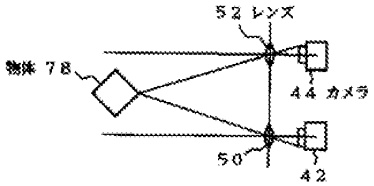
【図9】

図3の画像生成装置と表示制御装置のブロック図



【図12】

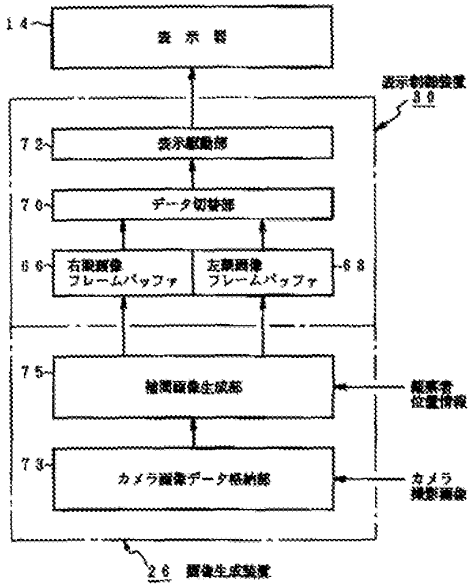
図11におけるカメラ配置の説明図



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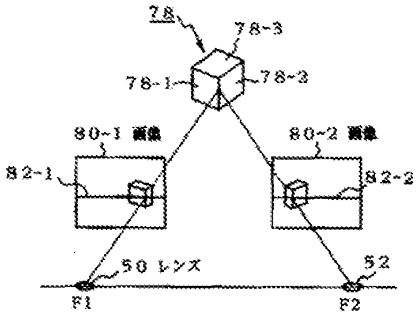
【図11】

画像補間を行う図3の画像生成装置と表示制御装置のブロック図



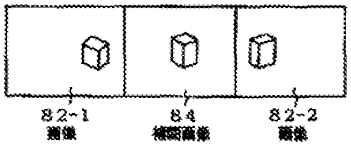
【図13】

2台のカメラによる撮影画像の説明図



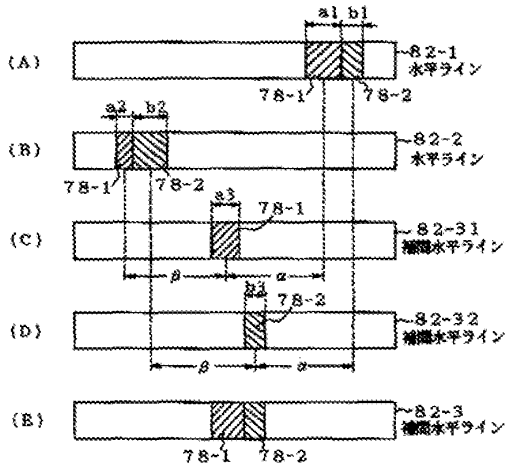
【図15】

図14の補間処理で生成した画像の説明図



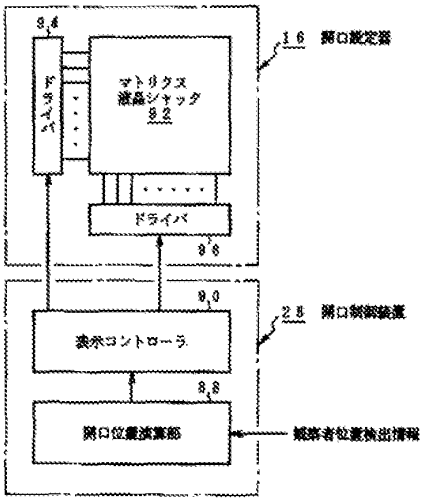
【図14】

図11の装置による水平方向での画像補間の説明図



【図16】

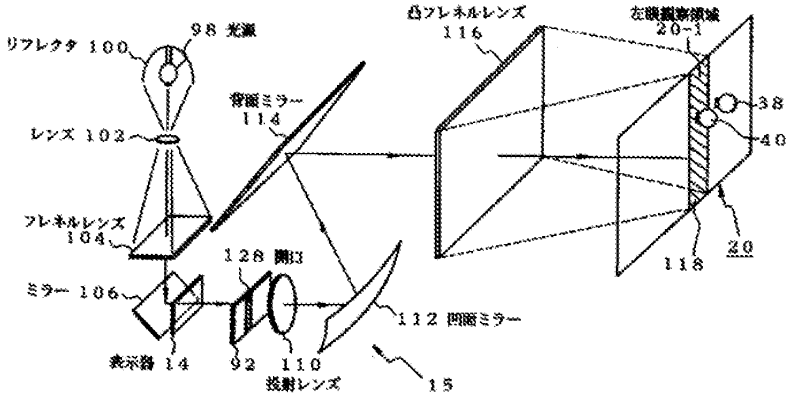
図2の開口設定器と開口制御装置のブロック図



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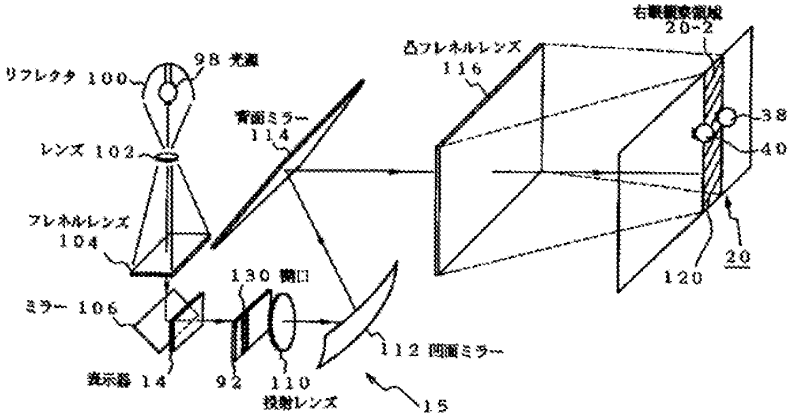
【図17】

時分割による右眼画像投影状態での図2の投映光学ユニットの説明図



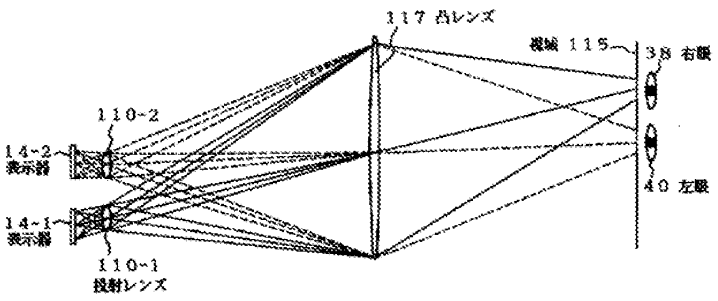
【図18】

時分割による左眼画像投射状態での図2の投映光学ユニットの説明図



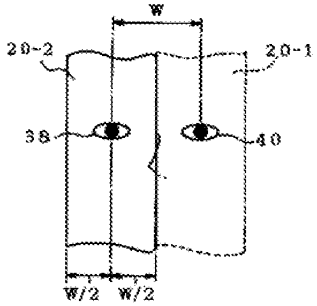
【図20】

図19の等価光学系に相当するプロジェクタ2台を用いた投映光学系の説明図



【図22】

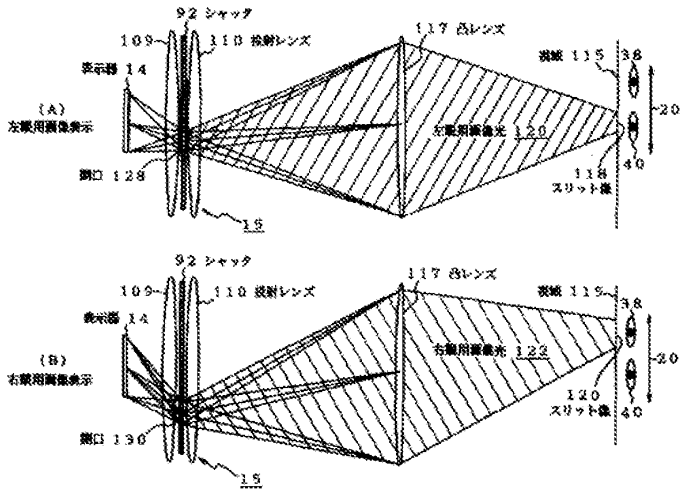
観察者の眼の間隔に対する投映領域の説明図



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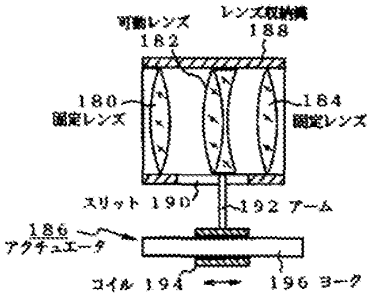
【図19】

図17、図18の等価光学系による時分割画像投映の説明図



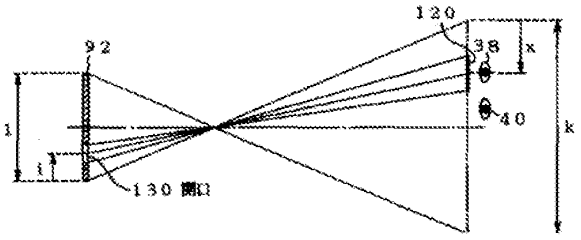
【図32】

図31の投射レンズの組立構造の説明図



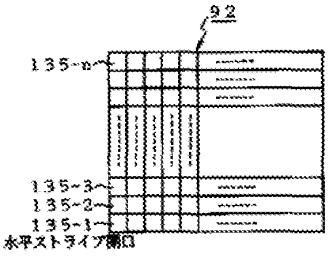
【図21】

観察者の検出位置の開口位置の相関関係の説明図



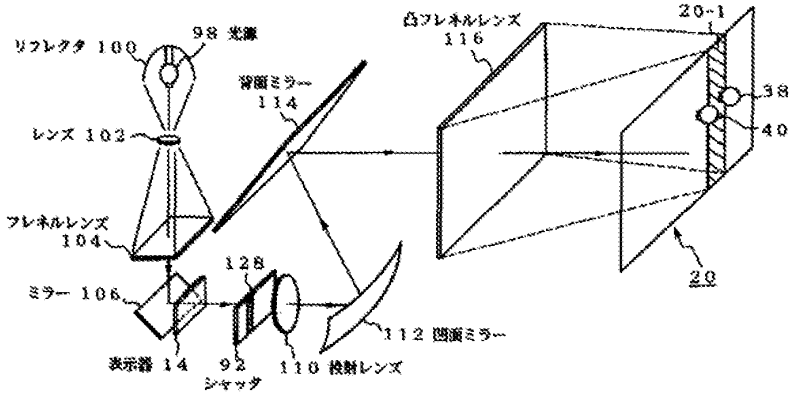
【図35】

図34のシャッタの正面図



【図26】

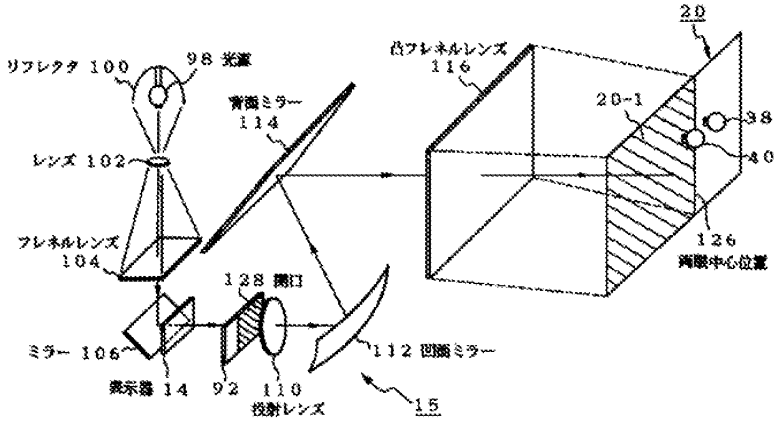
立体画像の観察を可能とする時分割による右眼画像投映状態での図2の投映光学ユニットの説明図



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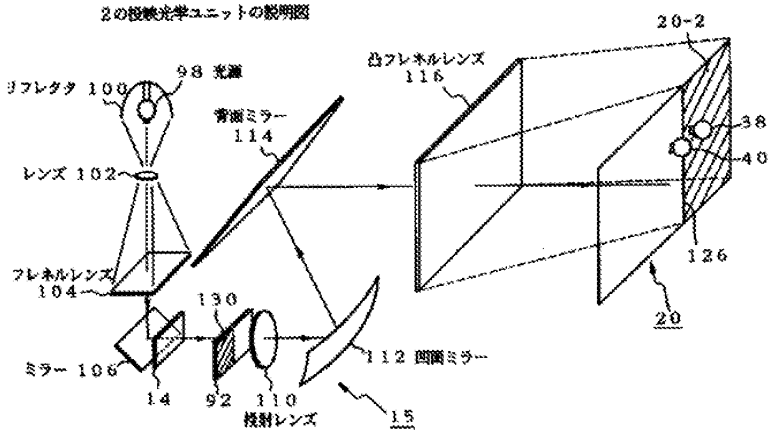
【図23】

立体画像と二次元画像の観察を可能とする時分割による左眼画像投映状態での図2の投映光学ユニットの説明図



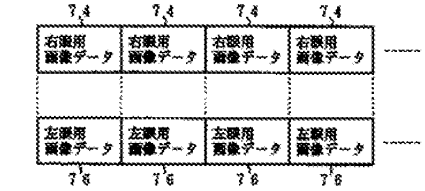
【図24】

立体画像と二次元画像の観察を可能とする時分割による右眼画像投射状態での図2の投映光学ユニットの説明図



【図40】

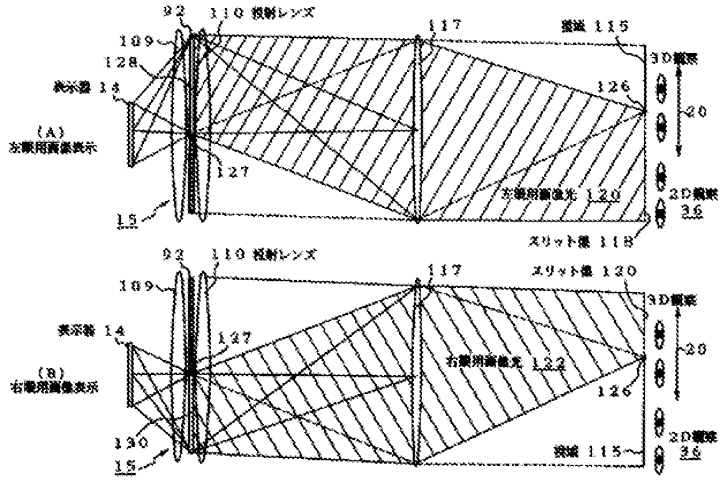
空間分割による右眼用と左眼用の画像データの転送表示の説明図



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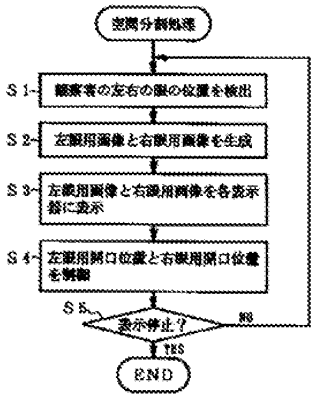
【図25】

図23、図24の等化光学系による空間分割画像投射の説明図



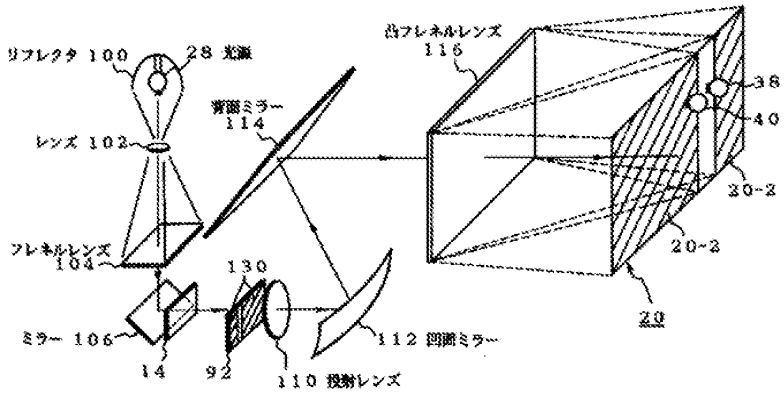
【図43】

空間分割による表示制御と開口制御のフローチャート



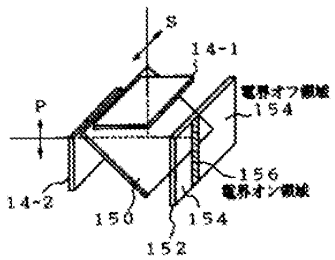
【図27】

立体画像と二次元画像の観察を可能とする時分割による左眼画像投射状態での図2の投射光学ユニットの説明図



【図46】

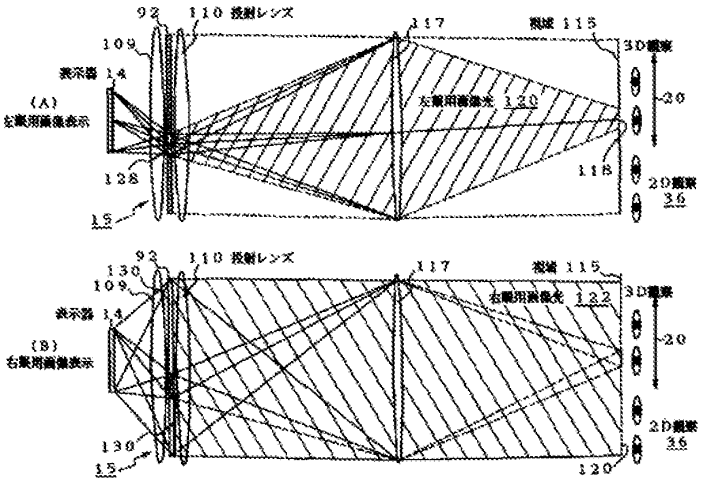
図45の偏光制御液晶開口設定器の部分を取り出した説明図



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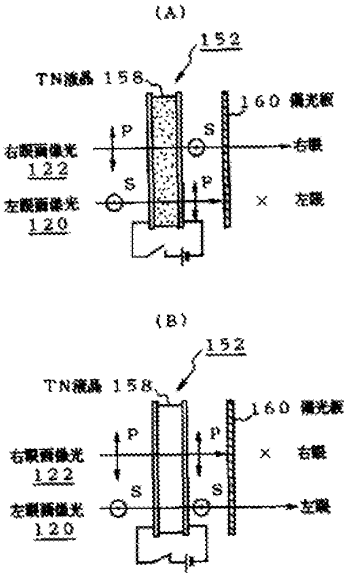
【図28】

図26、図27の等化光学系による空間分割画像投映の説明図



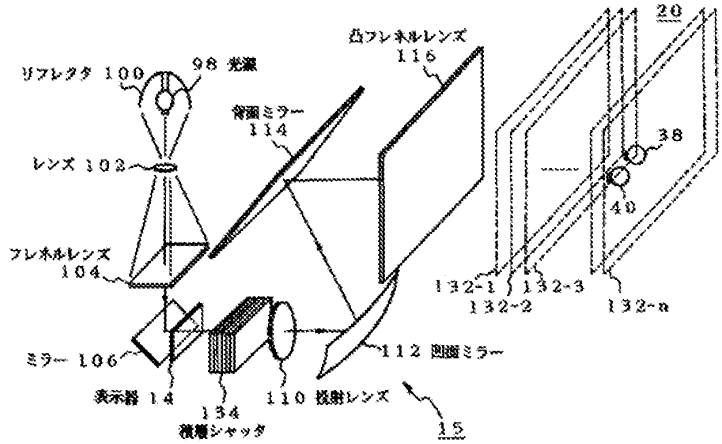
【図47】

図46の開口設定器の構造と開口設定の説明図



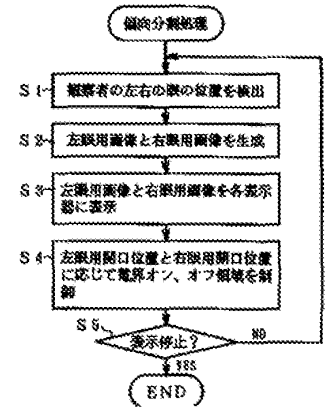
【図29】

視差シャッタを用いた前後方向に開口位置を制御する時分割による図2の投映光学ユニットの説明図



【図48】

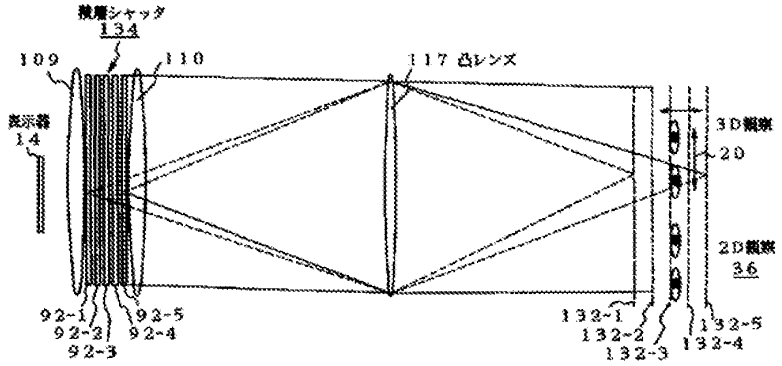
視光分割による画像投映と開口制御のフローチャート



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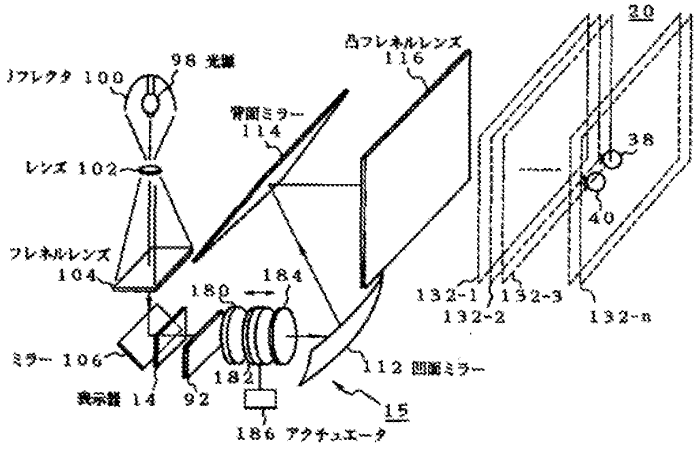
【図30】

図29の等化光学系による開口位置の前後方向の制御の説明図



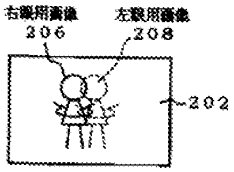
【図31】

投射レンズの移動により前後方向に開口位置を制御する時分割による図2の投映光学ユニットの説明図



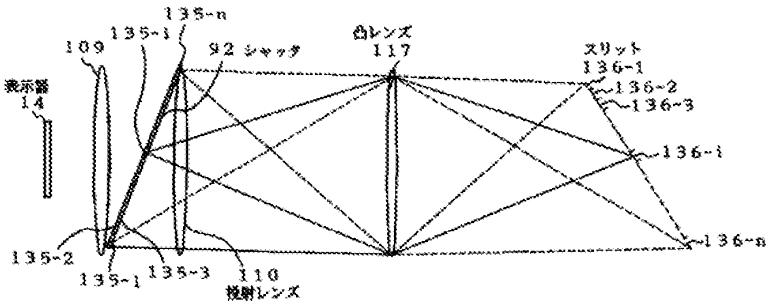
【図56】

図55で表示する右眼用と左眼用の画像説明図



【図34】

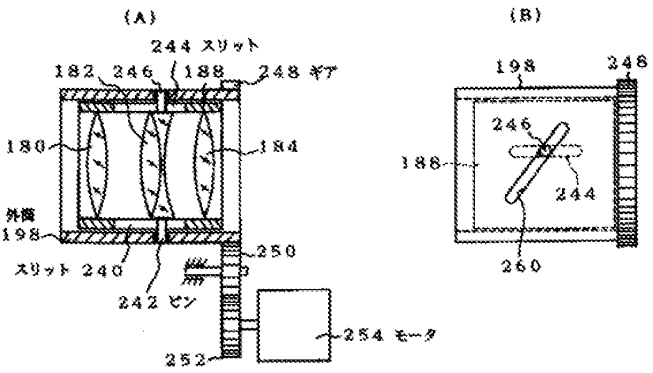
視差シャッタを斜めに配置して前後方向に開口位置を制御する時分割による図2の投映光学ユニットの等化光学系の説明図



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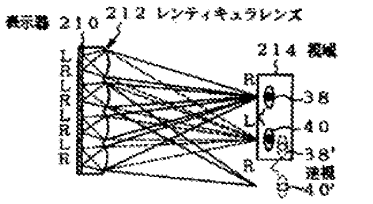
【図33】

図31の投射レンズの他の駆動機構の説明図



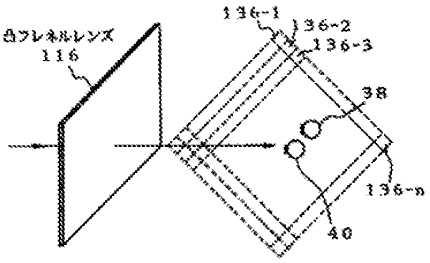
【図57】

レンティキュラ方式による従来の立体表示装置の説明図



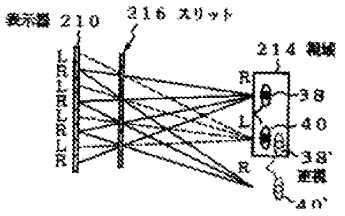
【図36】

図34のスクリーン位置に凸フレネルレンズを用いた実際の光学系における観察領域でのスリット像の前後移動の説明図



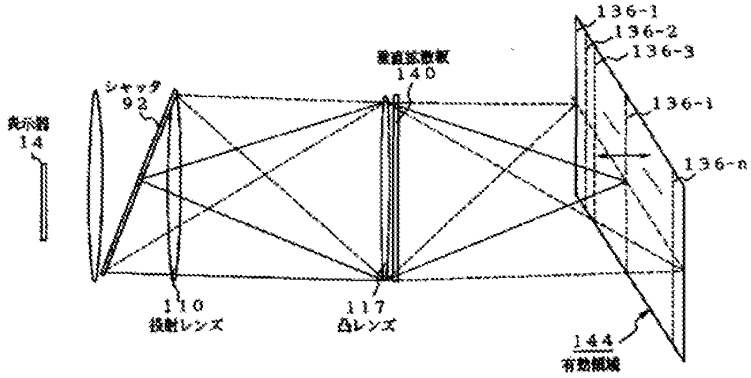
【図58】

パララックスバリア方式による従来の立体表示装置の説明図



【図37】

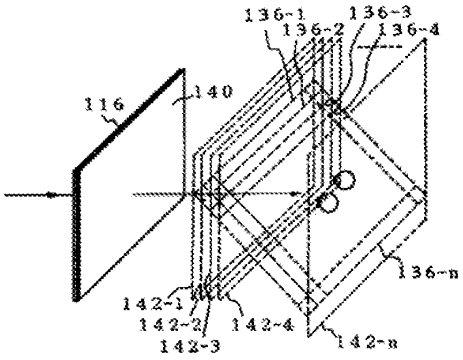
図34の凸レンズに垂直拡散板を設けて観察領域で垂直方向に視野を拡大した説明図



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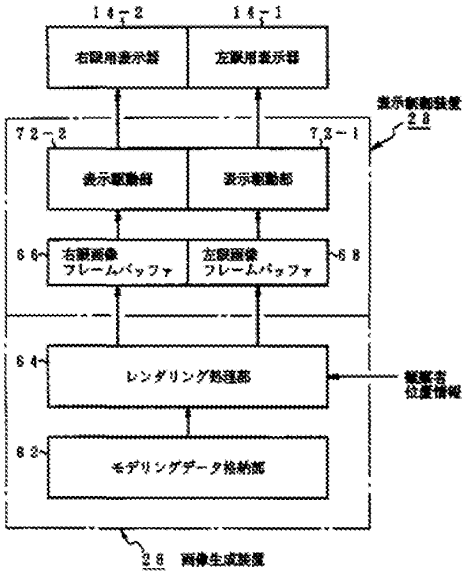
【図38】

図37を実際の光学系に適用した場合の垂直方向での視野の拡大の説明図



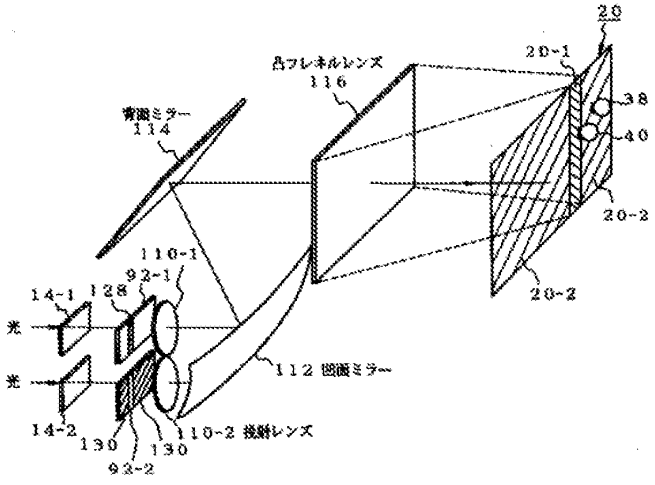
【図39】

空間分割による図2の画像生成装置と表示制御装置のブロック図



【図41】

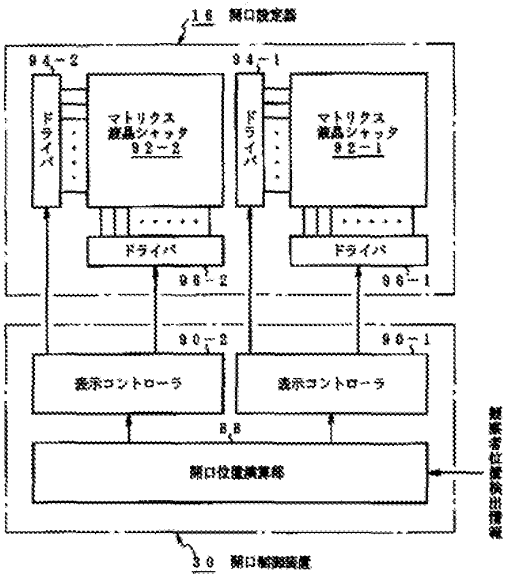
空間分割による図2の投映光学ユニットの説明図



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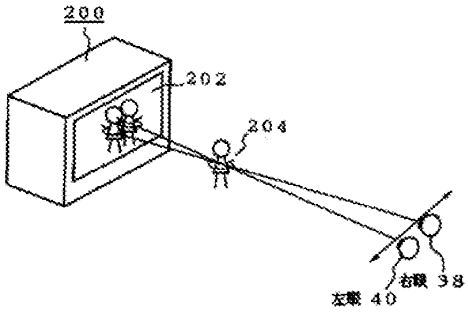
【図42】

空間分割による開口制御装置と開口設定器のブロック図



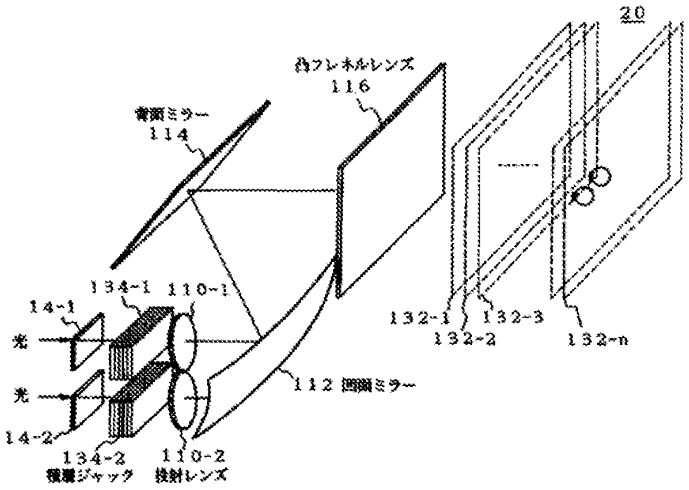
【図55】

偏光眼鏡を使用する従来の立体表示装置の説明図



【図44】

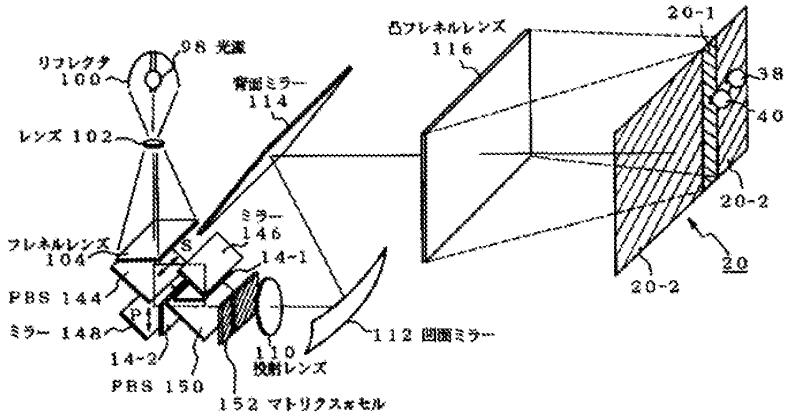
開口位置を前後に制御する空間分割による図2の投映光学ユニットの説明図



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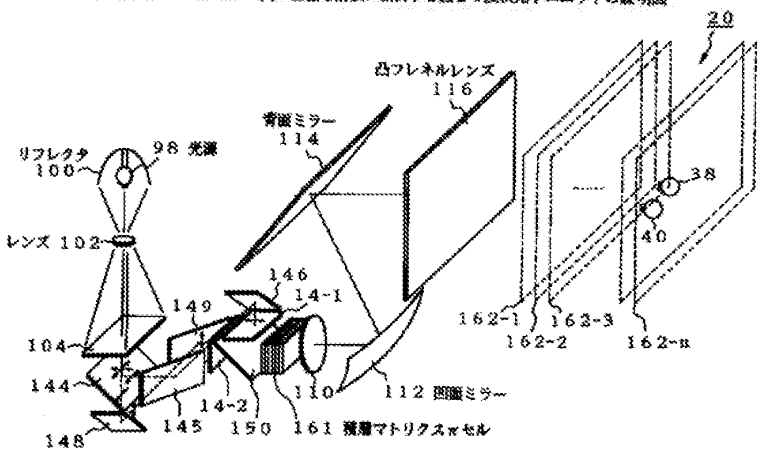
【図45】

偏光分割による図2の投映光学ユニットの説明図



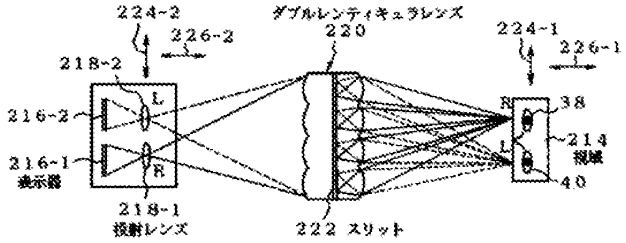
【図49】

開口設定器の装置により開口位置を前後に制御する図2の投映光学ユニットの説明図



【図59】

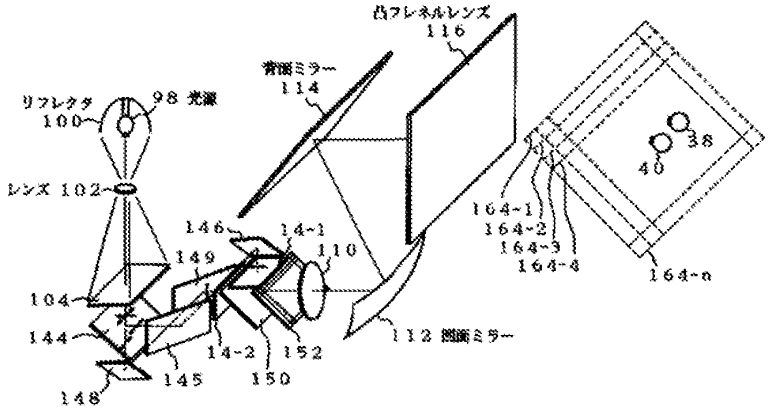
視差領域を拡大したレンティキュラ方式による従来の立体表示装置の説明図



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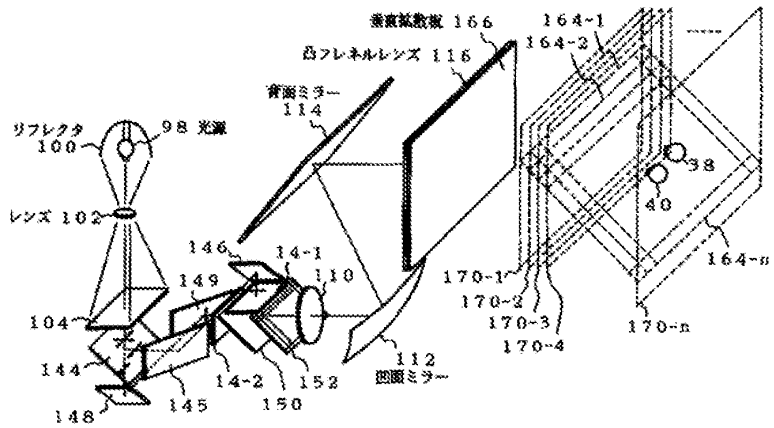
【図50】

開口設定器の斜め配置により開口位置を前後に制御する図2の投映光学ユニットの説明図



【図51】

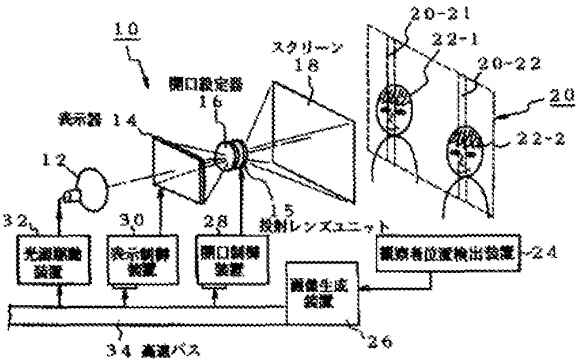
図50の凸フレネルレンズに垂直拡散板を配置した投映光学ユニットの説明図



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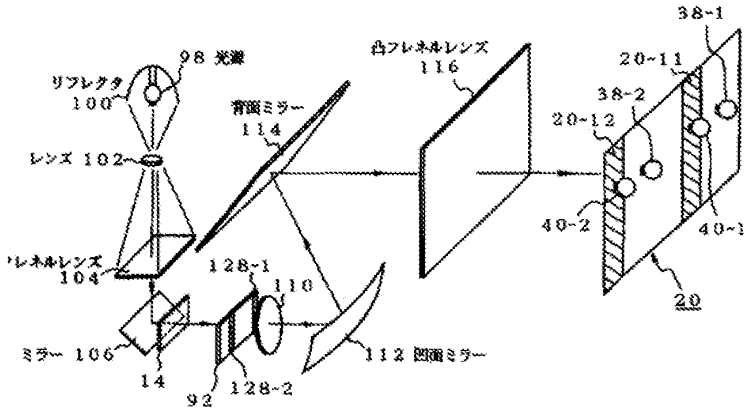
【図52】

複数の観察者による立体画像を観察可能とする本発明の装置構成の説明図



【図53】

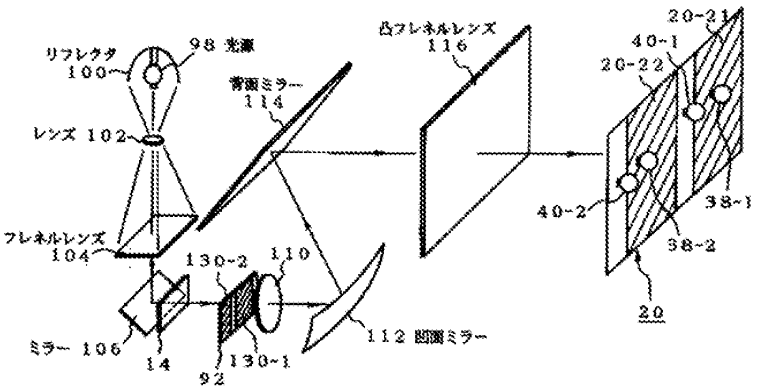
複数観察者による左眼画像投映状態での図52の投映光学ユニットの説明図



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【図54】

複数観察者による右眼画像投映状態での図52の投映光学ユニットの説明図



【手続補正書】
【提出日】平成9年4月14日
【手続補正1】
【補正対象書類名】明細書
【補正対象項目名】0009
【補正方法】変更
【補正内容】
【0009】また、複数の観察者に対応して複数のプロジェクタを用意しても、各観察者に応じて異なった移動を行うと、各プロジェクタ間で副プローブによる映像の妨害が起こるため、一人の観察者にしか対応できないという問題があった。本発明は、眼鏡等の補助光学系なしで1又は複数の観察者の移動しながらの立体観察を可能とし、更に、立体観察領域以外の観察者は鮮明な二次元画像が観察できるようにした画像表示装置及び方法を提供することを目的とする。
【手続補正2】
【補正対象書類名】明細書
【補正対象項目名】0028
【補正方法】変更
【補正内容】
【0028】観察者位置検出装置24で検出された観察者22の検出位置、具体的には観察者22の右眼及び左眼の位置検出情報は、画像生成装置26に与えられている。画像生成装置26は、検出された観察者22の右眼と左眼の各位置から見た表示対象物の画像データを、それぞれ右眼画像データ及び左眼画像データとして生成する。
【手続補正3】
【補正対象書類名】明細書
【補正対象項目名】0032
【補正方法】変更
【補正内容】
【0032】更に本発明の画像表示装置10にあっては、観察者位置検出装置24で検出している観察者22以外の他の観察者からは、表示器14に時分割で切替表示している右眼画像または左眼画像のいずれか一方の二次元画像が観察できるように開口設定器16における開口設定を行っている。図3は図2の画像表示装置によるスクリーン18前面の観察領域である。画像表示装置10のスクリーン18の前方となる所定範囲に3D観察領域20が設定され、この3D観察領域20内に観察者の右眼38と左眼40が存在すると、それぞれ異なった視差の画像の投影を受けて立体画像を観察することができる。
【手続補正4】
【補正対象書類名】明細書
【補正対象項目名】0033
【補正方法】変更
【補正内容】
【0033】観察者は3D観察領域20内であれば、どの位置においても立体表示を観察することができる。即ち、3D観察領域20内に存在する観察者の位置を画像表示装置10側でリアルタイムで検出しており、観察者の動きに応じて各移動位置から対象物体を見たときの右眼画像と左眼画像をリアルタイムで生成して、観察者の右眼38と左眼40に投射する。このため、3D観察領域20内で観察者が移動すると、これに伴って運動視差をもった立体観察ができる。

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【手続補正５】
【補正対象書類名】明細書
【補正対象項目名】００４１
【補正方法】変更
【補正内容】
【００４１】この実施形態では、パターンマッチングにより得られた右眼３８と左眼４０の中間位置Ｐの座標（ｘ０，ｙ０，ｚ０）を演算する。まず図６（Ａ）の両眼の中心位置Ｐとカメラの撮像面５４，５６上の位置を結ぶ直線とレンズ５０，５２の光軸とのなす角度θ１，θ２、更に図６（Ｃ）の側面から見た撮像面５６と両眼中心位置Ｐを結ぶ直線の光軸に対する角度αは、次式の位置情報に対する関係をもつ。
【手続補正６】
【補正対象書類名】明細書
【補正対象項目名】００６９
【補正方法】変更
【補正内容】
【００６９】図１７は時分割による立体表示を行う図２の立体表示装置１０に設ける投影光学ユニットの実施形態である。まず光源ユニットは、光源９８とリフレクタ１００で構成される。光源９８としては、例えばメタルハライトランプ等の白色光源を使用する。光源９８からの光はレンズ１０２で集光され、フレネルレンズ１０４により平行光に変換され、ミラー１０６で反射されて表示器１４に入射する。
【手続補正７】
【補正対象書類名】明細書
【補正対象項目名】００７１
【補正方法】変更
【補正内容】
【００７１】マトリクス液晶シャッタ９２に続いては、投射レンズユニット１５として、この実施形態にあっては投影レンズ１１０を設けている。投射レンズ１１０は、スクリーンとして機能する凸フレネルレンズ１１６の位置に表示器１４の開口１２８を透過した画像を結像する。投射レンズ１１０に続いては、凹面ミラー１１２が設けられる。凹面ミラー１１２は、投射レンズ１１０の口径には限界があることから、投射レンズ１１０の口径をスクリーンとして機能する凸フレネルレンズ１１６のサイズに適合するように拡大する虚像生成素子として機能する。凹面ミラー１１２で拡大された画像光は背面ミラー１１４で反射され、スクリーンとして設置された凸フレネルレンズ１１６に画像光を結像するように入射する。
【手続補正８】
【補正対象書類名】明細書
【補正対象項目名】００７９
【補正方法】変更
【補正内容】
【００７９】このため、観察領域の視域１１５にはマトリクス液晶シャッタ９２の開口１３０の位置に対応してスリット像１２０が結像される。開口１３０は、観察者の右眼３８の検出位置に対応して設定されているため、観察者の右眼３８の前に開口１３０のスリット像１２０が結像されることになる。このため観察者は、右眼３８のみによって表示器１４の右眼画像を観察することができる。
【手続補正９】
【補正対象書類名】明細書
【補正対象項目名】００８３
【補正方法】変更
【補正内容】
【００８３】本発明の投影光学ユニットによれば、マトリクス液晶シャッタ９２の開口１３０は観察領域に設定した仮想平面である視域１１５上に図示のようにスリット像１２０を結像する。このスリット像１２０の幅は、開口１３０の拡大倍率Ｋで決まる。即ち、マトリクス液晶シャッタ９２の横幅を１、観察領域の視域１１５の幅をＫとすると、開口１３０は視域１１５においてＫ倍の幅をもつスリット像１２０として結像する。
【手続補正１０】
【補正対象書類名】明細書
【補正対象項目名】００８４
【補正方法】変更
【補正内容】
【００８４】このスリット像１２０の幅は、例えば右眼３８に画像光を投影し、左眼４０には画像光を投影しない必要があり、観察者の左右方向の若干の眼の動きによる立体像の視認を確実にするため、ある程度の幅をもつ必要がある。図２２はスリット像１２０の横幅の一例である。まず観察者の右眼３８と左眼４０の間隔Ｗは、統計的にＷ＝３２．５ｍｍ～９７．５ｍｍであることが分かっている。したがって、スリット像１２０の幅は、右眼３８の中心から左右にＷ／２の幅をもった右眼観察領域２０－２とする。同様にして左眼４０についても、左眼の中心から左右にＷ／２の幅をもった左眼観察領域２０－１を破線のように設定する。
【手続補正１１】
【補正対象書類名】明細書
【補正対象項目名】０１０１
【補正方法】変更
【補正内容】
【０１０１】可動レンズ１８２はアーム１９２に装着され、アーム１９２は軸方向に開口したガイドスリット１９０を介してアクチュエータ１８６のＶＣＭコイル１９４に装着されている。ＶＣＭコイル１９４は、光軸方向に固定設置したヨーク１９６に対し摺動自在に装着されている。このため、ＶＣＭコイル１９４に通電することによりヨーク１９６との間に実回路を形成し、ＶＣＭコ

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イル194を前後方向に移動でき，これによって可動レンズ182をレンズ収納筒188内で光軸方向に移動して焦点距離を変化させることができる。

【手続補正12】
【補正対象書類名】明細書
【補正対象項目名】0102
【補正方法】変更
【補正内容】
【0102】図32は図31の投射レンズユニット15の他の実施形態である。この実施形態にあっては、図33（A）のように、固定レンズ180，184、及び可動レンズ182を備えたレンズ収納筒188を外筒198の中に収めている。可動レンズ182には例えば半径方向の対称位置に、例えばピン242，246を固定しており、ピン242，246はレンズ収納筒188の光軸方向に形成したスリット240，244を介し，外側に位置する外筒198のスリットに嵌め込まれている。

【手続補正13】
【補正対象書類名】明細書
【補正対象項目名】0107
【補正方法】変更
【補正内容】
【0107】そこで実際の装置にあっては，図37のように、凸レンズ117に近接して垂直拡散板140を設け，垂直方向にスリット像結像領域136－1～136－nを拡大して有効領域144を形成する。図38は図37の実際の投影光学ユニットの凸フレネルレンズ116個であり，凸フレネルレンズ116に合わせて垂直拡散板140を設けている。

【手続補正14】
【補正対象書類名】明細書
【補正対象項目名】0108
【補正方法】変更
【補正内容】
【0108】この垂直拡散板140を設けたことで、図36の斜めの狭い各スリット像結像領域136－1～136－nは、垂直方向に拡大された垂直拡大領域142－1～142－nに変換でき、観察者の前後方向の移動に対し、垂直方向の必要領域を有効領域とした立体観察を実現することができる。

5．空間分割による投影開口制御
図39は観察者位置検出に基づいて生成した右眼画像と左眼画像を空間分割により3D観察領域に投射するための、図2の画像表示装置における画像生成装置26及び表示制御装置30のブロック図である。空間分割の画像投影にあっては、表示器14として左眼用表示器14－1と右眼用表示器14－2の2つを使用する。

【手続補正15】
【補正対象書類名】明細書
【補正対象項目名】0109
【補正方法】変更
【補正内容】
【0109】この左眼用及び右眼用表示器14－1，14－2としては、透過型の液晶表示デバイスが使用される。左眼用及び右眼用表示器14－1，14－2に対応して、表示制御装置30には表示駆動部72－1，72－2が設けられている。画像生成装置26は、図9の時分割の場合と同じであり、モデリングデータ格納部62とレンダリング処理部64で構成され、観察者位置情報に基づいてレンリング処理部64でモデリングデータに基づいた右眼画像と左眼画像を生成して、表示制御装置30の右眼画像フレームバッファ66及び左眼画像フレームバッファ68に書き込む。尚、画像生成装置26としては、図11のカメラ画像データ格納部73及び補間画像生成部75を用いたものであってもよい。

【手続補正16】
【補正対象書類名】明細書
【補正対象項目名】0110
【補正方法】変更
【補正内容】
【0110】図40は図39の表示制御装置30による右眼画像データと左眼画像データの読み出し動作であり，2つの表示駆動部72－1，72－2が対応する右眼画像フレームバッファ66及び左眼画像フレームバッファ68のそれぞれから並列的に右眼用画像データ74と左眼用画像データ76を読み出し、同時に右眼用表示部14－2，左眼用表示器14－1に対応する画像を表示する。

【手続補正17】
【補正対象書類名】明細書
【補正対象項目名】0115
【補正方法】変更
【補正内容】
【0115】図42は、図41の空間分割の投影光学ユニットに設けたマトリクス液晶シャッタ92－1，92－2と開口制御装置のブロック図である。開口設定器16としては、2つのマトリクス液晶シャッタ92－1，92－2とそれぞれのドライバ94－1，94－2，96－1，96－2が設けられる。開口制御装置28には、2台のマトリクス液晶シャッタ92－1，92－2に対応して表示コントローラ90－1，90－2が設けられ、並列的に開口設定制御を行う。開口位置演算部88は図16の時分割の場合と同じであり、観察者位置検出情報に基づいて右眼及び左眼用の開口位置を演算して表示コントローラ90に指示する。

【手続補正18】
【補正対象書類名】明細書
【補正対象項目名】0121
【補正方法】変更
【補正内容】

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【0121】一方、分離用偏光ビームスプリッタ144を透過したP偏光成分はミラー148で反射された後、右眼用表示器14－2に入射される。左眼用表示器14－1を通過した映像光となるS偏光成分と、右眼用表示器14－2を通過して映像光となったP偏光成分は、合成用偏光ビームスプリッタ150に与えられる。合成用偏光ビームスプリッタ150は、S偏光成分とP偏光成分を合成した後、偏光分割における開口設定器として機能するマトリクスγセル152に与えられる。マトリクスγセル152に続いては投影レンズ110が設けられ、それ以降の光学系は時分割及び空間分割の場合と同様、凹面ミラー112、背面ミラー114、3D観察領域20に結像機能をもつ凸フレネルレンズ116で構成される。

【手続補正19】
【補正対象書類名】明細書
【補正対象項目名】0124
【補正方法】変更
【補正内容】
【0124】このため、TN液晶158から出力されたS偏光成分即ち右眼画像光124のみが偏光板160を通過して右眼38側に投影される。したがって図46のマトリクスγセル152において、右眼用の開口を設定したい領域についてはTN液晶158の電解をオフした電解オフ領域154を設定すればよい。一方、TN液晶158の電極間に駆動電圧を印加した電解オン状態については、図47（B）のようになる。TN液晶158の電極間に駆動電圧を印加した電解オン状態にあっては、TN液晶158による偏光面の回転機能はなくなって透過状態となり、右眼画像光124であるP偏光成分も左眼画像光122であるS偏光成分もそのままTN液晶158を通過する。

【手続補正20】
【補正対象書類名】明細書
【補正対象項目名】0131
【補正方法】変更
【補正内容】
【0131】このためスクリーン位置となる凸フレネルレンズ116の前方の3D観察領域20には、斜めに配置したマトリクスγセル152の各水平ストライプ開口に対応する水平ストライプスリット像164－1～164－nが形成される。この場合、1つ1つの水平ストライプスリット像164－1～164－nの垂直方向の幅は極めて狭く、この幅を観察者の眼が外れると立体像を観察することができない。

【手続補正21】
【補正対象書類名】明細書
【補正対象項目名】0135
【補正方法】変更
【補正内容】
【0135】このため，モード1にあっては、一人の観察者の検出位置に対応した右眼画像と左眼画像であることから、既に説明した実施例における観察者一人を対象とした場合と同じ画像生成と表示制御装置30による表示器14に対する画像表示でよい。これに対しモード2の観察者22－1，22－2ごとにそれぞれの右眼画像と左眼画像を生成する場合には、例えば時分割にあっては単一の表示器14を使用して二人分の右眼画像と左眼画像を表示する必要があるため、一人分の表示周期例えば（1／120）秒周期で表示対象とする観察者の数Nの逆数を掛け合わせた表示周期で、例えば2人分の観察者の場合は（1／240）秒周期で高速に切替表示する必要がある。

【手続補正22】
【補正対象書類名】明細書
【補正対象項目名】0136
【補正方法】変更
【補正内容】
【0136】一方、開口設定器16に対する開口制御装置28による開口制御については、二人の観察者22－1，22－2のそれぞれの右眼とそれぞれの左眼の位置に対応した開口設定を行う。図示の3D観察領域20にあっては、観察者22－1，22－2の右眼観察領域20－21，20－22を設定した状態であり、これに対応して開口設定器16には2つの右眼用の開口設定が行われている。

【手続補正23】
【補正対象書類名】明細書
【補正対象項目名】0141
【補正方法】変更
【補正内容】
【0141】尚、図52の複数観察者を対象とした装置の投影光学ユニットは、図53、図54の時分割以外に図2の単一の観察者を対象とした投影光学ユニットの実施形態と同様、空間分割によるもの、偏光分割によるものの全てをそのまま使用することができる。更に本発明は発明の目的を逸脱しない範囲で適宜の変形が可能である。更にまた本発明は、実施例に記載された数値による限定は受けない。

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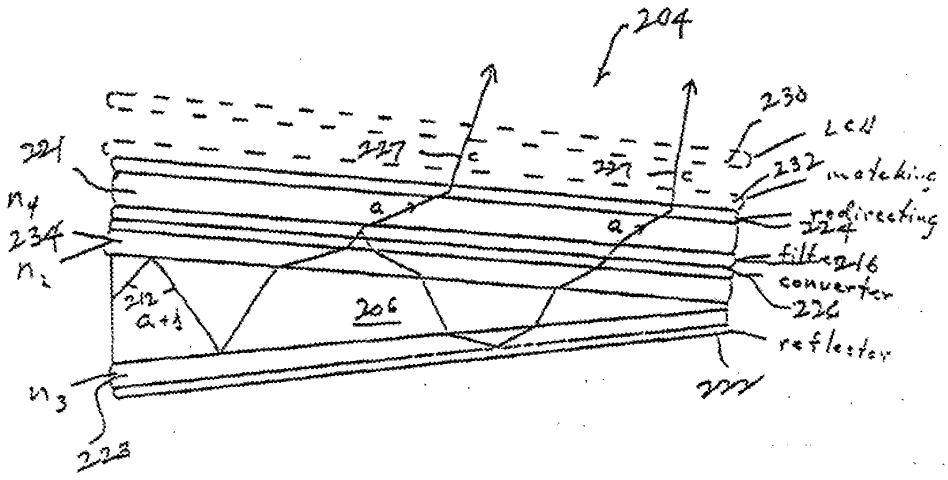
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(54) Title: TAPERED MULTILAYER LUMINAIRE DEVICE



(57) Abstract

An optical device (10) for collecting light and selectively outputting or concentrating the light. A wedge layer (12) has an optical index of refraction n1, and top (14), bottom (16) and side surfaces (18) intersecting to define an angle of inclination. A back surface (20) spans the top (14), bottom (16) and side surface (18). A first layer (28) is coupled to the bottom surface (16) of the layer (12) and has an index of refraction n2. The first layer (28) index n2 causes light input (24) through the back surface (20) of the layer (12) to be preferentially output into the first layer (28). A second layer (30) is coupled to the bottom (16) of the first layer (28) and selectively causes output of light into ambient. Additional layers, such as a light polarization layer (216), a polarization converting layer (226) and a post LCD diffuser layer (230), can be used to make preferential use of polarized light or diffuse light having passed through the LCD layer to enhance viewing of the output light.

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TAPERED MULTILAYER LUMINAIRE DEVICE

The present invention is concerned generally with a luminaire device for providing selected light illumination. More particularly, the invention is concerned with tapered luminaires, such as a wedge or disc shape, for backlighting by selective post diffusion of light output from a liquid crystal display layer and also by manipulating light polarization and filtering selected light polarizations to enhance light illumination and image output.

A variety of applications exist for luminaire devices, such as, for liquid crystal displays. For flat panel liquid crystal displays, it is important to provide adequate backlighting while maintaining a compact lighting source. It is known to use wedge shaped optical devices for general illumination purposes. Light is input to such devices at the larger end; and light is then internally reflected off the wedge surfaces until the critical angle of the reflecting interface is reached, after which light is output from the wedge device. Such devices, however, have only been used to generally deliver an uncollimated lighting output and often have undesirable spatial and angular output distributions. For example, some of these devices use white painted layers as diffuse reflectors to generate uncollimated output light.

It is therefore an object of the invention to provide an improved optical device and method of manufacture.

It is another object of the invention to provide a novel three dimensional luminaire.

It is a further object of the invention to provide an improved multilayer tapered luminaire for optical purposes, such as for controlled utilization of light polarization.

It is still another object of the invention to provide a novel tapered luminaire device for controlled transmission or concentration of light.

It is an additional object of the invention to provide a novel optical device for providing collimated polarized light illumination from the device.

It is yet a further object of the invention to provide an improved tapered luminaire having a polarization filter layer.

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It is still another object of the invention to provide a novel luminaire allowing conversion of polarized light to enhance illumination output from the invention.

It is yet a further object of the invention to provide an improved illumination system wherein a combination of a polarization filter layer and light redirecting layer are utilized to provide improved light illumination over a controlled angular range of output to the viewer.

It is still a further object of the invention to provide a novel luminaire optical device wherein a combination of a polarization filter, polarization converting layer and a post LCD diffuser layer are used to enhance light illumination from the optical device.

It is yet a further object of the invention to provide an improved luminaire optical device wherein an LCD layer is disposed adjacent an overlying post LCD diffuser layer to enable control of light distribution over broader angles to viewers without loss of light output or image qualities.

Other objects, features and advantages of the present invention will be readily apparent from the following description of the preferred embodiments thereof, taken in conjunction with the accompanying drawings described below.

Brief Description of the Drawings

FIGURE 1 shows a prior art wedge shaped device;

FIGURE 2A illustrates a multilayer tapered luminaire device constructed in accordance with the invention; FIG. 2B is a magnified partial view of the junction of the wedge layer, the first layer and the second faceted layer; FIG. 2C is an exaggerated form of FIG. 2A showing a greatly enlarged second faceted layer; FIG. 2D is a partial view of the junction of the three layers illustrating the geometry for brightness determinations; FIG. 2E is a multilayer wedge device with a light redirecting, internally transmitting layer on the bottom; FIG. 2F shows a wedge device with a lower surface translucent layer; FIG. 2G shows a wedge layer with a lower surface refracting faceted layer; FIG. 2H shows a wedge layer with a lower surface refracting layer and curved facets thereon; FIG. 2I shows a wedge layer with a refracting layer of facets

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having variable facet angles; FIG. 2J shows a single refracting prism coupled to a wedge layer; FIG. 2K shows a single refracting prism coupled to a wedge layer and with an integral lens; FIG. 2L shows a reflecting faceted layer coupled to a wedge device; FIG. 2M shows a reflecting faceted layer with curved facet angles and coupled to a wedge device; FIG. 2N shows a flat reflecting facet on a wedge layer and FIG. 2O shows a curved reflecting facet on a wedge layer;

FIGURE 3A illustrates a multilayer wedge device with curved facets on the ambient side of the second layer and FIG. 3B shows a magnified partial view of the junction of the various layers of the device;

FIGURE 4A shows calculated brightness performance over angle for an asymmetric range of angles of illumination; FIG. 4B shows calculated brightness distribution performance over angle for a more symmetric angle range; FIG. 4C illustrates calculated brightness performance over angle for the symmetry of FIG. 4B and adding an external diffuser element; FIG. 4D illustrates an output using flat reflecting facets, no parallel diffuser; full-width at half-maximum brightness (FWHM) = 7 degrees; FIG. 4E illustrates an example of nearly symmetrical output distribution, measured using flat facets with parallel lenticular diffuser; FWHM = 34 degrees; FIG. 4F illustrates an example of asymmetrical output distribution, measured using curved facets; FWHM = 32 degrees; FIG. 4G illustrates an example asymmetrical output distribution, measured using curved facets; FWHM = 26 degrees; FIG. 4H illustrates an example of a bimodal output distribution, measured using one faceted reflecting layer and one faceted refractive layer; and FIG.4I illustrates an example of an output distribution with large "tails", measured using a diffuse reflective bottom redirecting layer and a refracting/internally-reflecting top redirecting layer;

FIGURE 5A shows a top view of a disc shaped light guide and FIG. 5B illustrates a cross section taken along 5B-5B in FIG. 5A;

FIGURE 6A shows a cross sectional view of a multilayer tapered luminaire device with an air gap layer included; FIG. 6B shows another tapered luminaire in cross section with a compound parabolic light source/concentrator; FIG. 6C illustrates another tapered luminaire in

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cross section with a variable parametric profile light source and a lenticular diffuser; and FIG. 6D shows another tapered luminaire in cross section with non-monotonic wedge layer thickness;

FIGURE 7 illustrates a reflective element disposed concentrically about a light source;

FIGURE 8 illustrates a reflective element disposed about a light source with maximum displacement between the reflector center of curvature and the center of the light source;

FIGURE 9A illustrates use of a redirecting layer to provide a substantially similar angular distribution emanating from all portions of the device and FIG. 9B illustrates use of a redirecting layer to vary angular distribution emanating from different portions of the device, and specifically to focus the various angular distributions to enhance their overlap at a selected target distance;

FIGURE 10 illustrates one form of pair of lenticular arrays of a luminaire; and

FIGURE 11 illustrates a lenticular diffuser array and curved facet layer of a luminaire;

FIGURE 12A illustrates a wedge shaped luminaire having a pair of diffraction gratings or hologram layers; FIG. 12B shows a wedge shaped luminaire with a pair of refracting facet layers and diffusers; FIG. 12C illustrates a wedge shaped luminaire with a pair of faceted layers; FIG. 12D shows a wedge shaped luminaire with two refracting single facet layers; FIG. 12E illustrates a wedge shaped luminaire with a refracting single facet layer and a bottom surface redirecting layer; FIG. 12F shows a luminaire with a top surface redirecting layer of a refracting faceted layer and a bottom surface refracting and internally reflecting layer; FIG. 12G illustrates a luminaire with a top surface refracting/internally reflecting faceted layer and a bottom surface refracting/internally reflecting faceted layer; FIG. 12H shows a luminaire with a top surface refracting faceted layer and a bottom surface refracting/internally reflecting faceted layer; FIG. 12I illustrates a luminaire with a bottom surface specular reflector and a top layer transmission diffraction grating or transmission hologram; FIG. 12J shows a luminaire with a bottom

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surface specular reflector and a top surface refracting faceted layer and diffuser; FIG. 12K illustrates a luminaire with a bottom layer specular reflector and a top layer refracting/internally reflecting faceted layer; FIG. 12L shows a luminaire with a bottom specular reflector and a top layer refracting/internally reflecting faceted layer; FIG. 12M illustrates a luminaire with an initial reflector section including an integral lenticular diffuser; FIG. 12N shows a luminaire with a roughened initial reflector section of a layer; FIG. 12O illustrates a luminaire with an eccentric light coupler and converging to the wedge shaped section; FIG. 12P shows a luminaire with an eccentric light coupler and a diffuser and roughened or lenticular reflector; FIG. 12Q illustrates a luminaire with a bottom specular or diffusely reflecting layer and a top refracting layer and FIG. 12R shows a luminaire for generating a "bat wing" light output;

FIGURE 13 illustrates a combination of two wedge shaped sections formed integrally and using two light sources;

FIGURE 14 shows a tapered disk luminaire including a faceted redirecting layer;

FIGURE 15 illustrates a luminaire operating to provide a collimated light output distribution;

FIGURE 16A shows a prior art ambient mode LCD and FIG. 16B illustrates a prior art transflective LCD unit;

FIGURE 17 shows a luminaire operative in ambient and active modes with a faceted redirecting layer and a lenticular diffuser; and

FIGURE 18A illustrates a luminaire with an array of microprisms for a faceted surface disposed over a diffuse backlight and with the microprisms having equal angles on both sides, but each microprism having progressively changing facet angles across the face; FIG. 18B shows a microprism array as in FIG. 18A with the sides of each microprism having different angles varying again across the faceted surface;

FIGURE 19A illustrates a luminaire having a polarization filter layer; FIG. 19B shows a luminaire with a plurality of layers including a polarization filter layer; and FIG. 19C shows a variation on FIG. 19B

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with layer indices enabling output of both polarizations of light on one side of the luminaire;

FIGURE 20A illustrates a luminaire similar to FIG. 19B but further includes a reflector layer; FIG. 20B illustrates a luminaire as in FIG. 20A but a redirecting layer is disposed on the same side of the base layer and the polarization filter; and FIG. 20C is a variation on FIG. 20B with an additional redirecting layer and rearranged n_2/filter/redirecting layers;

FIGURE 21A illustrates a luminaire having a polarization converting layer and polarization filter layer; FIG. 21B is a variation on FIG. 21A with the polarization filter layer and polarization converting layer on the same side of the base layer;

FIGURE 22A illustrates a luminaire with a polarization filter layer one side of the base layer and a polarization converting layer on the other side; FIG. 22B shows a variation on FIG. 22A with the filter and converting layers adjacent one another on the same side of the base layer; FIG. 22C shows a further variation of FIG. 22A and B and with a reflector layer added; FIG. 22D illustrates a further variation on FIG. 22C with the converting layer moved to the other side of the base layer and FIG. 22E shows another variation on FIG. 22D;

FIGURE 23A illustrates a luminaire having plural layers including a polarization filter, a converting, a redirecting, a reflector and an LCD layer; FIG. 23B shows a variation on FIG. 23A; and FIG. 23C illustrates yet another variation on FIG. 23A;

FIGURE 24A illustrates conventionally a luminaire with two polarization filter layers for two polarization states; FIG. 24B shows a variation on FIG. 24A plus an added light redirecting layer; FIG. 24C is a further variation on FIG. 24B with a matching layer, a second redirecting layer and an LCD layer; FIG. 24D is yet another variation on FIGS. 24B and C; FIG. 24E is a variation on FIG. 24D with an added converting layer and two polarization filter layers and two redirecting layers and FIG. 24F is still another

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variation on FIG. 24E with LCD layers on both sides of the base layer;

FIGURE 25A illustrates a general construction utilizing two polarization filter layers and a polarization converting layer; FIG. 25B shows a variation on FIG. 25A with an added redirecting layer;

FIGURE 26A illustrates a multilayer luminaire with a light source coupled to a light angle transformer to control spatial uniformity of light ouput from the device; FIG. 26B is a variation on FIG. 26A;

FIGURE 27A illustrates a luminaire with a faceted redirecting layer and light polarization and polarization converting layers; and FIG. 27B is a variation on FIG. 27A, wherein the redirecting layers includes a reflecting layer with curved facets for focusing light in a preferred viewing zone;

FIGURE 28A illustrates a luminaire including a polarization light filter, polarization converter and a faceted redirecting and diffusing layer; FIG. 28B shows a variation on FIG. 28A with two polarization filter layers and two faceted redirecting layer; FIG. 28C shows a light source coupled to a luminaire and is a variation on FIG. 28A; FIG. 28D is a variation on FIG. 28C; and FIG. 28E is yet another variation on FIG. 28C;

FIGURE 29A illustrates a luminaire with polarized light output in combination with an LCD layer and FIG. 29B is a variation on FIG. 29A;

FIGURE 30A illustrates a conventional LCD display system; FIG. 30B shows a polarization filter layer; FIG. 30C illustrates a multilayer thin film form of polarization filter; FIG. 30D shows a Brewster Stack form of polarization filter; FIG. 30E illustrates a birefringent plate and interacting polarized light; FIG. 30F shows Eulerian angles and optical vectors; FIGURE 30G shows a backlight providing collimated light in the xz plane and FIG. 30H shows a detailed enlargement of a zone from FIG. 30G;

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FIGURE 31A illustrates a luminaire with a coupled birefringent layer; FIG. 31B shows a luminaire and birefringent layer and an added light redirecting layer; FIG. 31C illustrates a luminaire system similar to FIG. 31B with an added light polarization converting layer; FIG. 31D is similar to FIG. 31C but the converting layer is on the same side of the base layer as the birefringent layer; FIG. 31E illustrates a variation on FIG. 31C with the converting layer coupled directly to the base layer; FIG. 31F is similar to FIG. 31D but the redirecting layer comprises a faceted layer; FIG. 31G is based on the embodiment of FIG. 31F but also includes a matching layer, an LCD layer and a diffuser layer; and FIG. 31H is a variation on FIG. 31G; and

FIGURE 32A illustrates a luminaire system including an LCD layer and a post LCD diffuser layer for processing unpolarized light; FIG. 32B is a variation on FIG. 32A; and FIG. 32C is a variation on FIG. 32B.

Detailed Description of Preferred Embodiments

A multilayer luminaire device constructed in accordance with one form of the invention is illustrated in FIG. 2 and indicated generally at 10. A prior art wedge 11 is shown generally in FIG. 1. In this wedge 11 the light rays within the wedge 11 reflect from the surfaces until the angle of incidence is less than the critical angle ($\sin^{-1}1/n$) where n is the index of refraction of the wedge 11. The light can exit equally from both top and bottom surfaces of the wedge 11, as well as exiting at grazing angles.

The multilayer luminaire device 10 (hereinafter "device 10") shown in FIG. 2A includes a base or wedge layer 12 which has a characteristic optical index of refraction of n_1. The term "wedge layer" shall be used herein to include all geometries having converging top and bottom surfaces with wedge shaped cross sectional areas. The x, y and z axes are indicated within FIGS. 2A and 2C with the "y" axis perpendicular to the paper. Typical useful materials for the wedge layer 12 include almost any transparent material, such as glass, polymethyl methacrylate, polystyrene, polycarbonate, polyvinyl chloride, methyl

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methacrylate/styrene copolymer (NAS) and styrene/acrylonitrile. The wedge layer 12 in FIG. 2A further includes a top surface 14, a bottom surface 16, side surfaces 18, edge 26 and a back surface 20 of thickness t_0 spanning the top, bottom and side surfaces. A light source, such as a tubular fluorescent light 22, injects light 24 through the back surface 20 into the wedge layer 12. The light 24 is internally reflected from the various wedge layer surfaces and is directed along the wedge layer 12 toward the edge 26. Other possible light sources can be used and will be described hereinafter. Generally, conventional light sources provide substantially incoherent, uncollimated light; but coherent, collimated light can also be processed by the inventions herein.

For the case where the surfaces 14 and 16 are flat, a single angle of inclination ϕ for a linear wedge is defined by the top surface 14 and the bottom surface 16. In the case of nonlinear wedges, a continuum of angles ϕ are definable; and the nonlinear wedge can be designed to provide the desired control of light output or concentration. Such a nonlinear wedge will be described in more detail later.

In the embodiment of FIG. 2A a first layer 28 is coupled to the wedge layer 12 without any intervening air gap, and the first layer 28 has an optical index of refraction n_2 and is optically coupled to the bottom surface 16. The first layer 28 can range in thickness from a few light wavelengths to much greater thicknesses and accomplish the desired functionality. The resulting dielectric interface between the wedge layer 12 and the first layer 28 has a higher critical angle than at the interface between the wedge layer 12 and ambient. As will be apparent hereinafter, this feature can enable preferential angular output and collimation of the light 24 from the device 10.

Coupled to the first layer 28 is a second layer 30 (best seen in FIG. 2B) having an optical index of refraction n_3 which is greater than n_2, and in some embodiments preferably greater than n_1. This configuration then allows the light 24 to leave the first layer 28 and enter the second layer 30. In the embodiment of FIG. 2A there are substantially no intervening air gaps between the first layer 28 and the second layer 30. In the preferred form of the invention illustrated in FIG. 2A, n_1 is about 1.5,

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$n_2<1.5$ and $n_3 \geq n_1$. Most preferably, $n_1=1.5$, $n_2<1.5$ (such as about one) and $n_3 \geq n_1$.

In such a multilayer configuration for the device 10 shown in FIG. 2, the wedge layer 12 causes the angle of incidence for each cyclic time of reflection from the top surface 14 to decrease by the angle of inclination 2ϕ (relative to the normal to the plane of the bottom surface 16). When the angle of incidence with the bottom surface 16 is less than the critical angle characteristic of the interface between the wedge layer 12 and the first layer 28, the light 24 is coupled into the first layer 28. Therefore, the first layer 28 and the associated optical interface properties form an angular filter allowing the light 24 to pass when the condition is satisfied: $\theta<\theta_c = \sin^{-1}(n_2/n_1)$. That is, the described critical angle is higher than for the interface between air and the wedge layer 12. Therefore, if the two critical angles differ by more than 6ϕ, nearly all of the light 24 will cross into the interface between the wedge layer 12 and the first layer 28 before it can exit the wedge layer 12 through the top surface 14. Consequently, if the two critical angles differ by less than ϕ, a substantial fraction, but less than half, of the light can exit the top surface 14. If the two angles differ by more than ϕ and less than 6ϕ, then substantially more than half but less than all the light will cross into the wedge layer 12 and the first layer 28 before it can exit the wedge layer 12 through the top surface 14. The device 10 can thus be constructed such that the condition $\theta<\theta_c$ is satisfied first for the bottom surface 16. The escaping light 24 (light which has entered the layer 28) will then enter the second layer 30 as long as $n_3>n_2$, for example. The light 24 then becomes a collimated light 25 in the second layer 30 provided by virtue of the first layer 28 being coupled to the wedge layer 12 and having the proper relationship between the indices of refraction.

In order to generate an output of the light 24 from the device 10, the second layer 30 includes means for scattering light, such as a paint layer 33 shown in FIG. 2E or a faceted surface 34 shown in both FIGS. 2B and 2C. The paint layer 33 can be used to preferentially project an image or other visual information. The paint layer 33 can comprise,

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for example, a controllable distribution of particles having characteristic indices of refraction.

By appropriate choice, light can also be redirected back through the wedge layer 12 and into ambient (see light 29 in FIGS. 2A and 2C) or output directly into ambient from the second layer 30 (see light 29' in FIG. 2F).

In other forms of the invention a further plurality of layers with associated "n" values can exist. In one preferred form of the invention the index of the lowest index layer can replace n_2 in equations for numerical aperture and output angle (to be provided hereinafter). Such further layers can, for example, be intervening between the wedge layer 12 and the first layer 28, intervening between the first layer 28 and the second layer 30 or be overlayers of the wedge layer 12 or the second layer 30.

In certain embodiments the preferred geometries result in output of light into ambient without being reflected back through the wedge layer 12. For example, in FIG. 2F the device 10 can include a translucent layer 37. In another form of this embodiment shown in FIG. 2G, a refracting layer 38 is shown. The refracting layer 38 can include flat facets 39 for providing a collimated output. Also shown in phantom in FIG. 2G is a transverse lenticular diffuser 83 which will be described in more detail hereinafter. The diffuser layer 83 can be used with any of the invention geometries, including above the wedge layer 12 as in FIG. 6A.

In yet another example shown in FIG. 2H, the refracting layer 38 can include curved facets 41 for providing a smoothly broadened output over a desired angular distribution. In a further example shown in FIG. 2I, the refracting layer 38 includes variable angle facets 42. These facets 42 have facet angles and/or curvature which are varied with position across the facet array to focus output light in a desired manner. Curved facets would enable producing a softly focused region within which the entire viewing screen appears to be illuminated. Examples of the application to computer screen illumination will be described hereinafter. In FIGS. 2J and 2K are shown, respectively, a single refracting prism element 43 and the prism element 43 with an integral

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lens 44 to focus the output light. FIGS. 2L and M show the faceted surface 34 with the facets angularly disposed to control the output distribution of light. In FIGS. 2K and 2L the light is output to a focal point "F", while in FIG. 2M the output is over an approximate viewing range 45. FIGS. 2N and 2O illustrate flat reflecting facets 48 and curved reflecting facet 49 for providing a collimated light output or focused light output, respectively.

As shown in FIGS. 2A and C the faceted surface 34 optically reflects and redirects light 29 through the second layer 30, the first layer 28 and then through the wedge layer 12 into ambient. Only a fraction of each facet is illuminated, causing the output to appear alternately light and dark when viewed on a sufficiently small scale. Since this pattern is typically undesirable, for the preferred embodiment shown in FIG. 2B the period of spacing between each of the faceted surfaces 34 is preferably large enough to avoid diffraction effects, but small enough that the individual facets are not detected by the intended observing means. The spacing is also chosen to avoid forming Moiré interference patterns with any features of the device to be illuminated, such as a liquid crystal display or CCD (charge coupled device) arrays. Some irregularity in the spacing can mitigate undesirable diffraction Moiré effects. For typical backlighting displays, a spacing period of roughly 0.001-0.003 inches can accomplish the desired purpose.

The faceted surface 34 in FIGS. 2B and 2C, for example, can be generally prepared to control the angular range over which the redirected light 29 is output from the device 10. The minimum distribution of output angle in the layer 30 has a width which is approximately equal to:

$$\Delta\theta = 2\,\phi[(n_1^2-n_2^2)/(n_3^2-n_2^2)]^{1/2}$$

Thus, since ϕ can be quite small, the device 10 can be quite an effective collimator. Therefore, for the linear faceted surface 34, the exiting redirected light 29 has a minimum angular width in air of approximately:

$$\Delta\theta air = n_3\Delta\theta = 2\phi(n_1^2-n_2^2)/[1-(n_2/n_3)^2]^{1/2}.$$

As described hereinbefore, and as shown in FIGS. 2H, 2I, 2K, 2L, 2M, and FIG. 3, the facet geometry can be used to control angular output in

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excess of the minimum angle and also focus and control the direction of the output light.

Fresnel reflections from the various interfaces can also broaden the output angle beyond the values given above, but this effect can be reduced by applying an anti reflection coating 31 on one or more of the internal interfaces, as shown in FIG. 2B.

The brightness ratio ("BR") for the illustrated embodiment can be determined by reference to FIG. 2D as well as by etendue match, and BR can be expressed as:

$$B.R. = \frac{\text{output brightness}}{\text{source brightness}}$$

or, B.R. = illuminated area/total area

B.R. = $[1-(n_2/n_3)^2]^{1/2}$ = 0.4-0.65 (for most transparent dielectric materials). For example, the wedge layer 12 can be acrylic (n_1 = 1.49), the first layer 28 can be a fluoropolymer (n_2 = 1.28-1.43) or Sol-gel (n_2 = 1.05-1.35, fluoride salts (n_2 = 1.38-1.43) or silicone based polymer or adhesive (n_2 = 1.4-1.45); and the second layer 30 can be a faceted reflector such as polycarbonate (n_3 = 1.59), polystyrene (n_3 = 1.59) epoxy (n_3 = 1.5-1.55) or acrylic (n_3 = 1.49) which have been metallized at the air interface.

The flat, or linear, faceted surfaces 34 shown, for example, in FIGS. 2B and 2C can redirect the incident light 24 to control direction of light output and also substantially preserve the angular distribution of light $\Delta\theta$ which is coupled into the second layer 30 by the angle-filtering effect (see, for example, FIG. 4D). For example, in one preferred embodiment shown in FIG. 2L, the faceted surfaces 34 reflect light with the flat facet angles varied with position to focus the output light. In FIG. 2M the faceted surfaces 34 include curved facet angles which vary with position to produce a softly focused viewing zone 45 within which the entire screen appears to be illuminated (see also, for example FIGS. 4F and 4G). Also show in phantom in FIG. 2M is an exemplary liquid crystal display 47 usable in conjunction with the invention. As further shown in FIGS. 3A and B, curved facets 36 also redirect the incident light

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24, but the facet curvature increases the resulting range of angular output for the redirected light 29 (see for comparison for flat facets FIG. 2D). For example, it is known that a concave trough can produce a real image, and that a convex trough can produce a virtual image (see, for example, FIG. 3B). In each case the image is equivalent to a line source emitting light uniformly over the desired angular output range. Consequently, an array of such trough shaped facets 36 can redirect the incoming form of collimated light 25 from the first layer 28 (see FIG. 2C), and a plurality of such line source images then form the redirected light 29. By arranging the spacing of the curved facets 36 to less than human eye resolution, the resulting array of line sources will appear very uniform to an observer. As previously mentioned, the choice of about three hundred to five hundred lines/inch or 0.002 to 0.003 inches for the period of facet spacing provides such a result. For a typical LCD display viewing distances of approximately twenty inches or greater are conventional.

Other useful facet shapes can include, for example, parabolic, elliptical, hyperbolic, circular, exponential, polynomial, polygonal, and combinations thereof. The user can thus construct virtually arbitrary distributions of averaged brightness of illumination using different facet designs. For example, polygon shaped facets can be used to produce output angular distributions having multiple peaks.

Examples of brightness distribution over various ranges of angular output using a curved-faceted reflector are illustrated in FIGS. 4A-4C, 4F and 4G. FIG. 4C and 4E shows the brightness distribution in the case of a reflector having linear facets, and further including a diffuser element 40 (shown in phantom in FIG. 2C). The predicted performance output is shown for the various angular ranges (see FIGS. 4A-4C) and compared with the measured angular output of light for a commercially available source (labeled "Wedge"), such as a "Wedge Light" unit, a trademark of Display Engineering. The preferred angular range can readily be modified to accommodate any particular viewing and collimation requirements up to the minimum angle $\Delta\theta$ (air) described hereinbefore by the equation in terms ϕ, n_1, n_2 and n_3. This modification can be accomplished by progressively changing the curvature of the curved

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facets 36 in the manner shown in FIG. 2M and discussed hereinbefore. In addition to the illustrated control of the vertical viewing angular range, modification of the horizontal viewing range can also be accomplished by appropriate changes of the shape of the curved facets 36. The above described angular distributions shown in FIGS. 4A-4I are representative when the device 10 is processing the light 24 within the numerical aperture $NA = (n_1^2 - n_2^2)^{1/2}$. When light is outside this range, additional techniques can be applied to help control the angular output range.

FIGS. 9A and 9B further illustrate the use of redirecting means to provide a tightly overlapping focused illumination output and a less overlapping focused illumination output, respectively. These concepts can be applied practically by considering that a typical portable computer screen 87 has a vertical extent "V" of about 150mm, while a typical viewing distance, "D", is 500mm. A viewer at distance "D", positioned normal to the vertical center of the computer screen 87 will view different areas of the screen 87 at angles ranging from -8.5° measured at the top of the screen 87 to +8.5° measured at the bottom of the screen 87. This variation in viewing angle can, however, cause undesirable effects in use of a system having such screen illumination. Such a limited illumination angle for the screen 87 implies a limited range of positions from which a viewer can see a fully illuminated screen 87 (see FIG. 9A). Defining the viewer position in terms of the angle and distance from the center of the screen 87, then the effective angular range is substantially reduced below the nominal illumination angle. For example, if the nominal illumination range is ±20° measured at each individual facet, then the effective viewing range is reduced to ±12° in the typical flat panel illuminator shown in FIG. 9A. The resulting illumination between 12°-20°, either side of center for the screen 87, will appear to be nonuniform to the viewer.

The invention herein can be used to overcome the above described nonuniformities by controlling the orientation of the faceted surface 34. As illustrated, for example, in FIG. 2M both surfaces of the facets are rotated progressively such that the flat facet surface is varied from 35.6° to 33.3° relative to, or parallel to, the edges of the planes defining the

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various layers of the device 10. This systematic variation from the top to the bottom of screen 89 (see FIG. 9B) results in the redirected output illustrated. The faceted surface 34 can further be combined with the diffuser 83 and the like to produce a variable, but controllable light illumination output distribution. A flat faceted surface 168 can further be combined with a diffuser 170. Therefore, as shown in FIG. 9B the ability to rotate the angular distributions of light at different points on the screen 89 enable compensation for the variation in viewing angle with position. Systematic variations in the faceted surface 34 can further include variations in one or more facet angles, the spacing of the facets 38, or the depth and width of the individual facets 38. In other embodiments, the same principles can be applied to focus the output of any faceted redirecting layer. Examples are shown in FIGS. 2I and 2L.

In another example of overcoming nonuniformities of illumination, an array of micro-prisms for the faceted surface 34 can be laid over a conventional diffuse backlight 101 (see FIG. 18A). This faceted surface 34 operates by a combination of refraction and total internal reflection to permit only a limited angular range to be output through the layer into ambient. This angular range depends on the facet angles. For the case of acrylic film (n=1.49), highest brightness is typically achieved with a prism included angle of 90-100 degrees, resulting in a viewing angle of approximately $\pm$ 35 degrees. Backlights using such a geometry show a sharp "curtaining" effect which is disconcerting to many viewers. This effect can be ameliorated by rotating the facets 38 from top to bottom of the screen to produce a focusing effect (see FIG. 18B). Simple ray-tracing shows that, for included angles in the range of 100°-110°, a facet rotated by an angle θ will produce an angular distribution rotated by approximately $\theta/2$. In the embodiment shown in FIG. 18 the progressive variation of facet face angle can vary as position χ along the faceted surface 34 wherein, for example:

$$\Psi_1 = 35^\circ - (0.133^\circ/\text{mm}) \cdot \chi$$

$$\Psi_2 = 35^\circ + (0.133^\circ/\text{mm}) \cdot \chi$$

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This progressive facet angle change will produce an angular distribution which varies by approximately ten degrees across the screen 89, and satisfies the generic constraints outlined above.

Whatever the desired facet shapes, the faceted surface 34 (see, FIG. 2D) is preferably formed by a conventional process such as molding or other known milling processes. Details of manufacture will be described hereinafter:

Nonlinear Wedges.

In another form of the invention the wedge layer 12, which is the primary lightguide, can be other than the linear shape assumed hereinbefore. These shapes allow achievement of a wide variety of selected light distributions. Other shapes can be more generally described in terms of the thickness of the wedge layer 12 as a function of the wedge axis "z" shown in FIGS. 2B and C (the coordinate axis which runs from the light input edge to the small or sharp edge 26). For the linear shaped wedge,

$$A(z) = A_0 - C \cdot z \qquad (1)$$

A_0 = maximum wedge thickness (see FIG. 2A)

C = constant = $\tan \phi$

A large range of desired spatial and angular distributions can be achieved for the light output power (power coupled to the second layer 30). This light output power is thus the light available for output to the ambient by the appropriately faceted surfaces 34 or 36, or even by the diffuse reflector 33 (see FIG. 2E) or other means.

For example, if L and M are direction cosines along the x and y axes, respectively, then L_0 and M_0 are the values of L and M at the thick edge (z=0). This initial distribution is Lambertian within some well-defined angular range, with little or no light outside that range. This distribution is especially important because ideal non-imaging optical elements have limited Lambertian output distributions. The key relationship is the adiabatic invariant, $A(z)\cos(\theta_c)$ which is approximately equal to A_0L_0 and which implicitly gives the position (z) of escape. To illustrate this concept, suppose we desire uniform irradiance so that dP/dz = constant. Suppose further that the initial phase

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space uniformly fills an elliptical area described by the following expression:

$$L_o^2/\sigma^2 + M_0^2/\tau^2 = 1 \qquad (2)$$

where τ is the dimension of an ellipse along the M axis and σ is the dimension of the ellipse along the L axis.

Then, $dP/dL = \text{const} \cdot [1-L^2/\sigma^2]^{1/2}$ but $dA/dz = [A_o/L_c]\, dL_o/dZ$ where $L_c = \cos\theta_c$. Therefore, $[1-(L_cA)^2/(A_o\sigma)^2]^{1/2}\, dA = \text{constant times}$ dz. Suppose $\sigma = L_c$ in the preferred embodiment. This result can be interpreted by the substitution $A/A_0 = \sin u$, so that $A = A_0 \sin u$ and $u + 1/2 \sin(2u) = (\pi/2)(1-z/D)$ where D is the length of the wedge layer 12.

If the desired power per unit length is dP/dz, more generally, then the desired shape of the wedge layer 12 is determined by the differential equation:

$$dA(z)/dz = - dP/dz \; \frac{(A_o/[1-(n_2/n_1)^2]^{1/2})}{dP/dL_o} \qquad (3)$$

Note that in all these cases the output distribution has only approximately the desired form because it is modified by Fresnel reflections. Note also that even when the wedge device 10 is curved, if the curvature is not too large, it may still be useful to define an average angle ϕ which qualitatively characterizes the system.

In another aspect of the invention the geometry of the above examples has an x,y interface between two refractive media with indices n_1 and n_2. The components nM,nN are conserved across the interface so that $n_1M_1 = n_2M_2$, $n_1N_1 = n_2M_2$. The angle of incidence projected in the x,z plane is given by $\sin\theta_{eff} = N/(L^2 - N^2)^{1/2}$. Then using the above relations, $\sin\theta_{2eff}/\sin\theta_{1\,eff} = (n_1/n_2)[1 - M_1^2]^{1/2}/[1 - (n_1/n_2)^2M_1^2]^{1/2} = (n_1/n_2)_{eff}$. For example, for $n_1 = 1.49$, $n_2 = 1.35$, $M_1 = 0.5$, the effective index ratio is $1.035(n_1/n_2)$, which is only slightly larger than the actual index ratio.

Variation of Index of Refraction Over Spatial Parameters.

In the general case of tapered light guides, the wedge layer 12 is generally along the z axis with the narrow dimension along the x axis

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(see, for example, FIG. 2A). If we introduce optical direction cosines (nL,nM,nM) where L,M,N are geometric direction cosines along x,y,z, then n is the refractive index which may vary with spatial position. For guided rays in the wedge layer 12, the motion in x is almost periodic, and the quantity $\phi nLdx$ for one period is almost constant as the ray propagates along z. This property is called adiabatic invariance and provides a useful framework for analyzing the lightguide properties.

In a first example the wedge device 10 shown in FIG. 2A has a uniform index in the wedge layer 12 and is linearly tapered in z with width $A(z) = A_0 - C \cdot z$. Then, along the zigzag ray path, $L(z)A(z)$ is approximately equal to a constant by adiabatic invariance. If a ray starts at $z = 0$ with $L = L_0$, then $(A_0 - C \cdot z)L(z)$ is approximately equal to L_0A_0. The ray will leak out of the wedge layer 12 when $L = \cos\theta_c$ where θ_c is the critical angle $= [1-(n_2/n_1)^2]^{1/2}$. Thus, the condition for leaving the wedge layer 12 is $A_0-C \cdot z = L_0A_0/\cos\theta_c$. This will occur at $z = (A_0/C)(1 - L_0/\cos\theta_c)$. Consequently, the density of rays emerging in z is proportional to the density of rays in the initial direction cosine L_0. For example, the density will be uniform if the initial distribution in L_0 is uniform.

In a second example, the index profile is no longer uniform but falls off both in x and in z. If the fall-off in z is much slower than in x, the light ray path is still almost periodic, and the above adiabatic invariance still applies. Then, as the light ray 24 propagates in z, the path in x,nL space is almost periodic. Therefore the maximum value of L(z) increases and at some z may reach the critical value for escape. The z value for escape depends on the details of the index (n) profile. When this is specified, the analysis proceeds as in example one above. Thus, for a parabolic index profile, the index profile has the form $n^2(x) = n^2_0[1 - 2\Delta (x/\rho)^2]$ for $-\rho<x\rho$, $= n_1^2 = n^2_0[1 - 2\Delta]$ for $|x| > \rho$. Then, the critical angle at $x = 0$ is still given by $\sin^2 \theta_c = 2\Delta = 1 - (n_1/n_0)^2$. Then, if we have n_0 a slowly decreasing function of z, the slope θ at $x = 0$ will slowly increase by the adiabatic invariance of $\phi nLdx$, while θ_c decreases so that light rays will escape. The details of the light ray distributions will depend on how the index (n) varies with z.

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Nonwedge Tapered Geometries

In the most general case the light can be input into any shape layer (e.g., parallelepiped, cylinder or non-uniform wedge), and the principles described herein apply in the same manner. In addition, the index of refraction can be varied as desired in (x,y,z) to achieve the appropriate end result when coupled to means to output light to ambient.

For example, consider a disc-shaped light guide 46 which is tapered in the radial direction r shown in FIG. 5. The direction cosines in cylindrical polar coordinates are k_r, k_θ, k_z. Light 48 propagating in this guide 46 satisfies the relationship:

$$\phi n k_z dz \sim \text{constant. (adiabatic invariance)} \quad (4)$$

$$nrk_\theta = \text{constant. (angular momentum conservation)} \quad (5)$$

The adiabatic invariance condition is identical with that for the wedge device 10, and the previous discussions pertinent to the wedge device 10 also thus apply to the light guide 46. The angular momentum conservation condition requires that as the light streams outward from source 47 with increasing radius, the k_θ value decreases. Therefore, the light becomes collimated in the increasing radial direction. This makes the properties fundamentally like the wedge device 10, and the light 48 can be made to emerge as light 52 at a selected angle to face 51, collimated along the z direction.

For purposes of illustration we take the guide material to have a constant index of refraction n. For such geometries the light rays 48 along the two-dimensional cross sectional plane taken along 5B-5B behave just as in the case of the wedge device 10 counterpart described hereinbefore. Similarly, various additional layers 54 and 56 and other means can be used to achieve the desired light handling features. For example, for the disc light guide 46 a preferred facet array 56 is a series of circles, concentric with the disk 46. Thus, if the facets 56 are linear in cross section, the light rays 52 will emerge in a direction collimated within a full angle of 2 ϕ times a function of the indices of refraction as in the device 10 described hereinbefore.

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Tapered Luminaires with Two Low-index Layers.

In another form of the invention shown in FIG. 6A, the device 10 includes a first layer 61 having an optical index of refraction n_1 and a first or top layer surface 62 and a second or bottom layer surface 64 converging to establish at least one angle of inclination ϕ. The first layer 61 also includes a back surface 65 spanning the top layer surface 62 and the bottom layer surface 64.

Adjacent the first layer 61 is layer means, such as a bottom transparent layer means, like a first intermediate layer 66 of index n_2 disposed adjacent to, or underlying, the bottom layer surface 64. In addition, the layer means can embody a top transparent layer means, second intermediate layer 81 of index n_2 disposed adjacent to the top layer surface 62. At least one of the layers 66 and 81 can be an air gap, or other gas or a transparent dielectric gap.

An air gap can be established by conventional means, such as by external supports, such as suspending the layers under tension (not shown) or by positioning spacers 68 between the first layer 61 and the adjacent light redirecting layer 70. Likewise, the spacers 68 can be positioned between the first layer 61 and the second light redirecting layer 82. Alternatively, solid materials can be used for the transparent dielectric to constitute layers 66 and 81 and can improve structural integrity, robustness and ease of assembly. Such solid materials can include, for example, sol-gels (n_2=1.05-1.35), fluoropolymers (n_2=1.28-1.43), fluoride salts (n_2=1.38-1.43), or silicone-based polymers and adhesives (n_2=1.40-1.45). Such solid materials for the transparent dielectric need no separate means to support or maintain it, but can result in lower N.A. acceptance since the index is higher than for an air gap.

The layers 66 and 81 allow transmission of light received from the first layer 61. In this embodiment, part of the light will achieve θ_c first relative to the top layer surface 62, and light will enter the layer 81 for further processing by the light redirecting layer 82. The remaining light will thereby achieve θ_c first relative to the bottom layer surface 64, thus entering the layer 66 for further processing by the light redirecting layer 70.

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In one preferred form of the invention (see FIG. 6A) both the layers 66 and 81 are present and can have similar, but significantly different indices n_{2a} and n_{2b}, respectively. The indices are considered similar when they establish critical angles at the interfaces 62 and 64 which are similar in magnitude to the wedge angle ϕ, for example:

$$|\arcsin(n_{2a}/n_1)-\arcsin(n_{2b}/n_1)| < 6\phi \quad (6)$$

In this case significant, but unequal, fractions of light will enter each of the layers 66 and 81 for further processing by redirecting layers 70 and 82, respectively. The larger fraction will enter the layer having the higher of the two indices n_{2a} and n_{2b}. The redirecting layer 70 processes only the fraction which enters the layer 66. Therefore, the influence of the redirecting layer 70 on the output angular distribution of light can be changed by varying the relationship between the indices n_{2a} and n_{2b}.

In another preferred form of the invention the layers 66 and 81 can be the same transparent material of index $n_2 < n_1$. In general, lower values of n_2 will enhance the efficiency of the device 10 by increasing the numerical aperture at the light input surface 65. Therefore, collection efficiency can be maximized when the layers 66 and 81 are gaps filled with air or other gases (with n_2 = 1-1.01).

The thickness of the layers 66 and 81 can be selectively varied to control the output power spatial distribution of the device 10 or to enhance its visual uniformity. For example, increasing the thickness of the layer 81 by 0.002"-0.030" sharply reduces non-uniformities which tend to appear at the thicker end of the device 10. The thickness of layers 66 and 81 can also be smoothly varied with position to influence a desired spatial distribution of the light being output (see FIG. 12L).

In one preferred form of the invention shown in FIG. 6A, the light redirecting layer 70 includes a reflective layer 71 which reflects the light back through the layer 66 and the first layer 61. The light is then output into the first layer 61 through the top layer surface 62, and ultimately through the light redirecting layer 82 for further processing. The reflective layer 71 can, for example, be any combination of a planar

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specular reflector, a partially or completely diffuse reflector, or a faceted reflector.

Use of a planar specular reflector leads to the narrowest angular distribution within the layer 81. Therefore, the reflector can simplify design of the light redirecting layer 82 when the desired output angular distribution is unimodal. Diffuse or faceted reflectors can also be used for the layer 71 in order to achieve a large range of angular distributions (see FIGS. 4H and I) or to increase uniformity (see FIG. 4N). Diffuse reflectors are preferred if the desired angular distribution has large "tails" (see, in particular, FIG. 4I). Faceted reflectors can produce a bimodal angular distribution within the layer 81(see FIG. 4H). Therefore, such faceted reflectors are preferred if the desired output angular distribution is bimodal. For example, a bimodal "batwing" distribution is preferred from luminaires for room illumination because it reduces glare.

In general each facet of the layer 71 can be shaped to control the angular distribution of the light reflected back through the layer 66 and the first layer 61 for further processing by the redirecting layer 82. The angular distribution within the device 10 will in turn influence the angular distribution of the light output into ambient from the redirecting layer 82. For example, curved facets can be used to smoothly broaden the angular distribution, as well as providing a diffusing effect to improve uniformity. The reflective layer 71 can also influence the output power spatial distribution as well as the angular distribution. The reflectivity, specularity, or geometry of the reflective layer 71 can be varied with position to achieve a desired output distribution. For example, as described hereinbefore, small variations in the slope (see FIG. 12L) of each element of the reflective layer 71 as a function of position significantly change the light output distribution.

The light redirecting layer 82 has an index $n_3 > n_2$, and is substantially transparent or translucent. The light in the low-index layer 81 enters the layer 82 and is redirected into ambient. The transmissive redirecting layer 82 also redirects the light which has been processed by reflection from the redirecting layer 71 then transmitted back through the low-index layer 66 and the first layer 61. The transparency or geometry

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of the layer 82 can be varied with position to further influence the output spatial distribution of the device 10. In one preferred form of the invention the redirecting layer 82 includes a faceted surface at the interface with the low-index layer 81, as shown in FIG. 6A. Light entering the layer 82 is refracted by one side 84 of each facet 85 as it enters, and then is totally internally reflected by second side 86 of each of the facets 85. In one form of the invention the redirecting layer 82 can be a "Transparent Right-Angle Film" (hereinafter, TRAF), which is a trademark of 3M Corp., and this product is commercially available from 3M Corp. This TRAF operates by refraction and total internal reflection to turn incident light through approximately a ninety degree angle, as would be desired in a typical LCD backlighting application. The acceptance angle of the prior art TRAF is about twenty-one degrees, which is large enough to redirect a large fraction of light 75 which enters the low-index layer 81. In a more preferred form of the invention, the facet angles are chosen to redirect more of the light 75 which enters the low-index layer 81 by the described mechanism of refraction plus total internal reflection. Either one or both of the facet surfaces 84 and 86 can be shaped to control the output angular distribution. For example, the use of curved facets smoothly broadens the distribution, as well as providing a light diffusing effect which can improve uniformity.

In another preferred embodiment, the facet angle surfaces of the redirecting layer 82 can be varied progressively to compensate for the variation in viewing angle with position, when viewed from typical viewing distances. The details of such a compensation effect were described earlier in reference to the design of the reflecting facet layer in the embodiment shown in FIG. 2M. Similar principles can be applied to the design of any faceted redirecting layer, including refracting layers and refracting/internally-reflecting layers. Examples of embodiments which can, for example, make use of such progressively varied faceted layers are shown in FIGS. 12E (layer 140), 12G (layer 152), 12H (layer 166), 12K (layer 186), 12N (layer 210), 12O (layer 228), and 12P (layer 246).

In another form of invention the layers 66 and 81 can have similar but slightly different indices n_2 and n_2', respectively. The operating

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principles of the device 10 will be substantially similar as long as the critical angles associated with interfaces between the first layer 61 and the two layers 66 and 81 do not differ by more than the first layer convergence angle:

$$|\arcsin(n_2'/n_1)-\arcsin(n_2/n_1)| < \phi \quad (7)$$

Therefore, in this case approximately equal fractions of the light will enter layers 66 and 81, for further processing by the redirecting layers 70 and 82, respectively.

All forms of the invention can further include an output diffuser layer 40, shown in phantom in FIG. 2C or transmissive or translucent diffuser layer 83 shown in FIG. 6A. In general this diffuser layer 40 can be a surface diffuser, a volume diffuser, or at least one array of micro lenses having at least a section of a cylinder (known as a "lenticular array"). These layers 40 and 83 can increase light uniformity or broaden the angular distribution into ambient. Lenticular arrays are advantageous because they have low back-scattering in comparison to surface or volume diffusers, and because they have sharper output angle cut-offs when illuminated by collimated light. Lenticular arrays also preferentially diffuse only those features which would otherwise run in the general direction of the axis of each cylindrical micro lens.

In one preferred embodiment shown in FIG. 10, the light redirecting layer 10 makes use of flat facets 111 such that the output light is highly collimated. The desired output angular distribution is further controlled by including a lenticular diffuser 112 having an appropriate focal ratio, with its cylindrical micro lenses running approximately parallel to the y-axis. The lenticular diffuser 112 also diffuses non-uniformities which would otherwise appear to be running in the general direction of the y-axis. In this embodiment a second lenticular diffuser 113 can be included to diffuse non-uniformities which would otherwise appear running in the general direction of the z-axis. This second lenticular diffuser's micro lenses run approximately parallel to the z-axis (see FIG. 12H and 12N). Note that the order of positioning of the diffusers 112 and 113 can be interchanged without loss of optical advantage. Similarly, the lenticular diffuser 112 and 113 can be inverted

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and can have concave contours rather than convex contours shown in FIG. 10. While such changes can affect the details of the performance, the diffuser layers 112 and 113 can still provide the general advantages described.

In another preferred embodiment shown in FIG. 11, the functions of the flat-faceted light redirecting layer 110 and the parallel lenticular diffuser 112 in FIG. 10 can both be performed by a light redirecting layer 114 having curved facets (see also, for example, FIGS. 2H, 2M and 3A illustrating curved facets). These curved-facet layers redirect the light, control the angular output by having an appropriate facet curvature, and act as a diffuser for non-uniformities running in the general direction of the y-axis. By combining these functions in a single-layer the number of components is reduced, which improves thickness, cost, and manufacturability. In this embodiment, a single lenticular diffuser 115 can be included to diffuse the remaining non-uniformities which would otherwise appear running in the general direction of the z-axis. This type of lenticular diffuser micro lens runs approximately parallel to the z-axis. Note that the lenticular diffuser 115 can be inverted and can have concave contours rather than the convex contours shown in FIG.10. Again, such changes can affect performance details, but the layers 114 and 115 perform as intended.

In all embodiments using multiple micro-structured layers, the facet or lenslet spacings of these layers described hereinbefore can be chosen to have non-rational ratios, in order to avoid undesirable Moiré patterns. Similarly, each layer's feature spacing can be designed to have non-rational ratios with the apparatus to be illuminated, such as a liquid crystal display or charge-coupled detector (CCD) array. Each of the lenticular diffuser layers 113, 112 and 115 can be tilted up to about 20° from the configuration shown in the figures in order to reduce Moiré interaction between layers or with a liquid crystal display.

Similar lenticular diffusers can be used with non-wedge geometries having wedge shaped cross-sections, with similar advantages if the diffuser cross sections are approximately as shown in FIGS. 10 and 11. One example is the tapered disk illustrated in FIG. 5. In this case the

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lenticular diffuser analogous to layer 112 in FIG.10 would have micro lenses whose axes run in concentric circles about the disk's axis of rotations. A diffuser analogous to the layer 113 in FIG. 10 and 115 in FIG. 11 would have micro lenses whose axes emanate radially from the disk's central axis.

Light Sources and Couplers

In a more preferred form of the invention shown in FIGS. 2A and B, a faceted layer 30 has been included for optically redirecting the light. The facets 34 can be integral to the layer 30 or a separate facet layer. Details of operation of such a faceted layer have been discussed hereinbefore. As shown further in FIG. 6A an input faceted layer 74 can also be disposed between a light source 76 and the first layer 61. The faceted layer 74 can be a prismatic facet array which provides a collimating effect for input light 78 which provides brighter or more uniform output light 80 into ambient.

Linear prisms parallel to the y-axis can improve uniformity by adjusting the input angular distribution to match more closely the input numerical aperture. Linear prisms parallel to the x-axis can limit the output transverse angular distribution, and also improve output brightness when used with a fluorescent lamp light source. In other forms of the invention, diffusion of input light is desirable wherein a diffuser 79 is used to diffuse the light distribution to spread out the light to improve light uniformity. The diffuser 79 is preferably a lenticular array, with cylindrical lenslets parallel to the y-axis. The diffuser 79 can also be a standard surface or volume diffuser, and can be a discrete film or coupled integrally to the wedge layer 61. Multiple prismatic or diffuser films can be used in combination. Such a film form of the diffuser 79 and the faceted film 74 can be interchanged in position to vary their effects.

In another preferred form of the invention, a portion of a dielectric total internally reflecting CPC portion 100 (compound parabolic concentrator) can be interposed between the light source 76 and the first layer 61 (see FIGS. 2L, 12O and 12P). The CPC portion 100 adjusts the input light to match more closely the input numerical aperture. The CPC portion 100 is preferably formed integrally with the first layer 61.

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Reflector elements 92 and 94 shown in FIGS. 7 and 8, respectively, can be shaped and positioned to maximize the throughput of light from the light source 76 to the light-pipe aperture. This is equivalent to minimizing the reflection of light back to the light source 76, which partially absorbs any returned light. The light source 76 is typically cylindrical and is surrounded by a transparent glass envelope 93, each having circular cross-sections as shown in FIGS. 7 and 8. Typical examples of such light sources include fluorescent tubes and long-filament incandescent lamps. The outer diameter of the light source 76 can be less than or equal to the inner diameter of the glass envelope 93. FIG. 7 shows a prior art U-shaped reflector 92 formed by wrapping a specular reflectorized polymer film around the light source 76 and making contact with the wedge layer 12 at each end of the film. The reflector element 92 typically is formed into a shape which is approximately an arc of a circle on the side of the light source 76 opposite the wedge layer 12, with approximately straight sections connecting each end-point of the arc with the wedge layer 12. This manner of coupling the reflector element 92 to the wedge layer 12 is most easily accomplished when the reflector element cross-section lacks sharp corners. In general the light source 76 is not permitted to touch either the wedge layer 12 or the reflectorized film, in order to minimize thermal and electrical coupling which can reduce lamp efficiency.

In one form of the present invention shown in FIG. 8, the reflector element 94 is advantageously designed and the light source 76 is advantageously placed to minimize the fraction of light returned to the light source 76, and thereby increases efficiency. In one preferred embodiment, at least a section of the reflector element 94 is shaped such that a line drawn normal to the surface of the reflector element 94 at each point is tangent to the circular cross-section of the light source 76. The resulting reflector shape is known as an involute of the light source 76.

While an involute provides maximum efficiency, other shapes can generally be more easily manufactured. Polymer films can be readily bent into smooth curves which include almost semicircular arcs, as described above. It can be shown that when the cross-section of the light

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source 76 and semicircular section of the reflector element 92 are concentric as shown in FIG. 7, then the semicircular section of the reflector element 92 will return all incident rays to the light source 76, leading to poor efficiency. Such inefficiency is a general property of self-absorbing circular sources and concentric semicircular reflectors. This general property can be derived from simple ray-tracing or the principal of skew invariance. Even if the reflector element 92 is not perfectly circular, each portion of the reflector element 92 will tend to return light to the light source 76 if the cross-section of the light source 76 is centered near the center of curvature of that reflector section.

In another preferred embodiment, the cross-section of the reflector element 94 in FIG. 8 includes one or more almost semicircular arcs, and efficiency is increased by displacing the center of the light source 76 away from the center of curvature of the reflector element 94. Ray-tracing and experiments have shown that such preferred embodiments can be determined using the following design rules:

1. The cross-section of the reflector element 94 has a maximum extent in the x-dimension equal to the maximum thickness of the wedge layer 12 (or light pipe);

2. The cross-section of the reflector element 94 has no optically sharp corners;

3. The radius of curvature of the reflector element 94 is as large as possible; and

4. The light source 76 is as far as possible from the wedge layer 12, but is far enough from the reflector element 94 to avoid contact with worst-case manufacturing variations.

FIG. 8 shows an example of a coupler which satisfies these above described design rules for the light source 76 with inner diameter = 2 mm, outer diameter = 3 mm, thickness of the wedge layer 12 (or light pipe) = 5 mm, and manufacturing tolerances which permit a 0.25 mm spacing between the reflector element 94 and the outer diameter of the glass envelope 93. In this example of a preferred embodiment the radius of curvature of the reflector element 94 is 2.5 mm, and the center of the light source 76 is displaced by 0.75 mm away from the aperture of the wedge

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layer 12. A coupler constructed according to this design was found to be 10-15% brighter than the comparable concentric coupler shown in FIG. 7.

The involute and the U-shaped reflector elements 92 and 94 previously described are designed to output light to the aperture of the wedge layer 12 with angles approaching ± 90 degrees relative to the aperture surface normal. In another preferred embodiment, the reflector element 94 is shaped to output light with an angular distribution which is closer to the N.A. of the device 10. As shown in FIGS. 6B and 6C, such shapes as the reflector element 94 can include other geometries, such as, a compound parabolic source reflector 86 and a nonimaging illumination source reflector 88. An example of the source reflector 88 is described in copending serial number 07/732,982 assigned to the assignee of record of the instant application, and this application is incorporated by reference herein.

In another embodiment of the invention shown in FIGS. 6D, 12L, 12N, and 12O, the wedge layer 90 has a non-monotonic varying wedge cross sectional thickness over various selected portions of the wedge shaped cross section. It has been determined that one can exert control over the light distribution being output by control of this cross section. Further, it has been determined that optical boundary effects, as well as intrinsic light source effects, can combine to give an output light distribution with unwanted anomalies. One can therefore also compensate for these anomalies, by providing a wedge cross section with nonlinear changes in the actual dimensions of the wedge layer 90, for example, near the thicker end which typically receives the input light. By control of these dimensions one can thus have another degree of freedom to exert control over the light distribution, as well as provide virtually any design to compensate for any boundary effect or light source artifact. Furthermore, one can vary the index of refraction within the wedge layer 90 in the manner described hereinbefore to modify the distribution of light and also compensate for light input anomalies to provide a desired light distribution output.

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Manufacture of Luminaire Devices

In one form of the invention, manufacture of the device 10 can be accomplished by careful use of selected adhesives and lamination procedures. For example, the wedge layer 12 having index n_1 can be adhesively bonded to the first layer 28 having index n_2. An adhesive layer 60 (see FIG. 3B) can be applied in liquid form to the top surface of the first layer 28, and the layer 28 is adhesively coupled to the bottom surface 16 of the wedge layer 12. In general, the order of coupling the various layers can be in any given order.

In applying the layer 12 to the layer 28 and other such layers, the process of manufacture preferably accommodates the formation of internal layer interfaces which are substantially smooth interfacial surfaces. If not properly prepared such internal layers can detrimentally affect performance because each interface between layers of different indices can act as a reflecting surface with its own characteristic critical angle. If the interfacial surfaces are substantially smooth, then the detrimental effect of uneven surfaces is negligible. Therefore in effectuating the lamination of the various layers of the device 10, the methodology should utilize adhesives and/or joining techniques which provide the above described smooth interfacial layers. Examples of lamination processes include, without limitation, joining without additional adhesive layers, coatings applied to one layer and then joined to a second layer with an adhesive and applying a film layer with two adhesive layers (one on each layer surface to be joined to the other).

In a preferred embodiment lamination of layers is done without any additional internal layer whose potential interfacial roughness will distort the light distribution. An example of such a geometry for the device 10 can be a liquid layer between the wedge layer 12 and the second layer 30. This method works best if the first layer 29 (such as the liquid layer) acts as an adhesive. One can choose to cure the adhesive either before, partially or completely, or after joining together the various layers of the device 10. The optical interface is thus defined by the bottom surface of the wedge layer 12 and the top surface of the second layer 30.

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In another embodiment wherein a coating is used with an adhesive layer, the first layer 28 can be the coating applied to the second layer 30. Then, the coated film can be laminated to the wedge layer 12 in a second step by applying an adhesive between the coated film and the wedge layer 12. It is preferable to apply the low index coating to the second layer 30 rather than directly to the wedge layer 12 since the second layer 30 is typically supplied in the form of continuous film rolls. In practice it is more cost effective to coat such continuous rolls than to coat discrete pieces. With this methodology it is more convenient to control thickness of the applied low index layer.

In another embodiment, the second layer 30 is manufactured in such a way that it adheres to the first layer 28 directly without use of additional adhesives. For example, the second layer 30 can be manufactured by applying a layer of polymer material to the first layer 28, and then casting this material to have the desired second layer geometry. In another example, the first layer 28 can serve as a carrier film during the embossing of the second layer 30. By use of appropriate temperatures during the embossing process, the second layer 30 can be heat-fused to the first layer 28. Such heat-fusing can be accomplished using a conventional FEP first-layer film by embossing at almost five hundred degrees F or higher.

In a further embodiment using a film and two adhesives, the first layer 28 can be an extruded or cast film which is then laminated to the wedge layer 12, or between the wedge layer 12 and the second layer 30 using adhesive between the two types of interfaces. In order to minimize the detrimental light scattering described hereinbefore, the adhesive layer should be flat and smooth. The film can be obtained as a low index material in commercially available, inexpensive forms. Such additional adhesive layers can increase the strength by virtue of the multi-layer construction having adhesive between each of the layers.

In the use of adhesive generally, the performance of the device 10 is optimized when the index of the adhesive between the wedge layer and the first layer is as close as possible to the index of the first layer 28. When the critical angle at the wedge/adhesive interface is as low as

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possible, then the light undergoes a minimal number of reflections off the lower quality film interface before exiting the device 10. In addition, the index change at the surface of the first layer film is minimized which decreases the effects of film surface roughness.

Manufacture of faceted surfaces can be accomplished by micro-machining a mold using a master tool. Machining can be carried out by ruling with an appropriately shaped diamond tool. The master tool can be replicated by known techniques, such as electroforming or casting. Each replication step inverts the shape of the desired surface. The resulting mold or replicates thereof can then be used to emboss the desired shape in the second layer 30. A directly ruled surface can also be used, but the above described embossing method is preferred. Known "milling" processes can include chemical etching techniques, ion beam etching and laser beam milling.

In yet another method of mechanical manufacture, the faceted surface 34 (see FIGS. 2B and 2M, for example) is manufactured by a welding process, such as embossing or casting, using a hard tool which has on one surface the inverse of the profile of the desired faceted surface 34. Therefore, the manufacturing problem reduces to the matter of machining an appropriate tool. Usually the machined tool is used as a template to form the tools actually used in the casting or embossing process. Tools are typically replicated by electroforming. Since electroforming inverts the surface profile, and electroforms may be made from other electroforms, any number of such inversions can be accomplished and the directly machined "master" can have the shape of the faceted surfaces 3A or its inverse.

The tooling for the faceted surface 34 can be manufactured by single-point diamond machining, wherein the distance between cutting tool and the work is varied to trace out the desired profile. The diamond cutting tool must be very sharp, but in principle nearly arbitrary profiles can be created. A given design can also require specific adaptations to accommodate the non-zero radius of the cutting tool. If curved facet surfaces are required, then circular arcs are preferred to facilitate fabrication. The cutting tool is moved through the cutting substrate and

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cuts a groove having the approximate shape of the tool. It is desirable to machine the entire piece using a single diamond tool. When this method is used for making a "focusing" type of the faceted surface 34, the variable groove profile therefore should be designed such that the various groove profiles can be machined by the same tool. The required shape variations can still be accomplished by varying the angle of the tool, as well as the groove spacing and depth.

Design of the faceted surface 34 preferably satisfies a few general constraints:

1. Approximately linear variation in the center of the illumination angular distribution as a function of position. A variation of 11 degrees (± 5.5°) from top to bottom of typical computer screens is effective;

2. The width of the variable angular distribution of light output should be approximately proportional to the local illuminance in order to achieve approximately uniform brightness to an observer. Examples given below show the spatial distribution is approximately uniform, so the angular cones have approximately uniform width; and

3. Spacing between grooves of the facets 38 should be large enough or irregular enough to avoid diffraction effects, but also be chosen to avoid Moiré patterns when used with an LCD panel. In practice these requirements limit the allowed spatial variations.

In the manufacture of the device 10, for example, the viewing angle depends on the tilt and curvature of each of the facets 38. Focusing is accomplished by rotating the facet structure as a function of position. Using the example of a 150 mm screen viewed from 500 mm away, the illumination cone can be varied by 17 degrees (i.e., ± 8.5 degrees) from top to bottom. For typical materials, acrylic and FEP, this requires the facet structure to rotate by approximately 5.7 degrees from top to bottom of the screen 89 (see FIG. 9B).

Design constraints can result when limitations (1)-(3) are combined with the need to machine variable curved grooves with a single tool. For example, maintaining a constant angular width (Constraint #1) at a constant cutting depth requires a compensating variation in groove

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spacing or groove depth. Specifically, a linear change in groove spacing can reduce the brightness variation to a negligible level when the form tool which cuts the groove is shaped so that portions of each curved reflector facets (see FIG. 2M) are shadowed by the top edge of the adjacent facets. This spacing variation can be small enough to satisfy Constraint #3.

Further methods of manufacture can include vapor deposition, sputtering or ion beam deposition of the first layer 28 since this layer can be quite thin as described hereinbefore. Likewise, the second layer 30 can be controllably applied to form the faceted layer 30 shown in FIG. 2B (such as by masking and layer deposition).

Wedge Light Pipe as a Simple Collimator Device

In the most general embodiment the wedge layer 12 can function in the context of the combination as a simple collimating optical element. The substantially transparent wedge layer 12 has an optical index of refraction n_1 and the top surface 14 and the bottom surface 16 converge to establish at least one angle of inclination ϕ (see FIG. 15). The wedge layer 12 also includes the back surface 20 spanning the top surface 14 and the bottom surface 16. Adjacent to the wedge layer 12 is the transparent first layer 28 having index of refraction n_2 including an air gap. Adjacent to the first layer 28 is a specular reflective layer, such as the faceted surface 34 of the second layer 30.

Substantially uncollimated light is introduced through the back surface 20 by the source 22. The light propagates within the wedge layer 12, with each ray decreasing its incident angle with respect to the top and bottom surfaces 14 and 16 until the incident angle is less than the critical angle θ_c. Once the angle is less than θ_c, the ray emerges into ambient. Rays which emerge through the bottom surface 16 are reflected back into the wedge layer 12 and then output into ambient. By virtue of the angle-filtering effect previously described, the output light is collimated within a cone of angular width approximately:

$$\Delta\theta \cong 2\phi^{1/2}(n^2-1)^{1/4} \qquad (8)$$

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An area 99 to be illuminated lies beyond the end of the wedge layer 12 and substantially within the above-defined cone of width $\Delta\theta$.

In another preferred embodiment a light-redirecting means can be positioned beyond the end of the wedge layer 12 and substantially within the above-defined cone of width $\Delta\theta$. The light-redirecting means can be a lens, planar specular reflector, or curved reflector. The light-redirecting means reflects or refracts the light to the area to be illuminated. Further details and uses of such redirecting means, such as lenticular diffusers, will be described hereinafter.

In the embodiments of FIG. 6 having two air gaps or transparent dielectric layers, the light redirecting layers are independent, and thus one can construct devices having layers of different types. For example, the use of two transmissive redirecting layers is preferred when light is to be emitted from both sides of the device 10 or whenever maximum collimation is desired. Examples of the redirecting layer 82 in general for all inventions for two redirecting layers can include the examples in FIG. 12 where the letter in parenthesis corresponds to the appropriate figure of FIG. 12: (a) diffraction gratings 120 or a hologram 122 in FIG. 12A, (b) two refracting facet layers 124 with diffusers 126 in FIG. 12B, (c) two faceted layers 128 with facets 130 designed to refract and internally reflect light output from the wedge layer 12; such facets 130 are capable of turning the light output through a larger angle than is possible by refraction alone; (d) two refracting single facet layers 132 (prisms); (e) a top surface redirecting layer for the wedge layer 12 having a refracting single facet layer 134 with a curved output surface 136 for focusing. A bottom surface 138 includes a redirecting layer for refracting and internally reflecting light using a faceted layer 140; facet angles are varied with position to focus output light 142 at F; (f) a top surface redirecting layer 144 comprised of a refracting faceted layer 146 and a bottom redirecting layer comprised of a refracting/internally reflecting layer 148 with narrow angle output for the light, and a diffuser layer 150 can be added to smoothly broaden the light output angular distribution; (g) a top surface redirecting layer of refracting/internally reflecting faceted layer 152 with refracting surfaces 154 convexly curved to

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broaden the output angular distribution; the facet angles can be varied with position and thereby selectively direct the light output angular cones to create a preferred viewing region at a finite distance; this arrangement can further include a transverse lenticular diffuser 156 to diffuse nonuniformities not removed by the curved facet layer 152; the bottom redirecting layer comprises a refracting/internally reflecting faceted layer 158 with a reflecting surface 160 being concavely curved to broaden the light output angular distribution in a controlled manner; (h) a top redirecting layer, including a refracting faceted layer 162 with curved facets 164 to broaden the output angular distribution in a controlled manner and to improve uniformity; a bottom redirecting layer, including a refracting/internally-reflecting faceted layer 166 with flat facets 168 for narrow-angle output, with facet geometry varied with position to focus output light at a finite distance; a parallel lenticular diffuser 170 can be used to smoothly broaden the output angular distribution in a controlled manner and to improve uniformity; the transparent image shown in phantom can be printed on or adhesively based to a lenticular diffuser; a transverse lenticular diffuser 172 is used to diffuse non-uniformities not removed by the parallel lenticular diffuser 170. The combination of a focused flat-faceted layer 166 and the diffuser 170 cooperate to create a preferred viewing zone at a finite distance, similar to using focused curved facets. Also shown is an LCD component 173 (in phantom) usable with this and any other form of the device 10 for illumination purposes.

In other architectures, one transmissive and one reflective redirecting layer can be combined. These are combinations of reflective redirecting layers with the various types of transmissive redirecting layers discussed above. Reflective redirecting layers can be specular, partially diffuse, diffuse, faceted or any combination thereof. These architectures are preferred when light emission is desired from one side only, or in some cases when minimum cost is paramount. Examples of such architectures are in FIG. 12: (i) a bottom surface specular reflector 174 combined with a top layer transmission diffraction grating or transmission hologram 176; (j) a bottom surface specular reflector 178 combined with

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a top surface refracting faceted layer 180, with a diffuser 182 (shown in phantom in FIG. 12J and an intervening image-forming layer 171; (k) a bottom layer specular reflector 184 with a top layer refracting/internally-reflecting faceted layer 186, with facet geometry being varied with position to focus output light at a finite distance; a diffuser 188 is shown in phantom; (l) a bottom layer specular reflector 190 with a top layer refracting/internally-reflecting faceted layer 192, and curved facets 194 are used to smoothly broaden the angular output of light in a controlled manner and to improve uniformity. The thickness of the wedge layer 12 and of both top and bottom surface low-index layers 196 (e.g., air gaps) are varied to influence the light output spatial distribution; (m) a bottom reflector 198 is partially specular, partially diffuse to improve uniformity; FIG. 12M shows the initial reflector section made controllably diffuse by addition of an integral lenticular diffuser 200; the diffuser 200 is designed to selectively reduce nonuniformities which would otherwise appear in the output near the thicker end, and running in the general direction of the y-axis; also included is a top redirecting layer 202 which is refracting/internally-reflecting and has a reflecting surface which is curved; and (n) a bottom reflector layer 204 which is partially specular, partially diffuse to improve uniformity; FIG. 12N shows the initial reflector section 206 which is slightly roughened to reduce specularity, and thereby selectively reduces nonuniformities which would otherwise appear in the output near thicker end 208; a top redirecting layer 210 is used which is refracting/internally-reflecting with a flat-faceted layer 212, and the facet geometry is varied to redirect light from each facet to a common focus at finite distance; a transverse lenticular diffuser 213 is shown in phantom; a parallel lenticular diffuser 214 is used to smoothly broaden the output angular distribution in a controlled manner, converting the focal zone of the flat-faceted layer 212 to a wider preferred viewing zone; the lenticular diffuser 213 also improves uniformity; an LCD display 216 or other transparent image is show in phantom; (o) in a preferred embodiment an eccentric coupler 218 uses a uniformity-enhancing lenticular diffuser 220 shown in phantom in FIG. 12O. A converging tapered section 222 or CPC (integral to the wedge layer)

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transforms the output angular distribution to match more closely the input N.A. of the wedge layer 12. The wedge layer 12 thickness is smoothly varied to influence output spatial distribution and improve uniformity; a bottom redirecting layer 224 is a specular or partially diffuse reflector; a top redirecting layer 226 is a refracting/internally-reflecting faceted layer 228 with reflecting surfaces 230 convexly curved to smoothly broaden output angle in a controllable manner; facet geometry is varied with position to selectively direct the angular cone of light from each face to create a preferred viewing zone 232 at a finite distance; a transverse lenticular diffuser 234 is shown in phantom; an LCD display 236 or other transparent image is also shown in phantom; the more converging N.A.-matching section is advantageous in combination with the faceted redirecting layers, because the redirecting and low-index layers do not need to overly the more converging section; therefore, the input aperture (and thus efficiency) of the device 10 is increased with minimum increase in total thickness of the device; (p) another preferred embodiment for LCD backlighting uses an eccentric coupler with a uniformity-enhancing diffuser shown in phantom in FIG. 12P; a converging half-tapered section 240 or half-CPC (integral to the wedge layer 12) transforms a coupler output angular distribution to match more closely the input N.A. of the wedge layer 12. A diffuser 239 (in phantom) can also be interposed between light source 217 and the wedge layer 12. The sufficiently truncated half-CPC 240 is just a simple tapered section. A bottom reflector 242 which is partially specular, partially diffuse is used to improve uniformity; FIG. 12P further shows an initial reflector section 244 which is slightly roughened to reduce specularity, or alternatively shaped into a series of parallel reflective grooves, which thereby selectively reduces nonuniformities which would otherwise appear in the output near the thicker end; a top redirecting layer 246 is a refracting/internally-reflecting faceted layer 248, with refracting surfaces 250 convexly curved to smoothly broaden output angle in a controllable manner; facet geometry is varied with position to selectively direct angular cones of light from each facet to create a preferred viewing zone at a finite distance; a transverse lenticular diffuser 252 is shown in

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phantom. Also included is an LCD display 254 or other transparent image shown in phantom.

The more converging N.A.-matching section (such as half tapered section 240) is advantageous in combination with the faceted redirecting layers, because the redirecting and low-index layers do not need to overly the more converging section; therefore, the light-accepting aperture of the device 10 is increased without increasing the total thickness. The advantage is also conferred by the fully-tapered section 222 shown in FIG. 12O; but in comparison the half-tapered section 240 in FIG. 12P provides greater thickness reduction on one side, at the expense of being longer in the direction of taper for equivalent N.A.-matching effect. It can be desirable to concentrate the thickness reduction to one side as shown, because the top surface low-index layer can be made thicker to improve uniformity. This configuration can be more easily manufactured because the bottom reflector layer can be integral to the coupler reflector cavity, without need to bend a reflective film around a corner; (q) a bottom specular or diffusely reflecting layer 256 can be combined with single-facet refracting top layer 258 in yet another embodiment (see FIG. 12Q); and (r) in cases for interior lighting usage, a bimodal "bat-wing" angular light distribution 260 is preferred; in FIG. 12R is shown a top refracting layer 262 with facets 264 and has a curved front surface 266 to smoothly broaden angular output and improve uniformity, with output light directed primarily into a forward quadrant; a bottom reflecting layer 268 reflects light primarily through a back surface of a top redirecting layer, with output directed substantially into a backwards quadrant.

As understood in the art the various elements shown in the figures can be utilized with combinations of elements in tapered luminaire devices. Examples of two such combination geometries are shown in FIGS. 13 and 14, each figure also including features specific to the geometry shown. As illustrated in FIG. 13, two wedges 276 can be combined and formed integrally. This combination can provide higher brightness than a single wedge having the same extent because it permits two light sources to supply light to the same total area. While brightness

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is increased for this device, efficiency is similar because two sources also require twice as much power as one source. A redirecting film 272 with facets 274 can be a single, symmetric design which accepts light from both directions as shown. Alternatively, the redirecting film 272 can have a different design for each wing of the butterfly.

In FIG. 14 is shown a three dimensional rendition of a tapered disk 270, such as shown in FIG. 5, and is sectioned to show the appearance of the various layers. A faceted redirecting layer 280 comprises concentric circular facets 282 overlying a tapered light-pipe portion 284. Directly over a light source 288, overlying the gap at the axis of the light-pipe portion 284, the redirecting layer 280 takes the form of a lens (a Fresnel lens 280 is shown, for example). Directly below the light source 288 is a reflector 290 positioned to prevent light from escaping and to redirect the light into the light-pipe portion 284 or through the lens. At least one opening is provided in the reflector to permit passage of elements, such as wires or light-pipes.

Use of Imaging or Colored Layers

All embodiments of the invention can incorporate one or more layers which have variable transmission to form an image, or which impart color to at least a portion of the angular output. The image-forming layer can include a static image, such as a conventional transparent display, or a selectively controlled image, such as a liquid crystal display. The image-forming or color-imparting layer can overlay one of the redirecting layers, or alternatively it can comprise an intermediate layer between one of the low-index layers and the associated redirecting layer, or an internal component of a redirecting layer. For example, overlying image-forming layers 129 are shown in phantom in FIGS. 12C and 12G. Examples of an internal image-forming layer 171 are shown in FIGS. 12H and 12J.

In one preferred embodiment, the image-forming layer (such as 129 and 170) is a polymer-dispersed liquid crystal (PDLC) layer. By proper arrangement of the layers, the image or color may be projected from the device within selected portions of the output angular

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distribution. The image or selected color can be substantially absent in the remaining portions of the output angular distribution.

Bi-modal Reflective Wedge for LCD Panel Illumination

In some applications it is desired to illuminate a single LCD panel selectively with either ambient light or by active back-lighting. In these applications ambient illumination is selected in well-lit environments in order to minimize power consumption by the display. When available environmental illumination is too low to provide adequate display quality, then active backlighting is selected. This selective bi-modal operating mode requires a back-illumination unit which can efficiently backlight the LCD in active mode, and efficiently reflect ambient light in the alternative ambient mode.

The most widespread prior art bi-modal liquid crystal display is the "transflective display" 101, such as is shown in FIG. 16B. This approach uses a conventional backlight 102 and a transmissive LCD panel 103, with an intervening layer 104 which is partially reflective and partially transmissive. In order to achieve adequate ambient mode performance, it is typically necessary for the intervening layer 104 to be 80-90% reflective. The resulting low transmissivity makes the transflective display 101 inefficient in the active mode of operation.

Another embodiment of the invention is shown in FIG. 17. This embodiment outperforms prior art transflective displays in the active mode, and demonstrates comparable performance in the ambient mode. In this embodiment the wedge layer 12 (index = n_1) having the bottom surface 16 is coupled to a transparent layer 28 of index $n_2 < n_1$, which can be an air gap. The n_2 layer is coupled to a partially diffuse reflector layer 105. This reflector layer 105 is, for example, preferably similar to the reflectors used in conventional LCD panels used in ambient mode only, as shown in FIG. 16A. Overlaying the wedge layer top surface 14 is a faceted redirecting layer 106, such as a lenticular diffuser with micro lenses approximately parallel to the y-axis. A liquid crystal display panel 107 overlays the faceted redirecting layer 106. The back surface 20 of the wedge layer 12 is coupled to the light source 22.

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The lenticular redirecting layer 106 and the wedge-layer 12 are substantially transparent to the incident and reflective light, so that in ambient mode the device 10 operates in a manner similar to conventional ambient-mode-only displays. When an active mode is selected, the light source 22 is activated, and the multiple layers act to spread the light substantially uniformly over the device 10 by virtue of the relationship between the indices of refraction and convergence angles of the layers, as described before. The resulting uniform illumination is emitted through the top surface 14 of the wedge layer 12. In a preferred embodiment, the reflector layer 105 is nearly specular in order to maximize ambient-mode performance. In this preferred embodiment the light emitted from the top surface is emitted largely at grazing angles, unsuitable for transmission by the LCD display panel 107. The redirecting layer 106 redirects a fraction of this light by a combination of refraction and total internal reflection, as described hereinbefore. The redirecting layer 106 is preferably designed such that at least 10-20% of the light is redirected into angles less than 30 degrees from the LCD normal, because typically the LCD transmission is highest in this angular range. It is sufficient to direct only a fraction of the back-illumination into suitable angles, because the prior art transflective display is quite inefficient in the active mode of operation.

Processing Polarized Light

In another aspect of the invention, the light being processed by the optical device 10 has an inherent polarization (such as, linear, circular and elliptical) that can be used to advantage in improving the illumination from a liquid crystal display ("LCD") system or other output which depends on using polarized light. In a system which employs an LCD, it is necessary to remove one type of polarized light 308 and pass to the LCD layer only the other type of polarized light. For example in FIG. 30 a conventional polarization layer 312 preferentially absorbs one polarization of light amounting to about one-half the input light from light source 306, with the preferred polarization light being transmitted to LCD layer 316. The polarized light of the proper polarization is processed by the liquid crystals and a second polarizer 314 in the desired manner to provide the displayed feature of interest. In such a conventional system

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about half the light from the light source is "unwanted" and thus is lost for purposes of providing an LCD output of interest. Consequently, if a means could be found to utilize both types of polarized light (not removing light of an unwanted polarization), a substantial gain in efficiency and brightness can result for the liquid crystal display. The subject invention is directed in part to that end, and the following embodiments are preferred structures and methods for accomplishing that goal.

In the most general explanation of a polarization filter, referring to FIG. 30B, the function of a polarization filter layer 307 is to take the input light 308 consisting of two polarization states of type 1 and 2 and create transmitted light 309 consisting of polarization states 3 and 4 and reflected light 311 consisting of polarization states 5 and 6. This can be related to our specific references hereinafter to a "first" and "second" state as "states" 1,3 and 5 as the "first polarization light 218" and 2,4 and 6 as the "second polarization" light 220. Thus, we assume that the form of states 3 and 5 are chosen so that they alone specify the light that is transmitted and reflected due to the light portion incident in polarization state 1, and let states 4 and 6 be associated with polarization state 2. However, the form of the polarization states need not be related in any more specific way. For some range of incident angles over some spectral wavelength range and for some specific selection of input polarization states, the polarization filter layer 307 processes the input light 308 and produces output light 309 with a specific total power relationship. If we define the powers (P_i) in each of the polarization states (i, where i=1,2,3,4,5,6), the condition is:

$$\frac{P_3}{P_1} > \frac{P_4}{P_2}$$

By definition, any layer which exhibits the above characteristics over a suitable angular and spectral range is a form of the polarization filter layer 307. Generally, the polarization states considered can be of arbitrary type such as linear, circular, or elliptical. In later sections we

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will quantify the performance of the polarization filter layer 307 by a degree of polarization (P_T) defined as:

$$P_T = \frac{T_{31} - T_{42}}{T_{31} + T_{42}}$$

where

$$T_{31} = \frac{P_3}{P_1}, T_{42} = \frac{P_4}{P_2}$$

For lossless layers, the transmittance is related to the reflectance, R, by

$$T_{31} = 1 - R_{51}, T_{42} = 1 - R_{62}$$

where

$$R_{51} = R_5 / R_1 \text{ and } R_{62} = R_6 / R_2$$

There are a variety of implementations of a layer medium which has the properties described above for the polarization filter layer 307. These include, but are not restricted to, implementations containing one or more of the following types of layers: (1) thin-film layers produced by coating, extrusion, or some other process which are either non-birefringent or birefringent and are designed to operate as optical interference coatings; (2) "thick" film layers which are more than a single quarter wavelength optically thick somewhere in the spectral band of interest and may be produced by stacking, coating, extrusion, lamination, or some other process and are designed to operate as a Brewster Stack even when the angles and indexes do not exactly match the Brewster angle conditions; (3) a combination of the thin-film and thick film approaches; (4) correlated, partially correlated, or uncorrelated surface roughness or profile which results in polarization dependent scattering and produced by any method including etching, embossing, micro-machining, or other method; (5) and layers based on dichroic material. In general, an aggregate layer formed by one or more the above layer types is a suitable form of the polarization filter layer 307 layer if it satisfies the general functional specifications described above for polarization filter layers.

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The implementations of the polarization filter layer 307 can consist of either thin-film or thick-film birefringent or non-birefringent layers. Particular examples and discussion of birefringent layers will be provided in a labeled subsection presented hereinafter.

One example embodiment of a thick film form of the polarization filter layer 307 is based on a specific design center wavelength (λ_o) and a specific design operating angle (θ_{inc}) as shown in FIG. 30C and based on isotropic planar layers. Layers 313 in this design example consist of two types of alternating layers, called high (H) layer 314 and low (L) layer 315 of optical refractive index n_H and n_L respectively. From Snell's law, we know the angle with respect to the surface normals (θ_L,θ_H) at which the light 317 are traveling in any of the layer 313 in terms of the refractive indexes of the layers (n_{inc}, n_L, n_H) if we know the incidence angle. This implies:

$$n_{inc} \sin \theta_{inc} = n_L \sin \theta_L$$

$$n_{inc} \sin \theta_{inc} = n_H \sin \theta_H$$

For p-polarized form of the light 317 incident on an interface between two optically isotropic regions, there is an angle called the Brewster's Angle at which the reflectivity of the interface is zero. This angle measured to the surface normal ($\theta_{H/L}$, $\theta_{L/H}$) is:

$$\tan \theta_{H/L} = \frac{n_L}{n_H}$$

$$\tan \theta_{L/H} = \frac{n_H}{n_L}$$

The reflectivity of the interfaces to s-polarized light at Brewster's Angle can be significant. The layers 313 which preferentially transmits the p-polarization state is designed by spacing these interfaces by quarter-wave optical thicknesses. Such quarter wavelength thicknesses (t_L, t_H) are given by:

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$$t_L = \frac{\lambda_o}{4n_L \cos\theta_L}$$

$$t_H = \frac{\lambda_o}{4n_H \cos\theta_H}$$

One can show that the H and L indexes of refraction are related by the design equation:

$$\left(\frac{n_L}{n_H}\right)^2 = \frac{\left(\frac{n_{inc}}{n_H}\right)^2 \sin^2\theta_{inc}}{1-\left(\frac{n_{inc}}{n_H}\right)^2 \sin^2\theta_{inc}}$$

As an example, consider the specific case of:

$$n_H = 1.5, n_{inc} = 1.0, \theta_{inc} = 80°, \lambda_o = 500nm.$$

This implies that the design index of refraction of the low index layer and the physical thicknesses of the low and high index layers 314 and 315 should be respectively n_L=1.,31,t_L=145 nm, t_H=110nm. These can be achieved by using sputtered glass and vacuum deposited lithium chloride for n_H = 1.5 and n_L = 1.31, respectively. Assuming that the design is a matched design as in FIG. 30C, with the layers 313 surrounded by an index of refraction of 1.5, the reflectivity can be easily calculated with the well-known Rouard's Method. This matching assumption is quite general as the outer surfaces could always be anti-reflection coated. The reflectivity for a variety of basic layer counts for the layers 313 is shown in Table 1 below:

Table 1. Performance data for the polarization filter layer 307		
Layer Count	s-Reflectivity	P_T
1	0.069	0.036
5	0.45	0.29
11	0.85	0.75
15	0.95	0.90
21	0.99	0.98

There are a variety of similar alternative designs. More than a single refractive index may be used as part of the thin-film structure of

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the layers 313. The surrounding layers need not be air and the exact number of low and high index layers is variable. The carrier or substrate could have other refractive index values. The layers 313 can be varied from their quarter-wave thickness at the design angle and the wavelength so as to improve spectral and angular bandwidths. In fact, the operability of the layers 313 can be quite broad band and the Brewster angle design does not have to be followed with great precision in index and angle. For example, you can trade off s-reflectivity with p-transmission by changing refractive indexes. The whole system can be flipped without changing its function.

A variety of preferred embodiments include at least two layers of different indices. Such arrangements have the n_H and n_L such that $n_H/n_L > 1.15$ in order to minimize the number of layers required for high polarization selectivity. Further, optical interference is most preferably used to enhance performance by using at least one layer with index n and thickness t such that $50nm/(n^2-1)^{1/2} < t < 350nm/(n^2-1)^{1/2}$. This relationship derives from the equations provided hereinbefore regarding t_L and t_H, by noting that the wavelength is in the visible light range 400 nm to 700 nm, that the incident light is near the critical angle so that n sin $\theta \approx 1$ and optical interference effects are promoted by layers with an optical thickness between 1/8 and 1/2 of the light wavelength. Materials and methods for fabricating such layers are well-known in the art of multi-layer dielectric coatings.

The Brewster Stack approach is similar to the thin-film approach described above except that the layers are many wavelengths thick and tend to function largely on the basis of the incoherent addition of the waves rather than the coherent effect that occurs in optical interference coatings. The design of this form of the polarization filter layer 307 is the same as the design of the thin-film polarizer described above except that layer thicknesses are not important as long as they are at least several wavelengths thick optically. The lack of optical thickness effects suggests that the performance of the Brewster Stack implementation should generally be less sensitive to spectral wavelength and angular variations. The transmission ratio defined in terms of the transmission of

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the s and p polarized light (T_s,T_p) of the set of N layer pairs in the geometry of FIG. 30D can be estimated using the approximate formula:

$$T_s/T_p \approx \left[\frac{4(n_H^2 - 1)}{n_H^4}\right]^{2N}$$

The results of applying this formula to a geometry with varying numbers of layer pairs is shown in Table 2 below:

Table 2. Performance data for a Brewster Stack Form of the Filter Layer 307

Layer Pairs	T_s/T_p	P_T
1	0.9755	--
20	0.61	--
50	0.29	0.55
100	0.08	0.85

Generally speaking, this type of the polarization filter layer 307 requires much larger index differences and many more layers for the same reflectivities. There is no sharp dividing line between the thin-film design and the Brewster stack approach. As thickness increases, coherence effects slowly decrease and beyond some point which is dependent on the spectral bandwidth of the light signal, the coherence effects become small compared to incoherent effects. These examples described herein are simply the extreme of cases of the coherent and incoherent situations.

In FIG. 19 are shown variations on one form of a polarized light luminaire system 204. In particular, in FIG. 19B, the system 204 includes a base layer 206 having a wedge-shaped, cross-sectional area with optical index of refraction n_1, and a first surface 208 and second surface 210 converging to define at least one angle of inclination Φ. The base layer 206 further includes a back surface 211 spanning the first surface 208 and the second surface 210. Light 212 injected by a source

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(not shown) through the back surface 211 reflects from the first and second surfaces and exits the base layer 206 when the light 212 decreases its angle of incidence relative to a normal to the first and second surfaces with each reflection from the surfaces 208 and 210 until the angle is less than a critical angle θ_c characteristic of an interface between the base layer 206 and a first layer means, such as a layer 214. This layer 214 includes at least a layer portion having index n_2 less than n_1 disposed beyond the second surface 210 relative to the base layer 206. The first layer 214 enables the light 212 to enter the first layer 214 after output from the base layer 206 when the light 212 in the base layer 206 achieves the angle of incidence less than the critical angle θ_c characteristic of an interface between the base layer 206 and the layer portion having index n_2 in the layer 214.

The system 204 also includes a layer means for preferential processing of polarized light of one state relative to another state, such as a polarization filter layer 216 (see previous generic description of the polarization filter layer 307). In addition to the samples described for the filter layer 307, a further example of the polarization filter layer 216 is a birefringent material which will be described hereinafter in the context of particular embodiments in a separate subsection. In FIG. 19, the injected light 212 includes light 218 of a first polarization and light 220 of a second polarization. The filter layer 216 then interacts with the light 212 to preferably output the light 218 of a first polarization state compared to the light 220 of a second polarization state. This filter layer 216 is disposed beyond the second surface 210 relative to the base layer 206, and this filter layer 216 is also able to reflect at least part of the light 220. This reflected light 220 is then transmitted through both the first layer 214 and the base layer 206 and into a medium 207 having index n_3 (such as air). The light 218 on the other hand is output from the system 204 on the side of the base layer 206 having the polarization filter layer 216. In FIG. 19B, the light 218 is shown being output into a media 221 having index n_4. In this embodiment in FIG. 19B, the relationship among indices is:

$n_4 \geq n_2$ and

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$$\arcsin(n_2/n_1) - 2\Phi < \arcsin(n_3/n_1) < \arcsin(n_2/n_1) + 2\Phi \quad (9)$$

In this preferred embodiment n_2 *and* n_3 can be air layers with "n" being approximately one.

This same index relationship can apply to FIG. 19A which is a variation on FIG. 19B, but the first layer 214 of index n_2 is disposed further from the base layer 206 than the polarization filter layer 216. In the embodiment of FIG. 19B, the first layer 214 is closer to the base layer 206 than the polarization filter layer 216.

In another embodiment shown in FIG. 19C, the indices are such that Equation (10) below is followed and this results in the light 220 of second polarization state continuing to undergo internal reflection, rather than exiting through the first surface 208 as shown in FIGS. 19A and 19B. The angle of incidence made relative to the polarization filter layer 216 decreases with each cyclic reflection. The index n_3 can thus be made small enough such that the light 220 will decrease its angle beyond the range where the filter layer 216 exhibits its preferred reflectivity of the light 220. Consequently, at least part of the light 220 can pass through the second surface 210, but is separated in angle of output relative to the light 218 of first polarization state. In the embodiment of FIG. 19C the indices have the following relationship:

$$n_4 \geq n_2 \text{ and } \arcsin(n_3/n_1) < \arcsin(n_2/n_1) - 4\Phi \quad (10)$$

The polarization filter layer 216 most preferably outputs the light 218 and reflects the light 220 when the angle of incidence is greater than:

$$\theta_p = \arcsin[1 - 4\Phi((n_1/n_2)^2 - 1)^{1/2}] \quad (11)$$

When light is incident at angles less than θp, the filter layer 216 can therefore be substantially transparent to light of both polarization states (i.e., the light 218 and the light 220).

In another embodiment of the invention shown in, for example, FIGS. 20A-C, the system 204 includes light redirecting means, such as a light reflector layer 222 in FIG. 20A, or more generically, a light redirecting layer 224 as shown in FIGS. 20B and 20C. In general for the inventions of the device 10 (system 204 in FIG. 20), we can define light

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redirecting means in terms of the propagation directions of light rays incident on, and departing from, the light redirecting layer 224. Consider the case of a light ray propagating parallel to a unit vector $\bar{r}_i$ in an optical medium having an index of refraction n_i. If $\bar{u}$ is a unit vector perpendicular to the redirecting layer 224 at the point of light ray incidence and directed away from the redirecting layer 224 toward the side from which the incident light ray originates, then the incident light ray interacts with the light redirecting layer 224 to produce light rays which depart from the region of interaction. If the departing light rays propagate parallel to a distribution of unit vectors $\bar{r}_c$ in an optical medium having index of refraction n_c, then light redirecting means includes any layer which processes the incident light ray such that the departing light ray has one of the following properties with respect to incident light rays throughout the operative angular range:

(1) $n_c(\bar{r}_c \times \bar{u})$ *is not equal to* $n_i(\bar{r}_i \times \bar{u})$

for at least 25% of the departing light rays; (12)

(2) $\bar{r}_c = \bar{r}_i - 2(\bar{u} \cdot \bar{r}_i)\bar{u}$ for at least 90% of the departing light rays. (13)

The light redirecting layer 224 can redirect light according to condition (1) in Equation (12) if (a) the light interacts with optical surfaces which are rough, (b) if the light interacts with optical surfaces which have a different slope from the incident surface, or (c) if the redirecting layer 224 diffracts the light into appropriate angles. For example, light redirecting means according to condition (1) may be any combination of transmissive or reflective, diffusive or non-diffusive, and prismatic or textured layer. In addition, the light redirecting means can be a diffraction grating, a hologram, or a binary optics layer.

A light redirecting means which redirects light in accordance with condition (2) of Equation (13) is a specular reflector. Examples of such a specular reflector can be a metallic coating (e.g., the light reflector layer 222 in FIG. 20A can be a metallic coating), a multi-layer dielectric coating or a combination of these. In each case, the internal and external surfaces are preferably smooth and mutually parallel.

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In FIG. 20A one of the preferred embodiments includes light reflecting, redirecting means in the form of the reflector layer 222 which reflects the light 220. The reflector layer 222 is disposed beyond, or underlying, the first surface 208 of the base layer 206 and preferably is a flat, specular reflector, such as a metallic coating. Also shown is an intervening layer 223 of index n_3 disposed between the base layer 206 and the reflector layer 222. This intervening layer 223 can be considered to be part of the base layer 206, or a separate layer, depending on the functional interaction between the base layer 206 and the intervening layer 223. The index of refraction n_3 of this intervening layer 223 can be adjusted to controllably affect the resulting spatial and angular distribution of the light 212 after encountering the layer 223.

As can be seen, for example, in FIGS. 20B and 20C the light redirecting layer 224 can be positioned at different locations, and each layer 224 can also have different characteristics enabling achievement of different light output characteristics as needed for a particular application. Further examples of light redirecting means and uses, as well as specific embodiments, are illustrated in the remaining figures and will be described in detail hereinafter.

In another embodiment of the polarized light luminaire system 204, light converting means is included and is illustrated as a polarization converting layer 226 in FIGS. 21 and 22, for example. In these illustrated embodiments, the indices have $n_4 \geq n_2$ and the conditions of Equation (9) must in general be met. In these embodiments, a light converting means includes a layer which changes at least part of one polarization state (such as the light 220) to another polarization state (such as the light 218, or even light 227 of a third polarization state, which can be, for example, a combination of the first and second state).

The polarization converting layer 226 has the function of changing the polarization state to another state, such as rotating polarization by 90° ($\pi/2$). Moreover, such conversion is most preferably done for oblique incidence. As one example we describe the nature of such conversion for a uniaxial birefringent material where the index of refraction perpendicular to the optic axis is independent of direction. Many

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preferred materials, such as stretched fluoropolymer films are of this type. More general birefringent materials where the index of refraction is different in all directions can also be used following the general methods described herein. To understand the polarization conversion process, we first review the case for normal incidence.

As shown in FIG. 30E, a plate 229 of birefringent material has its transverse axis along vector K and the optic axis is along vector I (see vectors in FIG. 30F). For a stretched birefringent film, the direction of stretch would be along vector I. Vectors I, J, K are an orthogonal triad of unit vectors along the x,y,z axes. For normal incidence, the wave normal is along vector K. We can describe the polarization of the electromagnetic wave by its displacement vector D. Let D' be the polarization of the ordinary ray, and D" the polarization of the extraordinary ray. Let n' be the ordinary index of refraction, and let n" be the extraordinary index of refraction. We can orient the optic axis of the birefringent plate 229 so that it makes an angle of 45° ($\pi/4$) to the incident polarization vector D_0. This vector has two components $D_0x=(1/\sqrt{2})D_0\cos\omega t$ and $D_0y=(1/\sqrt{2})D_0\cos\omega t$. Upon emerging from the birefringent plate 229, the D vector has components $D_0x=(1/\sqrt{2})D_0\cos(\omega t-\delta")$ and $D_0y=(1/\sqrt{2})D_0\cos(\omega t-\delta')$, where $\delta' = (2\pi/\lambda)n'h$ and $\delta"=(2\pi/\lambda)n"h$, where h is the plate thickness. Hence the phase difference introduced is $\delta'-\delta" = |(2\pi/\lambda)(n"-n')|h$. In particular, if the emergent light has polarization vector D at right angles to the intial polarization vector D', we need $\delta'-\delta"=\pi$ (or more generally $\delta'-\delta"=(2m+1)\pi$, where m is any integer). This means the thickness h should be chosen as $h=|(2m+1)/(n"-n')|\lambda/2$.

In summary, we choose the thickness h in accordance with the above relation and orient the optic axis at 45° to the incident polarization. In a preferred form of the invention such as in FIG. 26B, the light traverses the converting layer 226 birefringent plate 229 twice, so that the actual thickness should be one-half of that specified above. In other words, the thickness is the well known $\lambda/4$ plate. Any reflections from a metallic mirror 231 introduces an additional phase shift of approximately π to both components and does not change the conclusions.

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In an embodiment wherein the light has oblique incidence with the converting layer 226 (see FIG. 26B), it is first necessary to show that splitting of the incident beam into two beams (the well-known birefringent effect) does not cause difficulties. The reason this is not a problem is that the two beams emerge parallel to the initial direction, but slightly displaced from one another. The two beams are coherent with each other and the displacement is $<\lambda$. The angular splitting is $\Delta\theta \approx \tan\theta_c \Delta n / n$ where θ_c is the critical angle and $\Delta n = (n''-n'), n = (n''+n')/2$. The displacement is $\approx h\Delta\theta/\cos\theta_c = h\Delta n / n \tan\theta_c / \cos\theta_c$. But, we will choose $h\Delta n / \cos\theta \approx \lambda/4$, so automatically the displacement is $<\lambda$ and the two light beams can be treated as one.

The geometry of oblique incidence on a uniaxial form of the birefringent plate 229 is somewhat complicated, and thus to simplify matters, we introduce the Eulerian angles as shown in FIG. 30F. The relations between the (i,j.k) vector triad and the (I,J,K) ventor triad can be read from Table 3.

TABLE 3

	I	J	K
i	- sin ϕ sin ψ + cos θ cos ϕ cos ψ	cos ϕ sin ψ + cos θ sin ϕ cos ψ	sin θ cos ψ
j	- sin ϕ cos ψ - cos ϕ cos θ sin ψ	cos ϕ cos ψ- cos θ sin ϕ sin ψ	sin θ sin ψ
k	sin θ cos ϕ	sin θ sin ϕ	cos θ

Let the normal to the air/plate interface = K, the direction of the incident wave normal = k, and the optic axis of the plate 229 = I. We wish to rotate the incident polarization D_0 by 90°. Since the incident polarization D_0 is in the interface plane, it is consistent to let D_0 be along i_0 so that $\psi_0 = \pi/2$. The polarization D' of the ordinary ray is perpendicular to both I and k. Therefore, let D' be along i'. Now $i'_x = 0$. From Table 3 we conclude that $\tan\psi' = \cot\phi \cos\theta$. The polarization of the extraordinary ray D" is perpendicular to both D' and k. Therefore, $\psi'' = \psi' \pm \pi/2$. We choose $\psi'' = \psi' - \pi/2$, and then $\tan\psi'' = \tan\phi/\cos\theta$. To achieve the desired output,

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we can appropriately orient the birefringent plate 229. Just as in the normal incidence case, we let ψ_0 to be at 45° to the D' and D" directions. Therefore, we chose $\psi'=\pi/2$, and then $\tan\phi=\cos\theta$. For a typical case, where θ is close to $\theta_c \approx 40°$, $\phi \approx 37°$. In practice, for a range of incidence angles and wavelengths one would readily adjust ϕ experimentally to get the most complete polarization conversion, using the above formulae as a starting point and guide. We next determine the thickness, h, of the birefringent plate 229. As in the case of normal incidence, the condition is: $h = |(2m+1)/(n"-n')|\lambda/2$. However, the extraordinary index of refraction n" now depends on the angle of incidence θ and must be read off the index ellipsoid: $(1/n")^2 = (1/n_0)^2 \sin^2\theta + (1/n_e)^2 \cos^2\theta$ where n_0 is the ordinary index of refraction and n_e is the extraordinary index of refraction. Also note that $n'=n_0$. Typically, the index of refraction differences are small, <0.1 and approximately, $(n"-n') \approx (n_e - n_c)\cos^2\theta$. In addition, the light path length for oblique incidence is greater than that for normal incidence. The length h for oblique incidence is greater than the thickness of the plate 229 by a factor of 1/cos θ. Therefore, since the effective index difference is reduced by $\cos^2\theta$, but the path length is increased by 1/cos θ, it follows that the thickness required for oblique incidence is larger than for normal incidence by $\approx$ 1/cos θ. In practice, for a range of incidence angles and wavelengths one would adjust h experimentally to obtain the most complete polarization conversion. In practice, for a range of incidence angels and wavelengths, one can adjust ϕ experimentally to obtain the most complete polarization conversion, using the above formulae as a starting point and guide.

In another example embodiment, the conversion of light of one polarization into another polarization state can be considered as involving three steps: (1) separation of different polarization states into substantially distinct beams at every point on the system 204, (2) polarization conversion without affecting the desired polarization and (3) light diffusion into an appropriate angular distribution without depolarization of the light output.

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As described herein, a variety of methods can be used to separate the different polarization states in the system 204. For example, the low index layer 214 can be birefringent, as shown, for example, in FIGS. 31A-C. The layer 214 can be, for example, an oriented fluoropolymer convertor layer which creates two light beams 218 and 220 of orthogonal polarization emerging from every point along the system 204. This can be used provided two conditions are met. The first condition requires that the birefringence of the layer 214 is large enough to significantly prevent substantial overlap between the two polarized beams 218 and 220. This condition is summarized by Equations (15)-(17) where C is at least 1 and preferably greater than 4. The second condition is that the direction of birefringence orientation (direction of stretch) of the first layer 214 is substantially parallel to the y axis.

For ϕ=1-1.5 degrees, the birefringence must be at least 0.03-0.05 to satisfy Equations (15)-(17). Measurements of the birefringence of various commercial fluoropolymer films yielded the following data (average index, birefringence):

Tefzel 250 zh: (1.3961,0.054)

Tefzel 150 zm: (1.3979,0.046)

Teflon PFA 200 pm: (1.347,.030)

The wedge layer 206 laminated with the 250zh material produced just-separated polarized beams where even the Fresnel reflected parts did not overlap.

In another embodiment, one can achieve even greater angular separation of polarization by using a faceted redirecting layer comprised of a highly birefringent material.

A third approach for separation of polarization states uses a sheet of polymeric beam splitters consisting of an alternating structure of birefringent/ transparent layers 427 shown in FIG. 30G and H. Such an array of the layers 427 can rest on top of a collimated backlight 428 and polarizes by selective total internal reflection. The index of the film of polymeric layers 429 parallel to the plane of light incidence is lower than that of a transparent layer 430, and the index perpendicular to the plane of light incidence is closely matched to the transparent layer 430, so that

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an incoming collimated light beam 431 from the backlight 428 (inclined to the beam splitter layers 427) is split: the parallel polarized beam 431 is totally internally reflected, but the perpendicular component is transmitted.

One example of this arrangement can be Mylar/Lexan layers. Mylar indexes are: (1.62752,1.6398,1.486). The Lexan index is: 1.586. The complement of the critical angle is twenty degrees; therefore, the beam splitter layer 427 will function as long as the complement of the incidence angle is less than twenty degrees (in the Lexan). However, at glancing angles, Fresnel reflection causes reduction in the degree of polarization. For example, for thirteen degrees the Fresnel reflected perpendicular component is 9%.

Another example of this arrangement of the layer 427 is uniaxial Nylon/Lexan. Nylon indexes are: (1.568,1.529,1.498). Here there are two critical angles, the complements of which are nine and nineteen degrees for perpendicular and parallel, respectively. So, the obliquity must be inside this angular range for polarization to be operative. Taking the same case for Fresnel reflection as for Mylar (thirtee degree angle), the Fresnel reflected perpendicular component is only 5%, because the index matching is better.

For either of these examples, each beam splitter layer 427 needs to have the appropriate aspect ratio such that all rays of the beam 431 have exactly one interaction with the film/Lexan interface.

In one embodiment, once the light of different polarization states is separated into two orthogonally polarized beams at every position along the backlight 428, there must be a means of converting the undesired polarization to the desired one, such as the polarization convertor layer 346 in FIG. 31C and 429 in FIG. 30G.

One method of performing the polarization conversion is by an alternating waveplate combined with a lens or lens array. In the single lens method, a light beam 218 and 220 will fall upon lenses focused to two nonoverlapping strips of light of orthogonal polarization at the focal plane. The alternating wave plate acts to rotate the polarization of only one of the beams (220) by ninety degrees, the emergent light will be

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completely converted to light 218. This can be effected by the presence of a half-wave retarder placed to capture only the light 220 of one polarization. This has been demonstrated visually with a large lens, a plastic retardation plate, and Polaroid filters (Polaroid is a registered trademark of Polaroid Corporation).

In a second approach using a lenticular array, one uses a thin sheet of lenses and an alternating waveplate structure (with the frequency equal to the lens frequency), where the retardation changes by 180 degrees for each lens. For a lenticular array 1 mm thick, each image can be of the order of 5 thousandth of an inch in size so the registration of the lenticular array with the waveplate would have to be exact enough to prevent stack-up errors of less than one thousandth of an inch.

Another method of performing the polarization conversion is by use of a double Fresnel rhombus ("DFR") which is another embodiment of a converting layer, such as the layer 346 in 31C and 427 in 30G. The DFR avoids registration problems by selectively retarding according to angle instead of position. Such a DFR causes the light of first polarization state to suffer from total internal reflection events corresponding to $4 \times 45° = 180°$ of phase shift, while the other polarization state light is only transmitted, so that the output light is completely polarized to the light of first polarization in one plane in the end. The DFR can be constructed, for example, by having four acrylic or Lexan films each embossed with 45 degree prisms, all nested. For the DFR to cause retardation the two orthogonal plane polarized beams L and R (by a 1/4-wave plate). If the L is transmitted by the DFR then the R beam will get converted to the L beam by the DFR. Finally the L beam is converted to plane polarized by another 1/4-wave plate, the orientation of which determines the final plane of polarization.

In a preferred embodiment shown in FIG. 21A, the converting layer 226 is disposed on the opposite side of the base layer 206 relative to the polarization filter layer 216. In the embodiment of FIG. 21B, the converting layer 226 is disposed on the same side as the polarization filter layer 216. As can be seen by reference to FIGS. 21A and B, the converting layer 226 can even convert the light 218 and 220 to the light

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of 227 of another third polarization state. This light 227 can be, for example, the light of a third polarization state or even a variation on, or combinations of, the first or second polarization states discussed hereinbefore. The resulting light polarization is dependent on the response characteristics of the converting layer 226. The converting layer 226 can therefore be designed to respond as needed to produce a light of desired output polarization state; and in combination with appropriate positioning of the layer 226, one can produce an output light in the desired direction having the required polarization characteristics.

In another form of the invention illustrated in FIGS. 22A-E, the converting layer 226 is utilized for other optical purposes. FIGS. 22, 23, 24 E-F, 25-27, 28A and C, and 29 all illustrate use of the converting layer 226 to change the light 220 of the second polarization state to the light 218 of the first polarization state. In addition, the elements of the luminaire system 204 are arranged such that the light being processed will pass through, or at least encounter, one or more of the polarization filter layer 216 at least once after passing through the converting layer 226. For example, in the case of processing the light 220, the arrangement of elements enables return of the light 220 to pass through the polarization filter layer 216 after passing through the converting layer 226. In some instances, the light 220 can encounter the polarization filter layer 216 two or more times before being output as the light 218 of the first polarization state. FIGS. 22A-E illustrate examples of a variety of constructions to achieve a desired output. In FIG. 22A, after the light 212 encounters the polarizing filter layer 216, the reflected light 220 passes through the converting layer 226, and is converted to the light 218. The light is then returned to the polarization filter layer 216 via internal reflection. In addition, in FIG. 22B, the light 220 also passes through the converting layer 226, is converted to the light 218, and is then returned again to the filter layer 216 after internal reflection. In these cases, n_3 is low enough such that the relationship among n_1, n_2 and n_3 in Equation (10) is met.

In the embodiments of FIGS. 22C-E, a redirecting means in the form of the light reflector layer 222 is added to return the light 220 to the polarization filter layer 216. As described hereinbefore for the

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embodiment of FIG. 20A, the intervening layer 223 has an index of refraction n_3 which can be adjusted to affect the spatial and angular distribution of light encountering the layer 224. In a preferred form of the invention shown in FIGS. 22C-E, the layers of index n_2 and n_3 can include air gaps, and in the most preferred form of the invention the layers of index n_2 are air gaps.

FIGS. 24A-F illustrate a sequence of constructions starting with use of one of the polarization filter layer 216 in FIG. 24A and continuing construction of more complex forms of the luminaire system 204. In FIGS. 24C-F, there is added one or more of the light redirecting layer 224, at least one liquid crystal display ("LCD") layer 230 and light matching means, such as a matching layer 232. The matching means acts to convert the light output by the assembly of the other layers to a particular polarization state preferred by a target device or additional layer, such as the LCD layer 230. The matching layer 232 is thus a special case of the converting layer 226.

In FIGS. 23A-C are illustrated other forms of the polarized light luminaire system 204 in combination with the LCD layer 230. In one general form of the embodiment of FIG. 23A, a layer 234 is included. In more particular forms of the inventions, for example as in FIG. 23, the preferred value of n_2 is about 1 (see, for example, FIGS. 23B and C). In certain forms of FIG. 23A, $n_2>1$ can also be utilized. Alternatively, preferably choices for the relationship among indices of refraction are set forth in Equation (9) and (10).

Further examples of preferred embodiments are shown in FIGS. 26A and B, and in FIG. 26A is included a cold cathode fluorescent tube ("CCFT") light source 236. This embodiment further includes an angle transformer layer 238 which operates to change the angular distribution of the light. This angle transformer layer 238 can, for example, change the distribution in the xz-plane to control the spatial uniformity of light output from the device 10. In the preferred embodiment, the distribution of the output light 250 is substantially uniform in its spatial distribution over at least 90% of the output surface. In addition, the angular

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distribution of the light 212 in the xz-plane is approximately $\pm\theta_{max}$ with respect to the normal to the back surface 211, where

$$\frac{\pi}{2} - \theta_c + 6\Phi \geq \theta_{max} \geq \frac{\pi}{2} - \theta_c \qquad (14)$$

and the back surface 211 is about perpendicular to at least one of the first surface 208 and the second surface 210. The angle transformer layer 238 can be a tapered light-pipe section, a compound parabolic concentrator (a "CPC"), a micro-prismatic film (FIG. 28C) a roughened-surface layer, or a hologram. The angle transformer layer 238 is most preferably optically coupled to the base layer 206 without an intervening air gap. The angle transformer layer 238 can also operate to change, and preferably narrow, the light distribution in the yz-plane to improve brightness, LCD image quality, and viewer privacy as well. In addition, in FIG. 26A, an output diffuser layer 248 has been added before the LCD layer 230 to broaden the angular distribution and enhance uniformity of output light 242 provided to the LCD layer 230.

In another preferred embodiment of FIG. 26B, a CPC 239 is coupled to a light source 244 operating to help maintain output light 250 within the proper angular distribution in the xz plane. In addition, one can control the range of angular output by use of a light redirecting means, such as a prismatic redirecting layer, such as the layer 246, using flat prismatic facets, such as the facets 247. See, for example, this type of layer and prismatic facets in FIGS. 28C, D and E and FIGS. 29A and B and the description in detail provided hereinafter. This embodiment as shown in FIG. 28E refers to the prismatic layer 251 and facets 253, and this embodiment also adds after the LCD layer 302 a light diffuser layer 304 for broadening light distribution in a specific plane. In a most preferred form of this embodiment, for example, shown in FIG. 28E, the light 242 is directed to pass through the LCD layer 302 within a narrow angular range in the xz-plane. The elements of the luminaire system 204 are therefore constructed to assist in providing transmission of the light 242 through the LCD layer 302 at an angle where the image forming properties are optimized. With the diffuser layer 304 positioned on the

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other side of the LCD layer 302 relative to the base layer 206, the diffuser layer 304 can broaden the angular distribution of viewer output light 250 without diffusing the light 250 in the xy-plane. For example, the diffuser layer 304 can be a "parallel" diffuser which can take the form of a holographic diffuser or lenticular diffuser with grooves substantially parallel to the y-axis. Viewers at a wide range of angles can then see the image which is characteristic of the optimal angle for the light 242 which is subsequently transmitted through the LCD layer 302 to form the light 250. Example configurations utilizing this form of general construction are thus shown in FIGS. 28D and E and FIGS. 29A and B. Further, FIGS. 28D and E and FIG. 29A also include a transverse diffuser layer 252 which diffuses the output light 242 provided to the LCD layer 302 only in the xy-plane in order to improve uniformity without broadening the distribution of the light 242 in the xz-plane . For example, the transverse diffuser 252 can be a holographic diffuser or a lenticular diffuser with grooves substantially parallel to the z-axis. Further details will be described hereinafter.

In FIGS. 27A and B are additional preferred embodiments wherein the first layer means of index of refraction n_2 is most preferably not air. These embodiments show different examples of the light redirecting layer 224. Further, in FIG. 27A medium 254 having index n_3 need not be air, but the various indices of the system 204 must meet the requirements of Equation (10) to achieve the total internal reflection illustrated. In FIG. 27B the medium 254 is air, the light redirecting layer 224 has curved facets 256, and the light 245 is focused within a preferred viewing zone 258.

The embodiments of FIGS. 28 and 29 preferably utilize an air gap layer 260 as the first layer means. The layer 260 enables light to enter the layer 260 after the light 212 has achieved an angle of incidence less than the critical angle θc characteristic of an interface between the base layer 206 and the air gap layer 260. The embodiment of FIG. 28B includes a first redirecting layer 262 between the base layer 206 and a diffuser layer 264 and a second redirecting layer 265 on the other side of the base layer 206. This first redirecting layer 262 includes refracting/internally

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reflecting prisms 266 while the second redirecting layer 265 includes refracting prisms 268. Two of the polarization filter layer 216 are disposed either side of the base layer 206, each transmitting the appropriate light 218 or 220 which is passed through the associated light redirecting layer, 262 and 265, respectively. In FIG. 28C is a more preferred embodiment wherein the light redirecting layer 246 comprises a refracting/internally reflecting layer having the relatively small prisms 247. The surface angles of each of the prisms 247 can vary across the illustrated dimension of the redirecting layer 246 in a manner described hereinbefore. This variation in angle enables focusing different cones of light coming from the prisms 247 onto the preferred viewing zone 258 (see FIG. 27B). The light reflector layer 222 can be a metallic coating as described hereinbefore.

The reflector layer 222 can be applied to the converting layer 226 by conventional vacuum evaporation techniques or other suitable methods. The other layers, such as the redirecting layer 246 can be formed by casting a transparent polymeric material directly onto the matching layer 232 (see FIGS. 24 C-F and 28C and D). The polarization filter layer 216 can likewise be manufactured by conventional methods, such as deposition of multiple thin layers directly onto the base layer 206. Also included is an angle transformer layer 274 coupled to the back surface 211 (see FIG. 28C). This angle transformer 274 includes prisms 276 which broaden the angular distribution of input light 212 to the base layer 206 to help provide a more spatially uniform form of the output light 218 to the LCD layer 230. Other forms of the angle transformer layer 274 can be a roughened layer and a hologram (not shown) coupled to the back surface 211 (or other input surface) without an intervening air gap.

In the preferred embodiment of FIG. 28D, a first prismatic light redirecting layer 249 is disposed between the base layer 206 and the polarization filter layer 216. This redirecting layer 249 reduces the angle of incidence of light 280 incident on the polarization filter layer 216. A second prismatic light redirecting layer 282 then redirects light 284 output from the filter layer 216 to an LCD layer 302 with a post diffuser

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layer 304, operable as a parallel diffuser as described hereinbefore. This embodiment further includes the CCFT light source 236 with a reflector 290 having a position following at least a portion of an involute of the light source 236 inner diameter. Another portion of the reflector 290 directly opposite the back surface 211 is convexly curved or bent.

In the preferred embodiment of FIG. 28E a light redirecting layer 251 comprises refracting micro prisms 253. A polarization filter layer 296 is disposed adjacent a converting layer 298, and the transverse diffuser layer 252 is positioned between the redirecting layer 251 and the LCD layer 302. A parallel diffuser 304 is disposed on the light output side of the LCD layer 302 with the light 242 directed through the LCD layer 302 at a preferred angle to optimize output light 301 for best image-forming quality of the LCD layer 302 (contrast, color fidelity and response time).

The embodiments of FIGS. 29A and B show some of the advantages of some forms of the invention over a conventional LCD polarizer system 304 shown in FIG. 30A. In FIG. 30A, a prior art backlight 306 emits light 308 of both polarizations in nearly equal proportions. A typical prior art LCD layer arrangement 310 includes a first form of polarization filter 312 and a second form of polarization filter 314 with the liquid crystal layer 316 sandwiched therebetween. In this LCD layer arrangement 310, the first polarization filter 312 must provide a high polarization ratio, that is, it must have an extremely low transmission of light of the second polarization state which is unwanted for input to the liquid crystal layer 316 in order for the LCD layer arrangement 310 to provide adequate LCD contrast. In practice, the polarization filter 312 has a high optical density for the desired light of the first polarization state as well. The resulting losses therefore further degrade the LCD light transmission and image output. In contrast to this prior art arrangement 310, the invention provides a much higher percentage of light which is preferred by the LCD layer arrangement 316 thereby making use of a substantial portion of the light of the unwanted second polarization and also minimizing loss of the desired light of the first polarization state.

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In the embodiment of FIG. 28A this advantageous processing of the light 218 and the light 220 for the LCD layer 316 is accomplished by positioning the converting layer 226 adjacent the base layer 206. Disposed adjacent the converting layer 226 is the polarization filter layer 216. The light redirecting layer 224 includes curved microprismatic facets 318 to broaden the angle of light distribution in the xz plane and improve the uniformity of light distribution output from the luminaire system 204. A transverse diffuser 320 is preferably laminated to the light redirecting layer 224 or can be formed on opposite sides of a single polymeric layer (not shown). The polarizing filter layer 216 can be laminated or is disposed directly onto the converting layer 226 which in turn is laminated or deposited directly onto the first surface 208.

In the preferred embodiment of FIG. 29A the advantageous processing of the light 218 and the light 220 for the LCD layer 302 is accomplished by using a first polarization filter layer 324 and a second polarization filter layer 322. The first filter 324 can, however, have a relatively low polarization ratio compared to the prior art polarization filter 312. For example, the polarization filter layer 324 can have a lower dye concentration than the prior art filter 312. This difference enables higher LCD light transmission and improved image-forming properties described hereinbefore. This preferred embodiment utilizes a post diffuser layer 328 which is coupled to an LCD system 330 (the combination of the layer 324, the liquid crystal layer 302 and the layer 322). Preferably the post diffuser layer 328 is laminated to, or integrally formed with, the second polarization filter layer 322.

In the preferred embodiment of FIG. 29B, the advantages are achieved by using only one polarization filter layer 248 which results in reduced cost for the luminaire system 204 and increased light transmission. In this embodiment the light output through the matching layer 232 is preferably at least 90% composed of light 218 of the LCD preferred polarization state. A coupled angle transformer 334 coupled to the back surface 211 reduces the angular width of light distribution in the yz plane, and this reduced angular distribution further improves quality of

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the output light 250 making up the LCD image from the luminaire system 204.

Birefringent Layers in Luminaire Systems

A birefringent material can be used to advantage in the polarized light luminaire system 204 discussed hereinbefore. In the embodiment illustrated in FIG. 31A, the first layer 214 can be a birefringent material of index n_2 with two different optical indices $n_{2\alpha}$ and $n_{2\beta}$ for the light 212 of two different polarization states "a" and "b", both indices being less than one. This light 212 encounters the layer 214 near the respective critical angles for these two polarization states,

$$\theta_{c\alpha} = \arcsin(n_{2\alpha} / n_1) \quad (15) \text{ and}$$

$$\theta_{c\beta} = \arcsin(n_{2\beta} / n_1) \quad (16)$$

The conditions of Equation (10) must be satisfied for n_2 equal to both $n_{2\alpha}$ and $n_{2\beta}$, independently. The light 212 of both polarization states decreases its angle of incidence by an angle 2Φ for each cyclic reflection from the first surface 208 and the second surface 210 as described previously. In this embodiment $n_{2\alpha} > n_{2\beta}$ and therefore $\theta_{c\alpha} > \theta_{c\beta}$. As the incidence angle for both polarization states decreases, the light 212 of both polarization states can encounter the interface with the birefringent first layer 214 with the light having an incidence angle less than the first critical angle $\theta_{c\alpha}$, but exceeding the second critical angle $\theta_{c\beta}$. Therefore, light 218 of the first polarization state is at least partially transmitted through the birefringent first layer 214, while the light 220 of the second state is preferentially reflected by total internal reflection. This reflected second-state light 220 and the residual first-state light 218 continue to decrease their angles of incidence with successive reflections. The light 218 of the first polarization state is transmitted at each successive encounter with the interface between the first layer 214 and the base layer 206. The light 220 of the second state continues to undergo total internal reflection at this interface until its angle of incidence becomes less than the second critical angle $\theta c\beta$, at which point this second-state light 220 also is at least partially transmitted through the

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birefringent first layer 214. By virtue of this mechanism and of the difference in indices $n_{2\alpha}$ and $n_{2}\beta$, the light exiting the birefringent first layer 214 has a different angle distribution for the two polarization states "a" and "b".

Birefringent materials can in general include crystalline materials having an anisotropic index of refraction. A preferred material is a stretched polymeric film such as stretched fluorinated film. The stretching orients the film and makes the index of refraction different along that direction. Elsewhere we give birefringence values of these stretched fluoropolymer film with Δn ranging from 0.030-0.054. Other films are PVA (Polyvinylalcohol). Polypropylene, Polyolefin or even Polyester (Mylar). Mylar is actually biaxial, but may still be used to rotate polarization. More traditional uniaxial birefringent materials are: Calcite and Quartz. These are not as practical as the stretched films. In practice the two polarization states are well-separated only if the two indices are sufficiently different. This condition may be expressed as,

$$\theta_{c\alpha} \geq \theta_{c\beta} + s\Phi \qquad (17)$$

where s must be at least 1 and is preferably greater than four. This condition may be achieved, for example, using uniaxially oriented fluoropolymer material for the birefringent layer, acrylic polymer for the base layer 206 and reasonable values
of Φ (between one and one-and-a-half degrees is typical for notebook computer LCD backlighting).

FIG. 31B is like FIG. 31A, but the redirecting layer 224 has been added; and the preferred embodiment uses air for the layer 207 having index n_3. The light 218 and the light 220 are output from the system 204 at different angles.

FIG. 31C illustrates another variation on FIGS. 31A and B, but the redirecting layer 224 comprises a flat faceted reflective layer 340. The light 218 and also the light 220 are directed to a converting layer 346 which transmits the light 218 without substantially changing its polarization state; however, the converting layer 346 does convert the light 220 to the light 218 of the desired first polarization state. The

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converting layer 346 shown in FIG. 31C has a construction that operates to convert the light polarization only within the angular range occupied by the light 220. The converting layer 346 thus utilizes the schematically illustrated angular separation of the light 218 and the light 220 to carry out the conversion of the light 220 to the light 218 without converting the light 218 to the light 220.

In the embodiments of FIGS. 31D and E, the reflected form of the light 220 is returned to the interface of the base layer 206 with the birefringent first layer 214. This is accomplished by virtue of total internal reflection of the light 220 together with passing at least twice through the converting layer 346, which results in at least partially converting the light 220 into the light 218 of the first polarization state. Since this light 218 has an incidence angle less than the first critical angle $\theta_{c\alpha}$, the light 218 is transmitted through the interface between the base layer 206 and the first layer 214. This light 218 can then be reflected or transmitted by the redirecting layer 224, depending on the particular nature of the redirecting layer 224. The alternatives of transmitted and reflected light are shown in phantom in FIGS. 31D and E. Further, in the embodiment of FIG. 31D, the converting layer 346 is on the same side of the base layer 206 as the birefringent first layer 214. The converting layer 346 is also disposed between the base layer 206 and the birefringent first layer 214. The embodiment of FIG. 31E shows another variation on FIG. 31D with the converting layer 226 and the birefringent first layer disposed on opposite sides of the base layer 206.

In the embodiment of FIG. 31F the system 204 is similar to the embodiment of FIG. 31D, but the redirecting layer 224 comprises a layer of facets 311. In the embodiment of FIG. 31G, the system 204 further includes the LCD layer 302, the matching layer 232, and the diffuser layer 304 is disposed in a spatial position after the light 218 has passed through the LCD layer 302. The redirecting layer 224 comprises the layer of microprisms 251 having flat faces and a metallic coating 342 for high light reflectivity. Also shown is the angle transformer layer 238 to control the spatial distribution of the light 253 output from the system

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204. The embodiment of FIG. 31H is similar to the embodiment in FIG. 31G, but the system 204 uses curved facets 345 for the redirecting layer 224 with facet angles adjusted at different spatial locations to focus the output light 250 onto a preferred viewing zone. The angle transformer 238 is illustrated as a CPC.

Light Diffuser After LCD Layer Processing

In the embodiments shown in FIGS. 12N and 12O the LCD display 216 or 236 provides an output light to the viewer. In a further improvement of these embodiments a post diffuser layer 350 is disposed in the path of the light 250 output from the LCD layer 302 (see FIG. 32A and B). In the preferred embodiments shown in these figures, the general operation is similar to the embodiments illustrated in FIGS. 26B, 28D and E; 29A and B and 31G, but without any of the polarization filter layers 216. As described hereinbefore, it is advantageous to provide light to the LCD layer 302 in a collimated angular range, preferably substantially perpendicular to the LCD layer 302 to optimize the image output therefrom. The use of the post diffuser layer 350 allows the output light 253 to provide an image to viewers over a wide angular range without compromising light contrast and color fidelity.

One aspect which is preferably controlled in a system including the post diffuser layer 350 is the width in the xz-plane of the angular distribution transmitted through the LCD layer 302. The output angular distribution preferably has a full width less than

$$\Delta\theta_{pd} = (2n_{lcd})\left(\frac{l}{d}\right) \qquad (18)$$

and a full width less than half of this value is even more preferred. In this equation $\Delta\theta_{pd}$ is in radians, n_{LCD} is the average index within the LCD layer 302, l is the repetition period of display pixel rows in the z-direction, and d is the thickness of the LCD layer 302. For a typical LCD used in notebook computers, n_{LCD} is approximately 1.5, l = 0.3 mm, and d = 3 mm. For this example, $\Delta\theta_{pd}$ is preferably less than 18 degrees, and a full-width of nine degrees or less is even more preferred. By comparison, Equation (8) can be used to calculate the output angular width of the current invention using a flat-facet prismatic redirecting layer, such as is

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shown in FIG. 32A (layer 359) or in FIGS. 28B (layer 262). For a typical notebook computer backlighting system, $\Phi = 1.3$ degrees and $n = 1.49$. In this example, Equation (8) gives an output angular distribution of eighteen degrees.

FIG. 32A shows a preferred arrangement of the system 204 having a parallel form of the post diffuser 350 disposed overlying the LCD layer 302. Also included is a holographic angle transformer 364 disposed on the back surface 211.

In another embodiment shown in FIG. 32B a refracting/internally reflecting layer 360 includes curved facets 362 in order to narrow the angular distribution in the xz-plane of light 364 directed through the LCD layer 302, and thereby to improve image quality by reducing parallax at the post diffuser layer 350. The embodiment has the curved reflecting facets 362, but flat refracting facets can achieve the desired function as well, as shown in FIG. 32C. In either case, the curved facets 362 preferably have a focal length less than the repetition period between each of the facets 362. The angular distribution in the xz-plane is preferably narrowed beyond the width given in Equation (8), and is most preferably narrowed beyond the width given in the equation above. In addition, the facet angles of the redirecting layer 224 are arranged to focus the light output from different portions of the sysyem 204 onto a preferred viewing zone. This figure also shows the micro-prismatic angle-transforming layer 274.

In FIG. 32C is shown a variation on the embodiment of FIG. 32B. In the system 204 an LCD layer arrangement 370 differs from the prior art LCD layer arrangement 310 illustrated in FIG. 30. In particular, a parallel light diffuser layer 372 (such as a holographic diffuser) is disposed between the LCD layer 302 (layer 316 in FIG. 30) and the second polarization filter layer 322 (layer 314 in FIG. 30). This arrangement enables the second polarization filter layer 322 to reduce the glare which can otherwise be caused by ambient light being reflected by the diffuser layer 372. FIG. 32C further shows a light redirecting layer 374 having curved refracting facets 376 which perform the same angle

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narrowing function as the curved reflecting facets 362 shown in FIG. 32B.

While preferred embodiments of the inventions have been shown and described, it will be clear to those skilled in the art that various changes and modifications can be made without departing from the invention in its broader aspects as set forth in the claims provided hereinafter.

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In the Claims:

1. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second layer surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means including a layer having index n_2 less than n_1 disposed beyond said second surface relative to said base layer and for enabling light to enter said first layer means after output from said base layer when the light in said base layer achieves the angle of incidence less than the critical angle θ_c characteristic of an interface between the base layer and said layer of index n_2; and

second layer means for preferably outputting light of a first polarization state compared to a second polarization state, said second layer means being disposed beyond said second surface relative to said base layer and said second layer means further able to reflect at least part of the light having the second polarization state.

2. The optical device as defined in Claim 1 further including light redirecting means for controlling angular range of light to be output from said optical device.

3. The optical device as defined in Claim 1 wherein said base layer includes an additional layer coupled thereto.

4. The optical device as defined in Claim 1 further including light converting means for changing light of the second polarization state to light of the first polarization state.

5. The optical device as defined in Claim 4 wherein said second layer means is disposed on the opposite side of said base layer relative to said converting means.

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6. The optical device as defined in Claim 4 further including light redirecting means for controlling angular range of light to be output from said device, said second layer means being disposed on the same side of said base layer as said light redirecting means and also closer to said base layer than said light redirecting means.

7. The optical device as defined in Claim 1 wherein at least one of said first and second layer means comprises a light converting means for at least partially changing light of one polarization to another polarization.

8. The optical device as defined in Claim 1 further including light redirecting layer means for changing the angle of light for output to the viewer.

9. The optical device as defined in Claim 8 wherein said light redirecting means further comprises means for controlling angular range of light output.

10. The optical device as defined in Claim 8 further including converting means for at least partially changing light of one polarization to light of another polarization.

11. The optical device as defined in Claim 1 further including at least one intervening layer disposed between said base layer and said first layer means, said intervening layer allowing transmission of at least part of the light and said intervening layer wherein said first layer means is comprised of at least an air gap.

12. The optical device as defined in Claim 10 wherein said converting means comprises a birefringent layer.

13. The optical device as defined in Claim 1 wherein said first layer means is disposed one of (a) further from said second surface than said second layer means and (b) nearer said second surface than said second layer means.

14. The optical device as defined in Claim 1 further including a liquid crystal display disposed adjacent said device with light redirected to said display by said optical device.

15. The optical device as defined in Claim 1 wherein said first layer means includes an air gap.

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16. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second layer surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal; and

layer means coupled to said base layer for preferably outputting light of a first polarization state compared to a second polarization state, said layer means further able to reflect at least part of the light having the second polarization state.

17. The optical device as defined in Claim 16 wherein said layer means includes a layer with index of refraction n_2 less than n_1.

18. The optical device as defined in Claim 17 wherein said layer means is coupled directly to said base layer.

19. The optical device as defined in Claim 17 wherein said layer means includes an air gap.

20. The optical device as defined in Claim 17 wherein said layer means comprises light converting means for at least partially changing light of one polarization to light of another polarization and also includes light redirecting layer means for operating on the light to control the angular output range of the light to the viewer.

21. The optical device as defined in Claim 20 wherein said light converting means and said light redirecting layer means are disposed adjacent one another.

22. The optical device as defined in Claim 20 wherein said light converting means comprises a birefringent layer.

23. The optical device as defined in Claim 22 wherein said birefringent layer is disposed on one side of said base layer compared to said light redirecting layer means.

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24. The optical device as defined in Claim 17 wherein said layer means comprises a birefringent layer, converting means for changing light of the second polarization state to light of the first polarization state and light redirecting layer means for operating on the light to exert control over angular output range of the light to the viewer.

25. The optical device as defined in Claim 24 wherein said light redirecting layer means is disposed further from said base layer than said birefringent layer and said converting means.

26. The optical device as defined in Claim 25 wherein said converting means is disposed closer to said base layer than said birefringent layer.

27. The optical device as defined in Claim 17 wherein said layer means further provides light of the first polarization state being transmitted through said first surface of said base layer and part of the light of the second polarization state being transmitted through said second surface of said base layer

28. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means including an air gap disposed beyond said second surface relative to said base layer and for enabling light to enter said air gap after output from said base layer when the light in said base layer achieves the angle of incidence less than the critical angle θ_c characteristic of an interface between the base layer and said air gap,

second layer means for preferably outputting light of a first polarization state compared to a second polarization state, said second layer means also disposed beyond said second surface relative to said

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base layer and said second layer means further enabling reflection of at least part of the light of the second polarization state; and

light redirecting means for operating on light having passed through said base layer to enable the light to be output from said device.

29. The optical device as defined in Claim 28, wherein said redirecting means includes means for operating on the light having passed through said second layer means to control angular output of the light.

30. The optical device as defined in Claim 29 wherein said light redirecting means operates on said reflected light and redirects the reflected light toward said second layer means.

31. The optical device as defined in Claim 30 wherein said light redirecting means is disposed beyond said top surface relative to said base layer.

32. The optical device as defined in Claim 31 wherein said light redirecting means includes at least a reflecting layer.

33. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means comprising an air gap layer disposed at least beyond said first surface relative to said base layer and for enabling light to enter said first layer means after output from said base layer when the light in said base layer achieves the angle of incidence less than the critical angle θ_c characteristic of an interface between said base layer and said air gap layer; and

second layer means for preferably outputting light of a first polarization state compared to a second polarization state, said second layer means disposed beyond said second surface relative to said base

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layer and said second layer means including an air gap and further enabling reflection of at least part of the light having the second polarization state.

34. The optical device as defined in Claim 33 further including a redirecting layer overlying said first layer, said redirecting layer transmitting light toward the viewer over a controlled angular range.

35. The optical device as defined in Claim 33 wherein said second layer means further comprises converting means for changing at least part of the light of the second polarization state to provide light of the first polarization state for output to the viewer.

36. The optical device as defined in Claim 33 wherein the light comprises at least one of linearly polarized light, circularly polarized light and elliptically polarized light.

37. The optical device as defined in Claim 35 wherein said second layer means converts light from the second to the first polarization state with at least a ten percent efficiency.

38. The optical device as defined in Claim 33 wherein said second layer means is transparent to light having both the first and second polarization states.

39. The optical device as defined in Claim 33 wherein said second layer means causes less than a ten percent change of angular distribution of the light output to the viewer for light incident at an angle x relative to the surface normal wherein,

$$\frac{\pi}{2} \geq x \geq \frac{\pi}{2} - 8^{1/2}\,\phi^{1/2}\left[\frac{n_1^2}{n_2^2} - 1\right]^{1/4}$$

where n_1 = index of refraction of said base layer and n_2 = index of refraction of said first layer means.

40. The optical device as defined in Claim 33 further including third layer means disposed between said base layer and the viewer, said third layer means for converting light of one polarization state to another polarization state.

41. The optical device as defined in Claim 40 wherein said third layer means further includes a liquid crystal layer electrically

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activated for converting the polarization of light passing therethrough from one polarization state to another polarization state.

42. The optical device as defined in Claim 33 further including an air gap layer between said liquid crystal layer and a separate layer portion forming said third layer means, for converting light from the first to the second polarization state.

43. The optical device as defined in Claim 35 wherein said means for changing polarization has an index of refraction $n \geq 1.4$, thickness $\geq 5\mu m$ and is birefringent such that $\Delta n > 0.05$.

44. The optical device as defined in Claim 33 wherein said birefringent second layer means comprises at least one of a biaxially oriented layer and a uniaxially oriented layer of birefringent material.

45. The optical device as defined in Claim 43 wherein said birefringent second layer means is selected from the group consisting of polyester, acrylic and polycarbonate materials.

46. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means including an air gap at least one of disposed beyond said first surface and beyond said second surface relative to said base layer and having an optical index of refraction n_2 for allowing transmission of light received from said base layer; and

converting layer means for changing light of one polarization state to another polarization state, said converting layer means disposed at least one of overlying and underlying said base layer.

47. The optical device as defined in Claim 46 further including light redirecting means at least one of overlying and underlying said first

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layer means, said redirecting means for selectively redirecting light output from said first layer means.

48. The optical device as defined in Claim 46 further including a reflecting layer beyond said second surface relative to said base layer for reflecting light of the second polarization state received from said base layer.

49. The optical device as defined in Claim 46 further including second layer means for preferably transmitting light of one polarization relative to another.

50. The optical device as defined in Claim 48 further including means beyond said reflecting layer relative to said base layer for rotating light of the second polarization state to provide light of the first polarization state for output to the viewer.

51. The optical device as defined in Claim 50 further including third layer means disposed between said first layer and the viewer, said third layer means for converting light of the first polarization state to light having an LCD preferred polarization state.

52. The optical device as defined in Claim 51 wherein said third layer means comprises a birefringent layer.

53. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means including an air gap beyond said second surface relative to said base layer and said base layer first surface for enabling light to enter said layer means from said base layer when the light in said base layer achieves the angle of incidence less than the

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critical angle θ_c characteristic of the interface between the base layer and the layer means;

light redirecting means for operating on light having passed through said base layer and for outputting the light toward the viewer; and

second layer means disposed in a layer position being a layer beyond said first surface relative to said base layer and being a layer beyond said light redirecting means relative to said base layer, said second layer means for preferably transmitting light of a first polarization state compared to a second polarization state and for preferably reflecting light of the second polarization state.

54. The optical device as defined in Claim 53 wherein said second layer means is disposed beyond said first surface relative to said base layer and the optical device further includes another light redirecting means disposed beyond both said second layer means and said first surface relative to said base layer.

55. The optical device as defined in Claim 53 wherein said redirecting means comprises at least one of a reflective layer able to reflect light and a transmissive layer able to modify the angular distribution of light passing therethrough.

56. The optical device as defined in Claim 53 wherein said second layer means is disposed beyond a first one of said light redirecting means, relative to said base layer, with an air gap disposed between said base layer and said second layer means and another air gap disposed between said second layer means and a second one of said light redirecting means.

57. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one

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of said first and second surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means including an air gap at least one of disposed beyond said first surface relative to said base layer and beyond said bottom layer surface relative to said base layer and having an optical index of refraction n_2 for allowing transmission of light received from said base layer;

second layer means for preferably transmitting light of a first polarization state relative to a second polarization state, said second layer means disposed at least one of (a) disposed beyond said first surface and said first layer means relative to said base layer and (b) disposed beyond said second surface and said first layer means and said second layer means further enabling reflection of at least part of the light having the second polarization state;

light redirecting means for operating on the light reflected by said second layer means and redirecting it back toward said second layer means; and

third layer means for converting at least part of the light of the second polarization state to light of the first polarization state.

58. The optical device as defined in Claim 57 wherein said light redirecting means includes a reflective layer disposed underlying said second surface of said base layer and said second layer means overlying said base layer.

59. The optical device as defined in Claim 57 wherein said third layer means is disposed between said second layer means and said light redirecting means.

60. The optical device as defined in Claim 58 wherein said third layer means is disposed between said reflective layer and said second layer means.

61. The optical device as defined in Claim 60 wherein said third layer means is disposed above said first surface along with said second layer means.

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62. The optical device as defined in Claim 60 wherein said third layer means is disposed below said second surface along with said reflective layer.

63. The optical device as defined in Claim 57 wherein said second layer means comprises a plurality of layers of material having alternating high and low indices of refraction.

64. The optical device as defined in Claim 63 wherein the indices of refraction n_H (high index) and n_L (low index) meet the requirement:

$$\tan\theta_H = n_H/n_L;$$

$$\tan\theta_L = n_L/n_H \text{ and}$$

$$n_H^2 n_L^2 \cong n_H^2 + n_L^2$$

65. The optical device as defined in Claim 64 wherein the thickness of each layer of said plurality of layers is about one quarter the wavelength of light in said layers.

66. The optical device as defined in Claim 64 wherein the thickness of each layer of said plurality of layers is at least twice the wavelength of light in said layers.

67. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second layer surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

layer means for preferably outputting light of a first polarization state compared to a second polarization state, said layer means including a first filter layer means for filtering the light to pass preferably said light of first polarization state and said layer means

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further including converting means for changing at least a part of said light of second polarization state to said light of first polarization state;

a liquid crystal display layer positioned to receive said light of first polarization state and output said light to the viewer; and

light diffuser means for diffusing light output from said layer means and said liquid crystal display layer to broaden the light in a narrow angular distribution in a plane thereby outputting light to a viewer over a range of viewing angle without distorting image quality.

68. The optical device as defined in Claim 67 wherein said layer means comprises at least one polarization filter layer and at least one light polarization converting layer.

69. The optical device as defined in Claim 67 wherein said light diffuser means comprises a parallel light diffuser.

70. The optical device as defined in Claim 67 wherein said light diffuser means comprises a light redirecting layer having a prismatic faceted surface.

71. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second layer surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal; and

first layer means including a layer having index n_2 less than n_1 disposed beyond said second surface relative to said base layer and for enabling light to enter said first layer means after output from said base layer when the light in said base layer achieves the angle of incidence less than the critical angle θ_c characteristic of an interface between the base layer and said layer of index n_2; and

a liquid crystal display layer positioned to receive the light output from said first layer means and output said light to the viewer; and

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light diffuser means for diffusing light output from said layer means and said liquid crystal display layer to broaden the light in a narrow angular distribution in a plane thereby outputting light to a viewer over a range of viewing angle without distorting image quality.

72. The optical device as defined in Claim 71 further including at least one of a reflector layer, a light redirecting layer, and a transverse diffuser disposed nearer said base layer than said liquid crystal display layer.

73. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second layer surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

first layer means including a layer having index n_2 less than n_1 disposed beyond said second surface relative to said base layer and for enabling light to enter said first layer means after output from said base layer when the light in said base layer achieves the angle of incidence less than the critical angle θ_c characteristic of an interface between the base layer and said layer of index n_2;

second layer means for preferably outputting light of a first polarization state compared to a second polarization state, said second layer means being disposed beyond said second surface relative to said base layer and said second layer means further able to reflect at least part of the light having the second polarization state;

light redirecting means for controlling angular range of light to be output from said device; and

a liquid crystal display layer positioned to receive said light of said first polarization state for output to the viewer.

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74. The optical device as defined in Claim 73 wherein said second layer means comprises at least one of a polarization filter layer and a polarization converter layer.

75. An optical device for operating on light from a source and for selectively outputting light to a viewer, comprising:

a base layer having a wedge-shaped cross-sectional area and having an optical index of refraction n_1, and a first and a second surface converging to define at least one angle of inclination ϕ, said base layer further including a back surface spanning said first and second surfaces, and the light exiting said base layer when the light being reflected therein decreases its angle relative to the normal to at least one of said first and second surfaces and achieves an angle of incidence less than a critical angle θ_c relative to the normal;

layer means including an air gap at least one of disposed beyond said first surface and beyond said second surface relative to said base layer and having an optical index of refraction n_2 for allowing transmission of light received from said base layer;

converting layer means for changing light of one polarization state to another polarization state, said converting layer means disposed at least one of overlying and underlying said base layer;

a liquid crystal display layer positioned to receive said light of said first polarization for output to the viewer.

76. The optical device as defined in Claim 75 further including light diffuser means for diffusing light output from said layer means and said liquid crystal display layer to broaden the light in a selected narrow angular distribution.

77. The optical device as defined in Claim 75 wherein said layer means comprises at least one polarization filter layer and at least one light polarization converting layer.

78. The optical device as defined in Claim 75 wherein said light redirecting means comprises at least one of a light redirecting layer disposed above or below said base layer and (2) a light redirecting layer disposed adjacent said back surface.

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Fig. 1
— PRIOR ART —

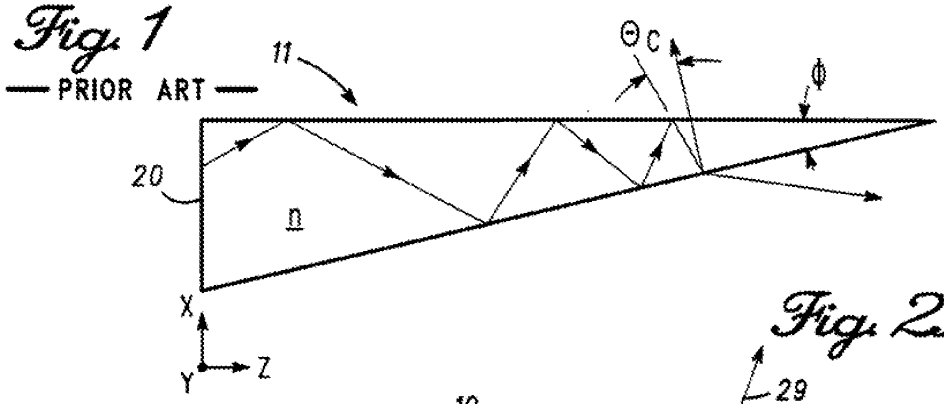


Fig. 2A

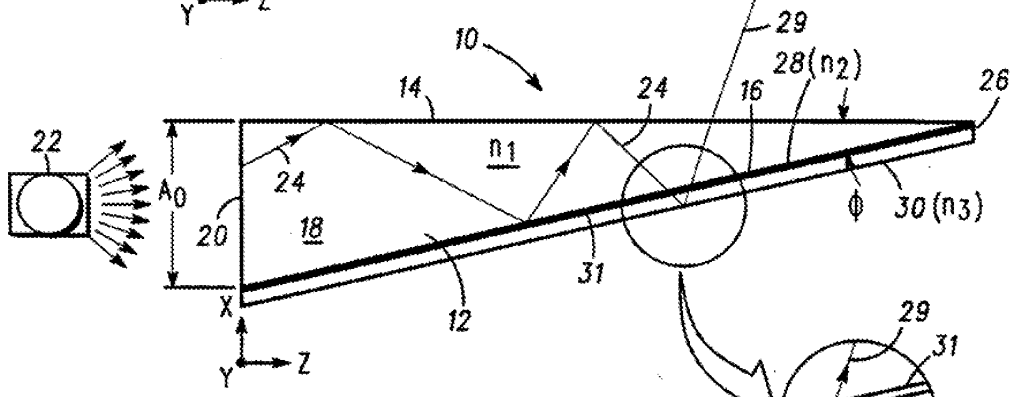


Fig. 2B

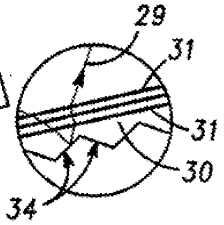


Fig. 2C

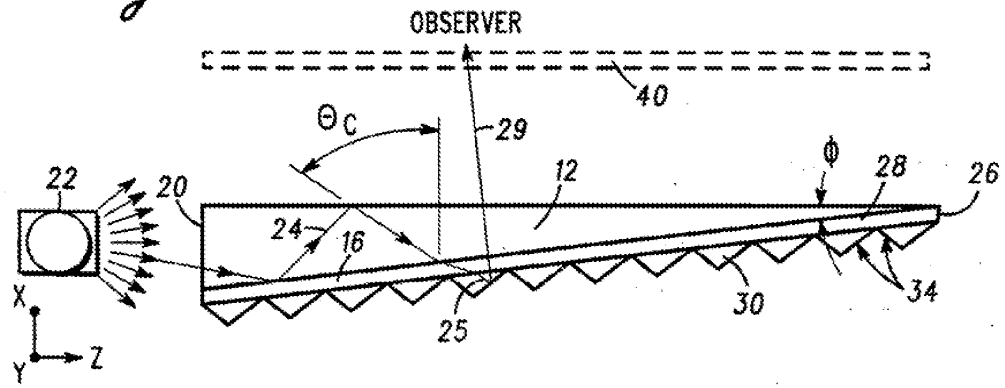
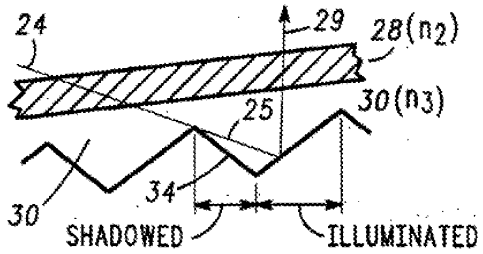


Fig. 2D



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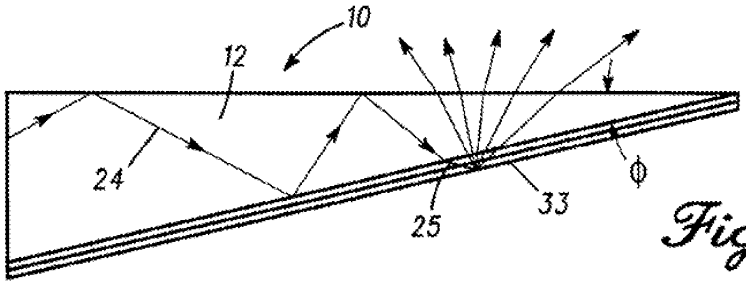


Fig. 2E

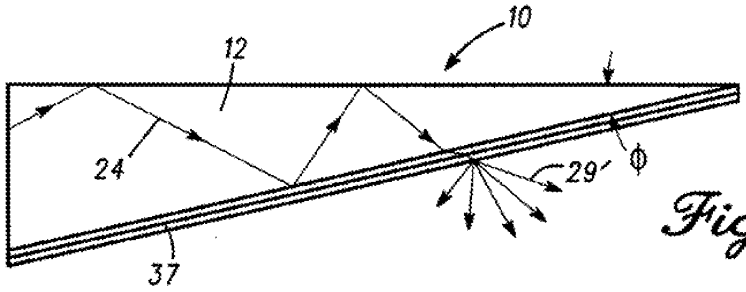


Fig. 2F

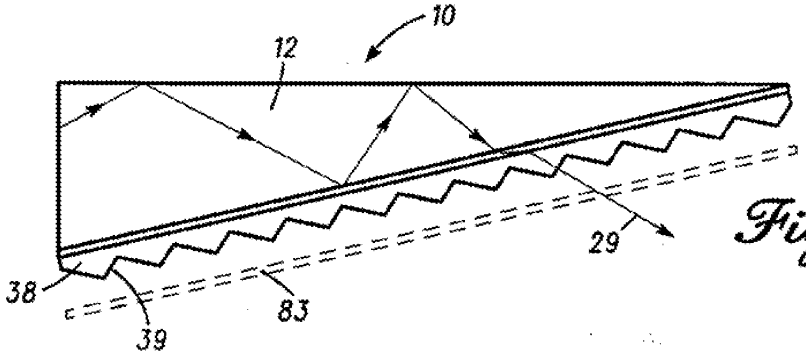


Fig. 2G

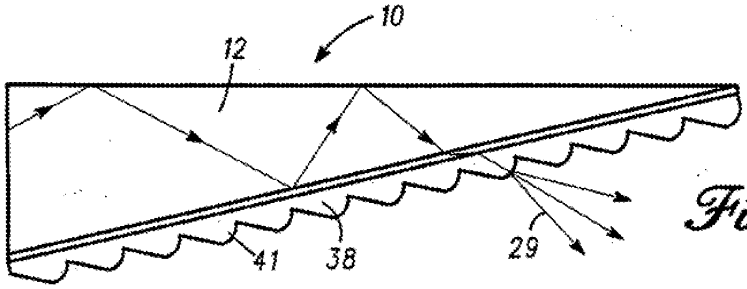


Fig. 2H

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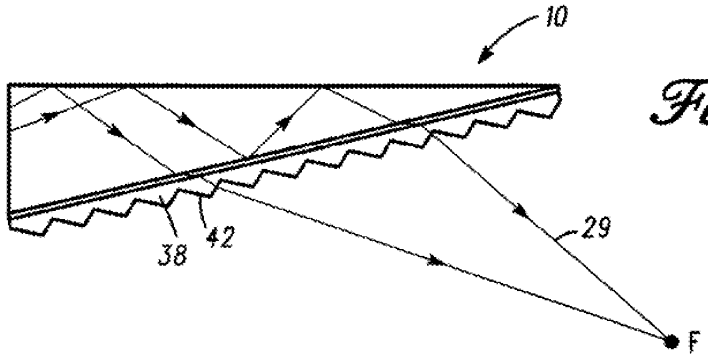


Fig. 2J

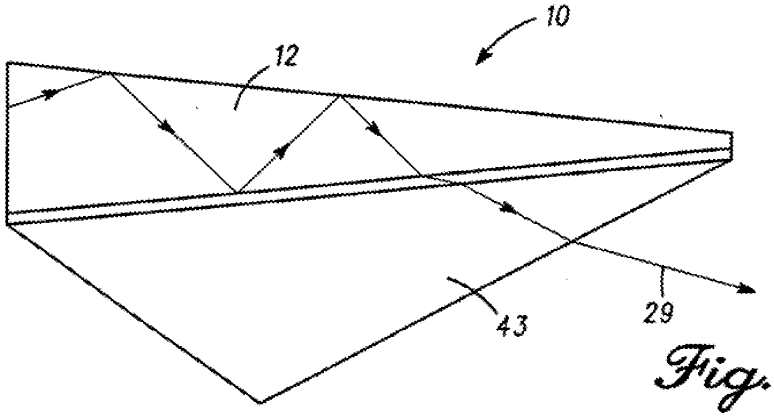


Fig. 2J

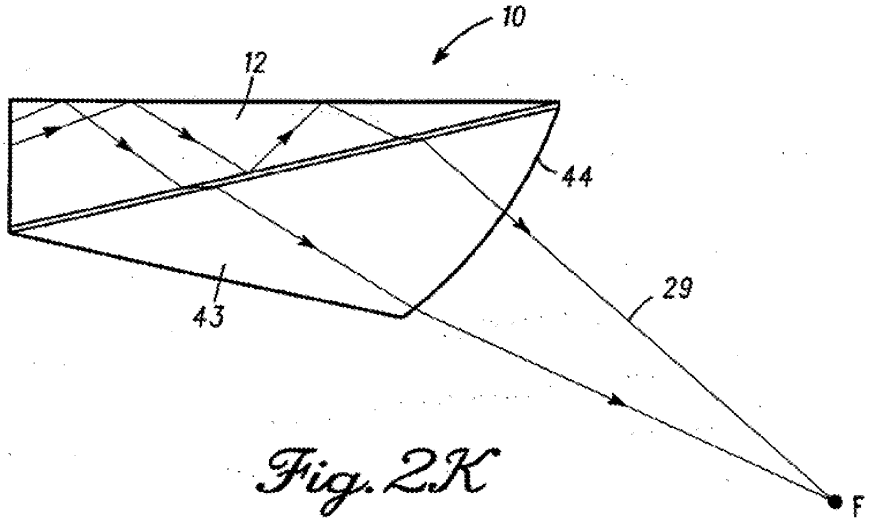


Fig. 2K

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Fig. 2L

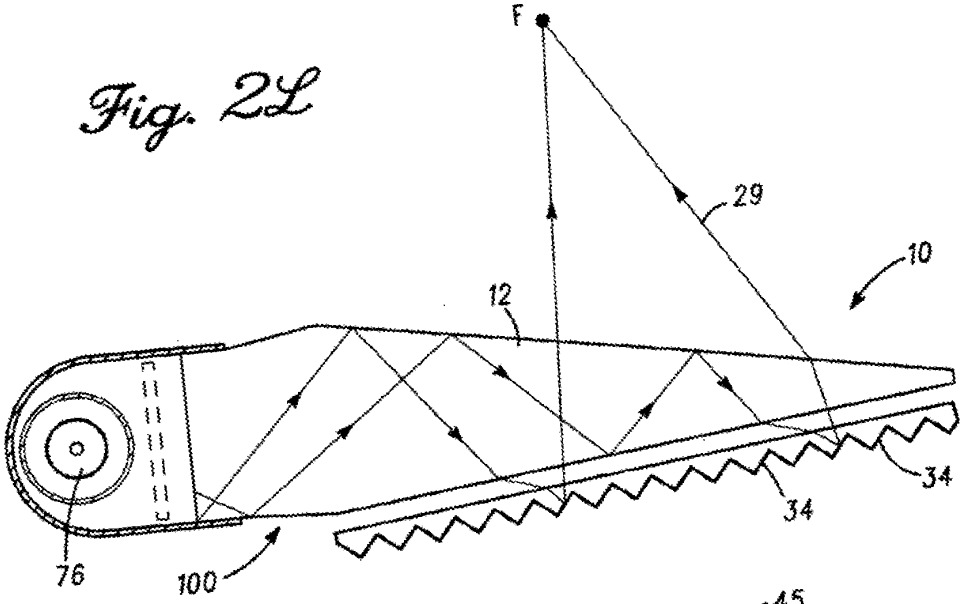
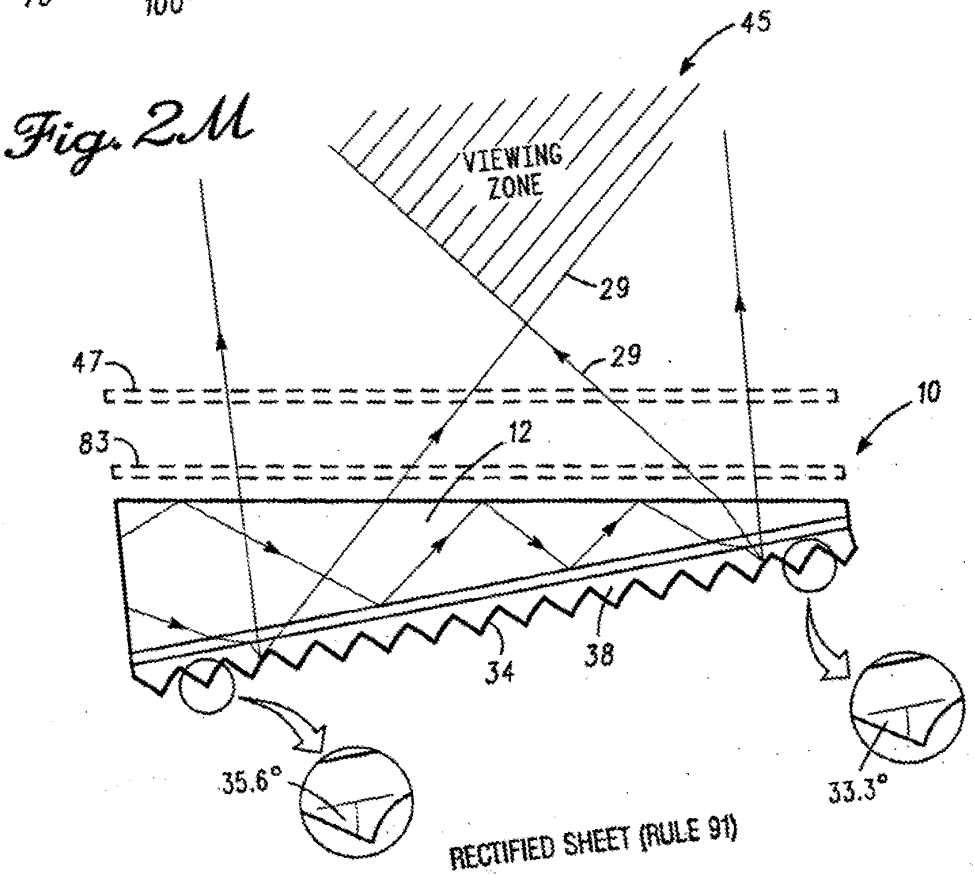


Fig. 2M



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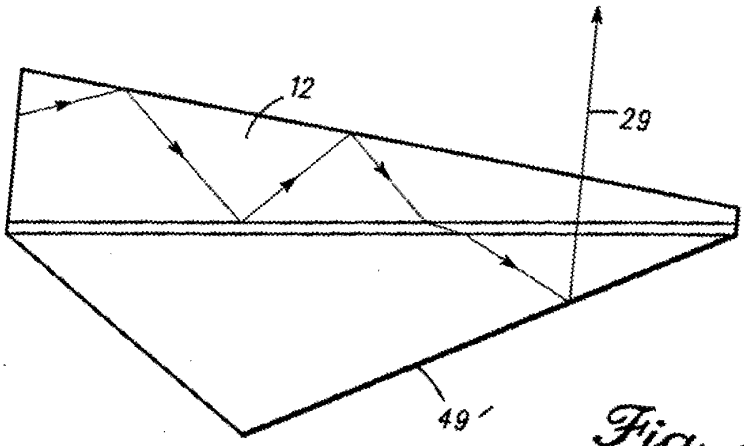


Fig. 2N

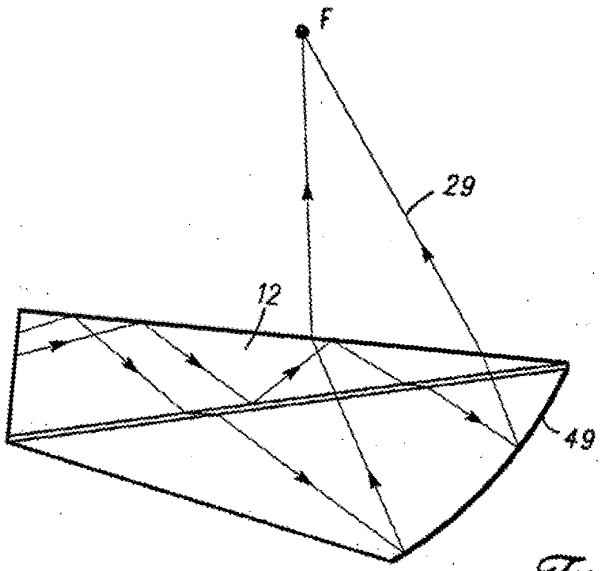


Fig. 20

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Fig. 3

Fig. 3A

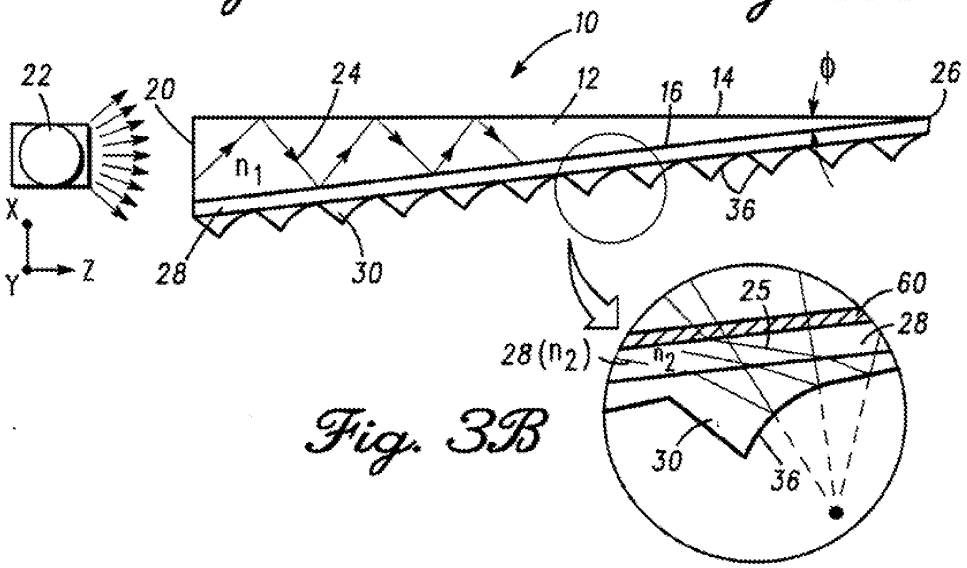
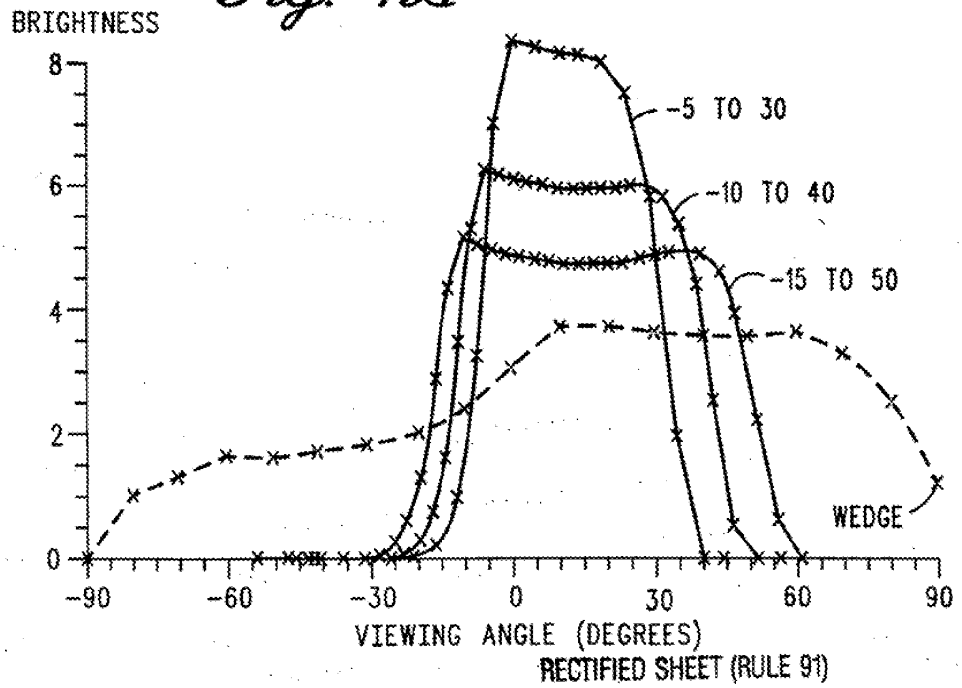


Fig. 3B

Fig. 4A



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Fig. 4B

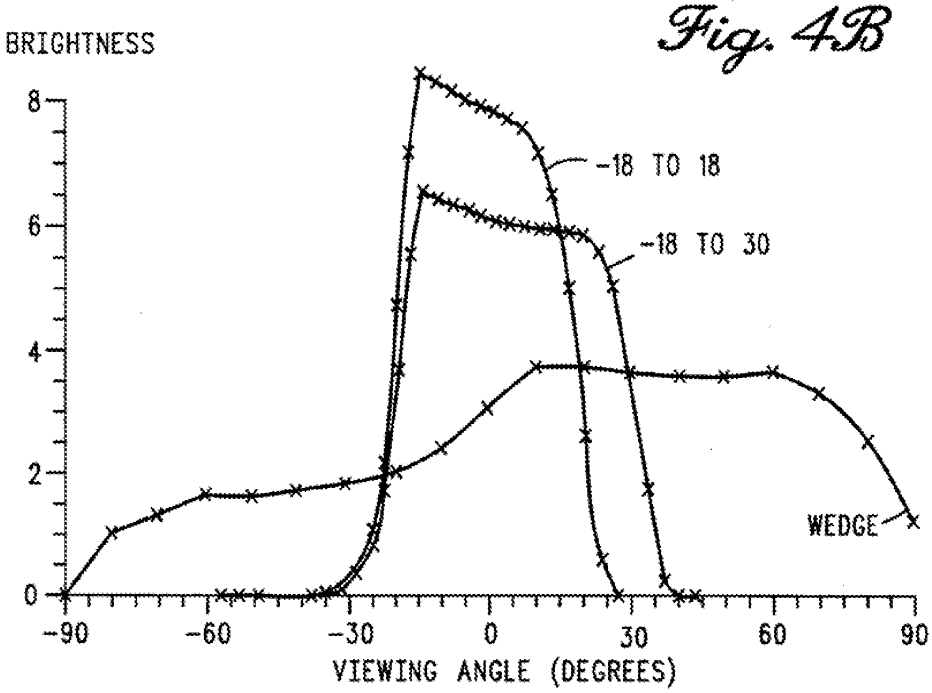
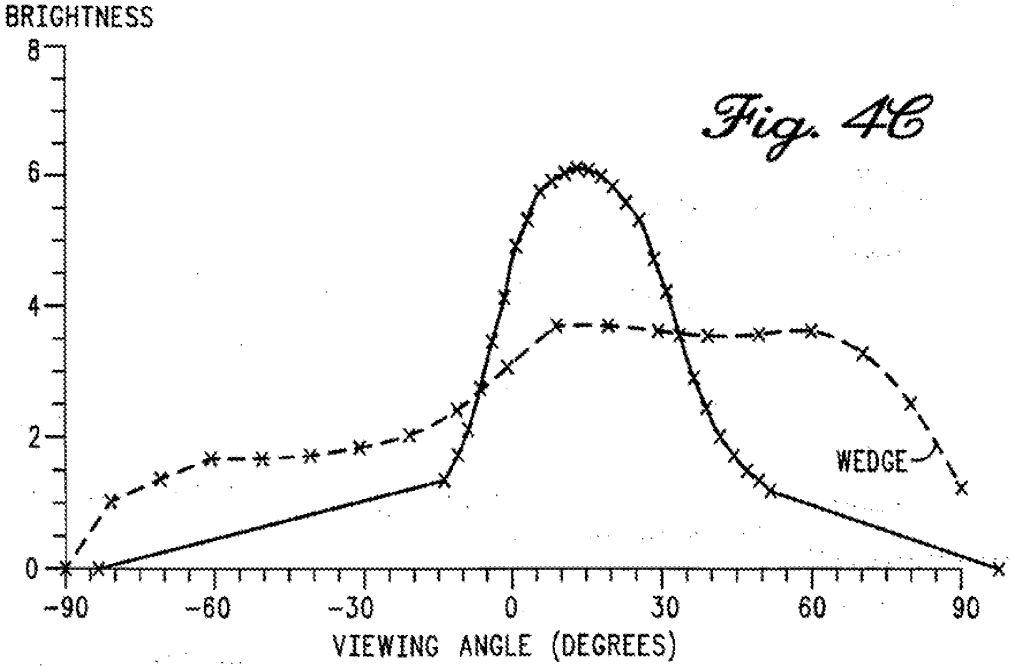


Fig. 4C



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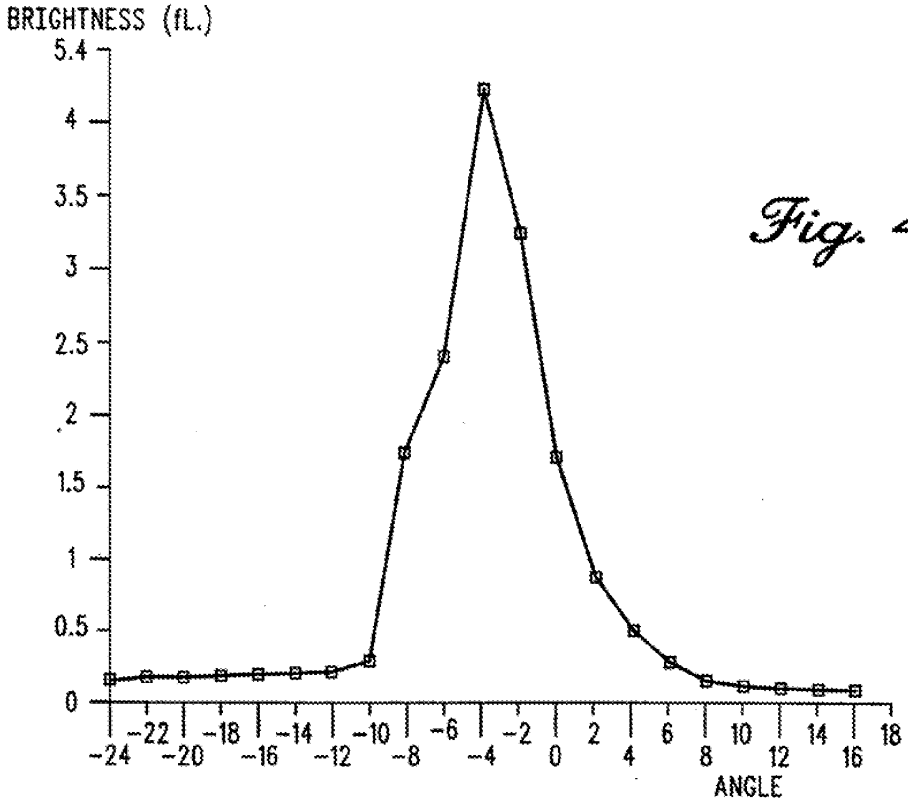


Fig. 4D

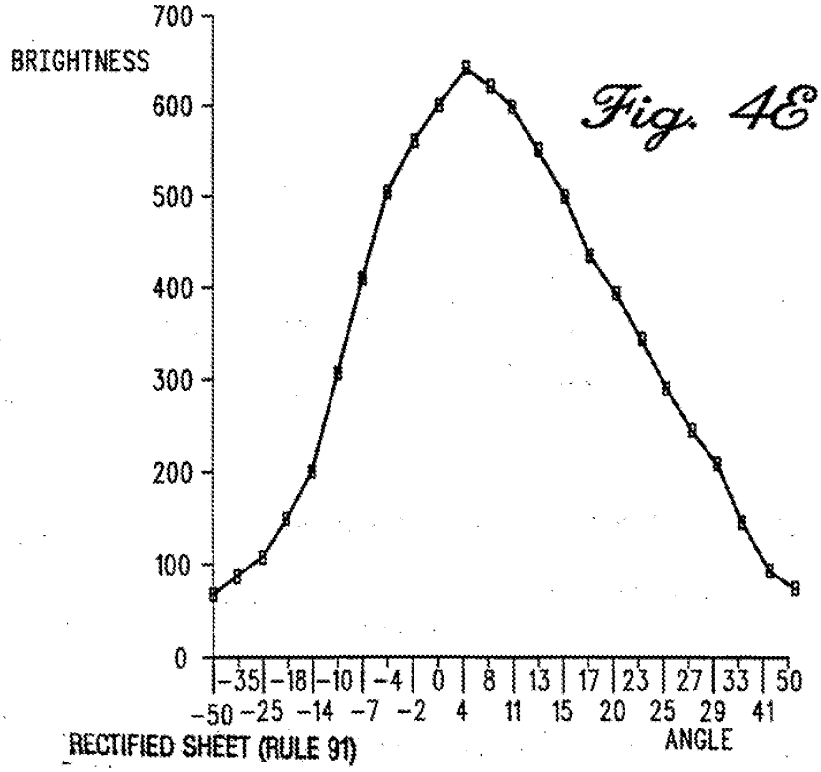


Fig. 4E

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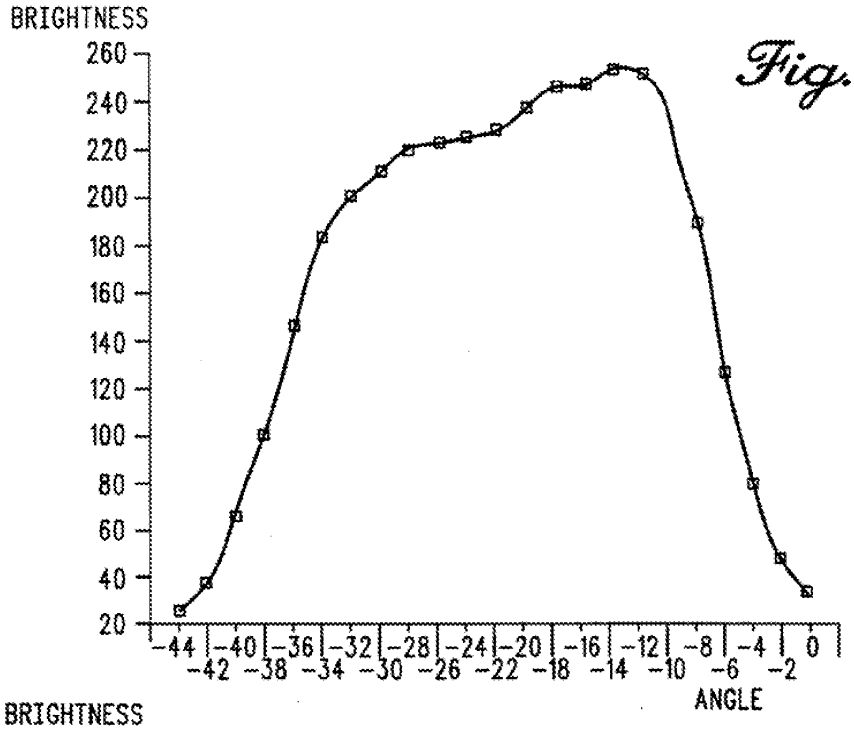


Fig. 4F

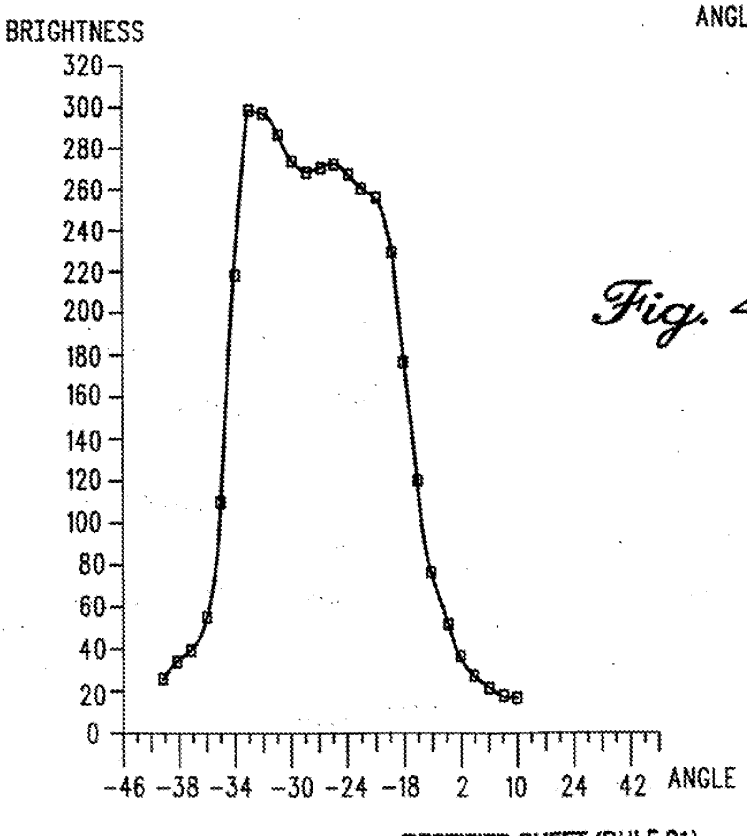


Fig. 4G

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Fig. 4H

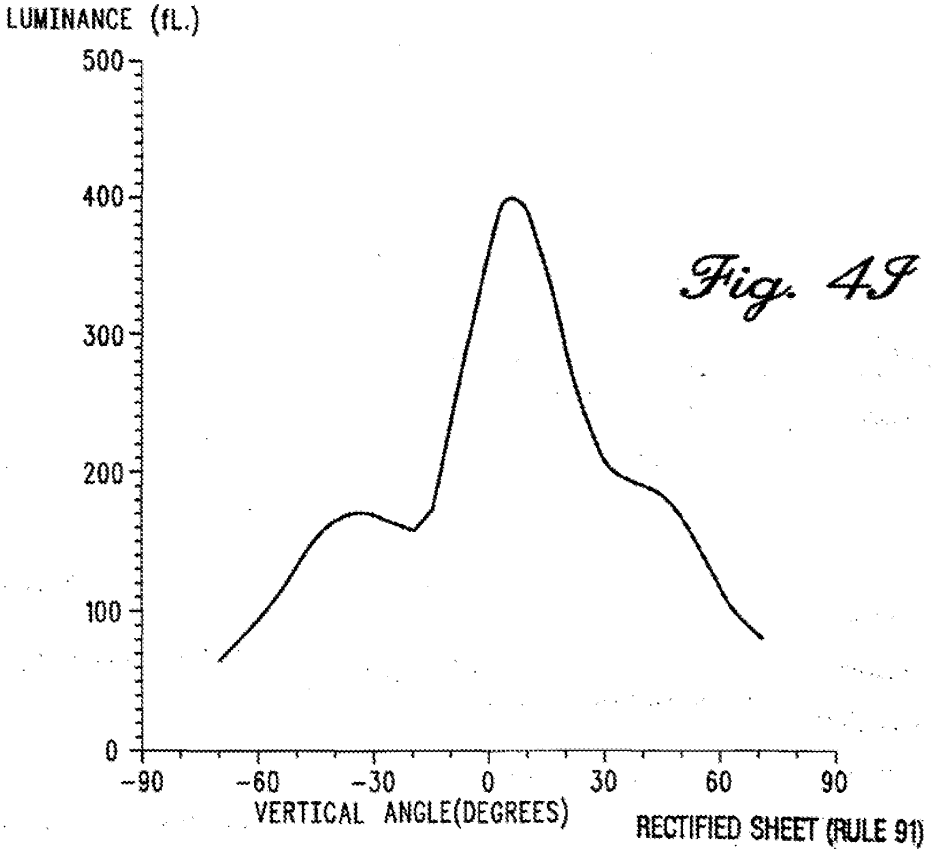


Fig. 4I

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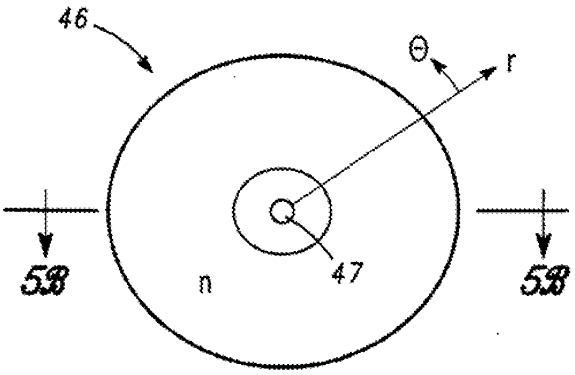


Fig. 5A

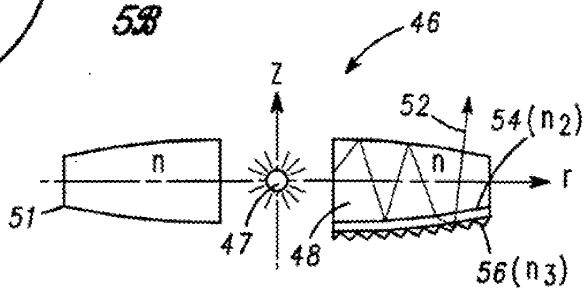


Fig. 5B

Fig. 6A

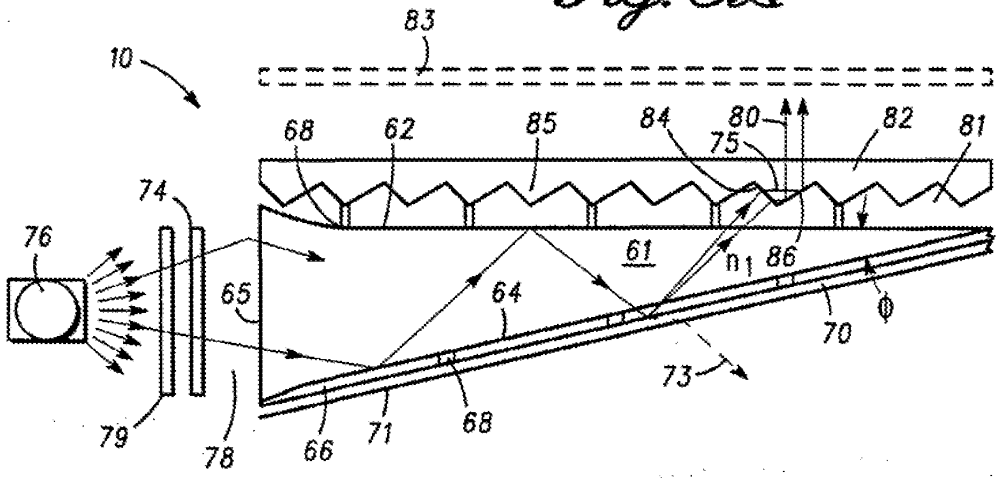
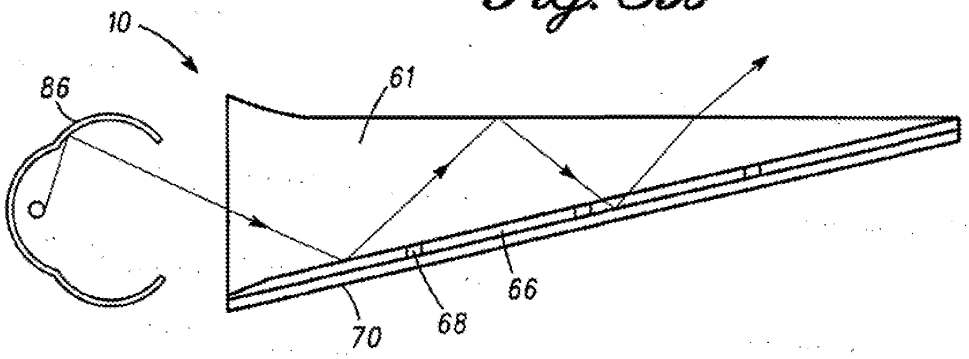


Fig. 6B



RECTIFIED SHEET (RULE 91)

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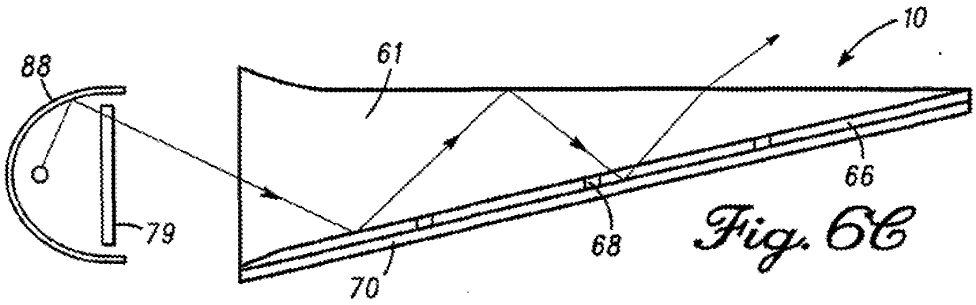


Fig. 6C

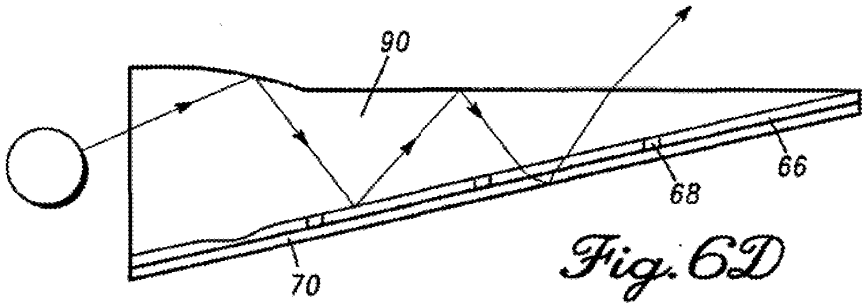
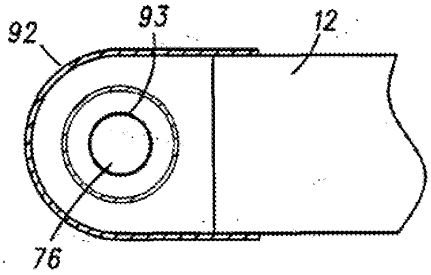


Fig. 6D



— PRIOR ART —

Fig. 7

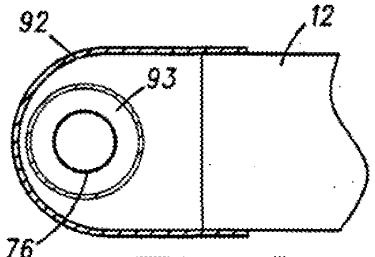


Fig. 8

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Fig. 9A

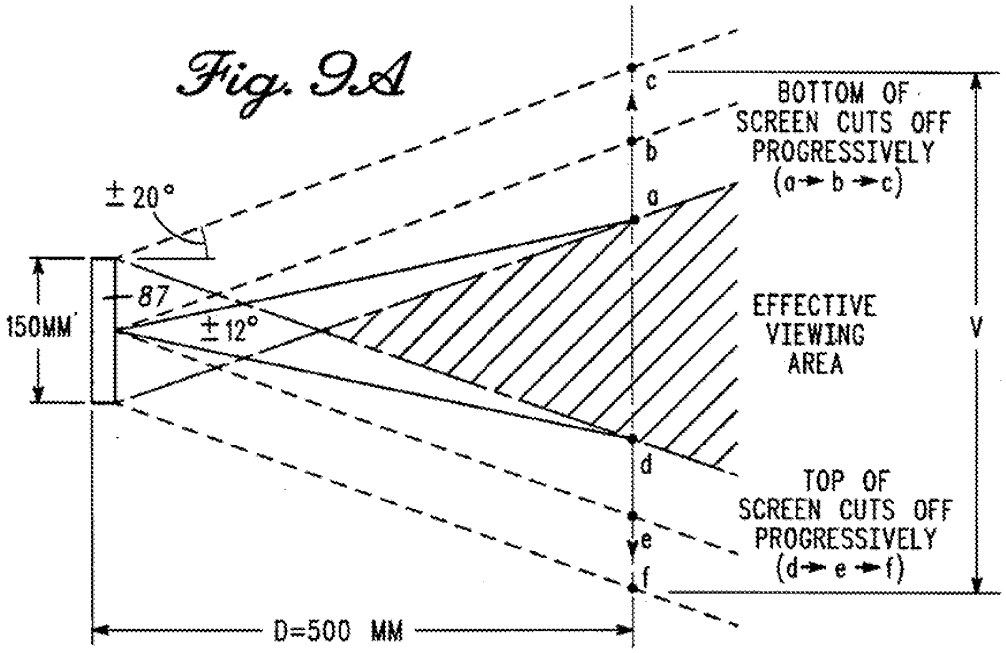
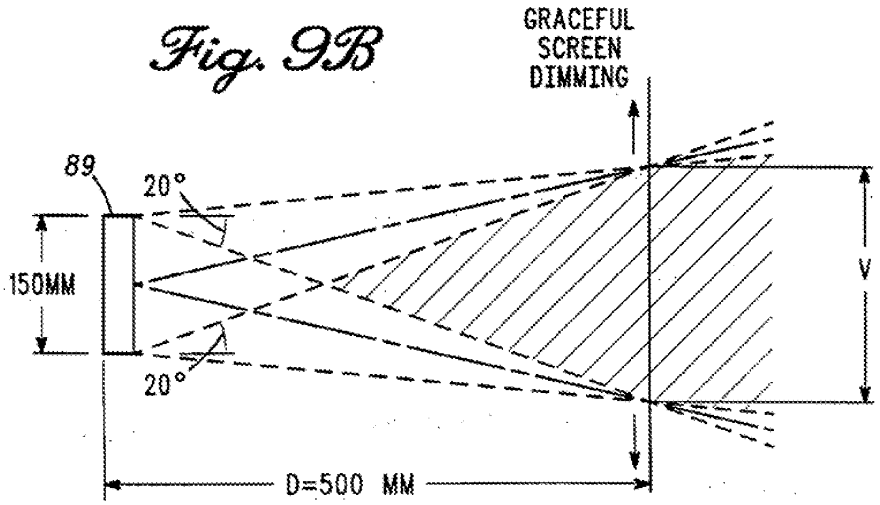


Fig. 9B



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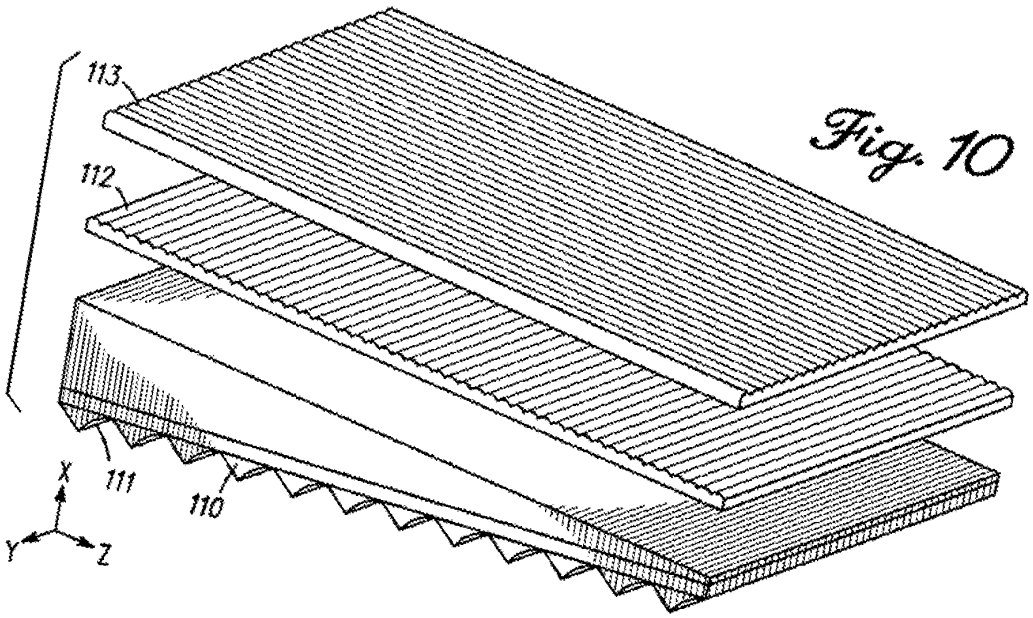


Fig. 10

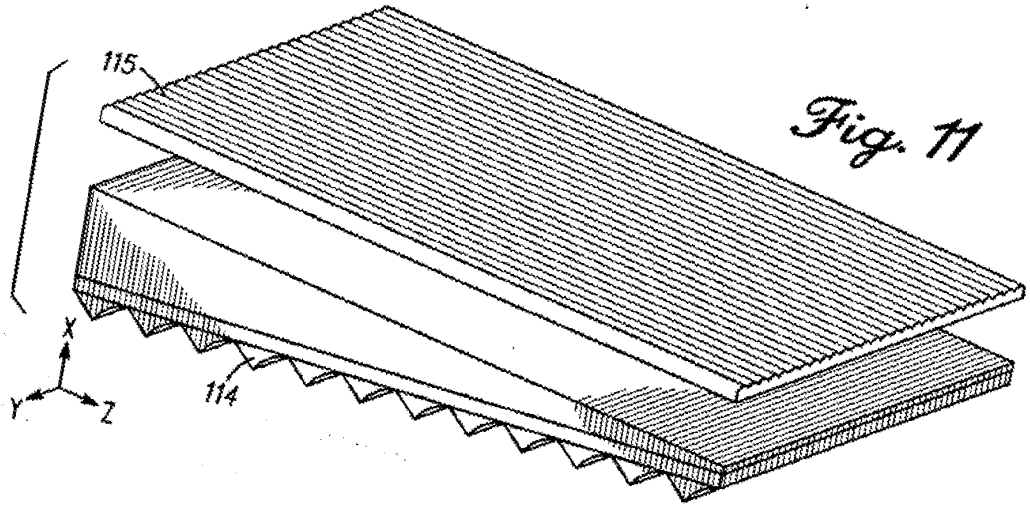


Fig. 11

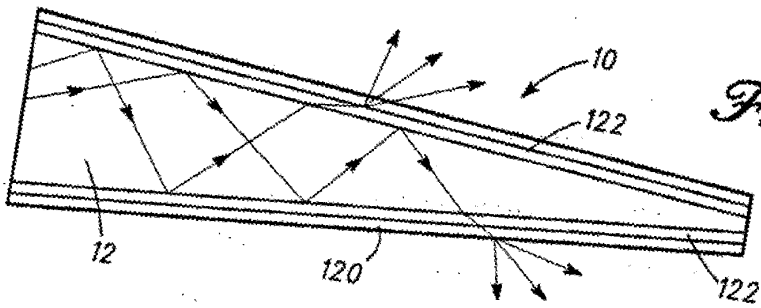


Fig. 12A

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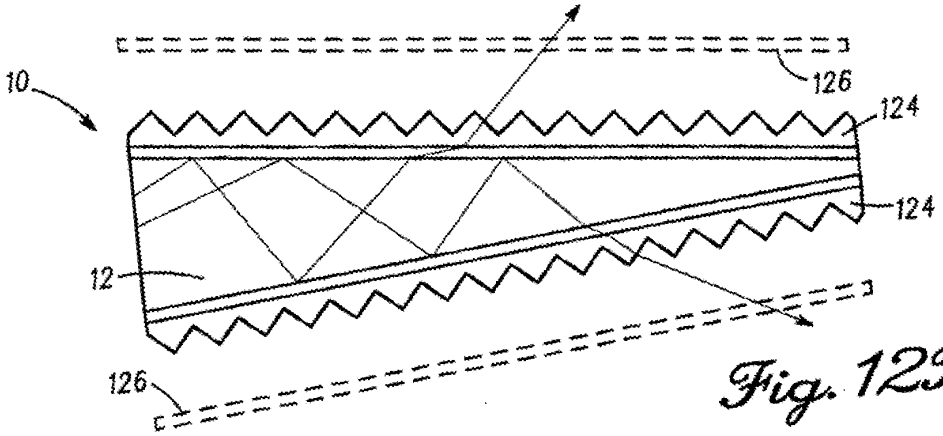


Fig. 12B

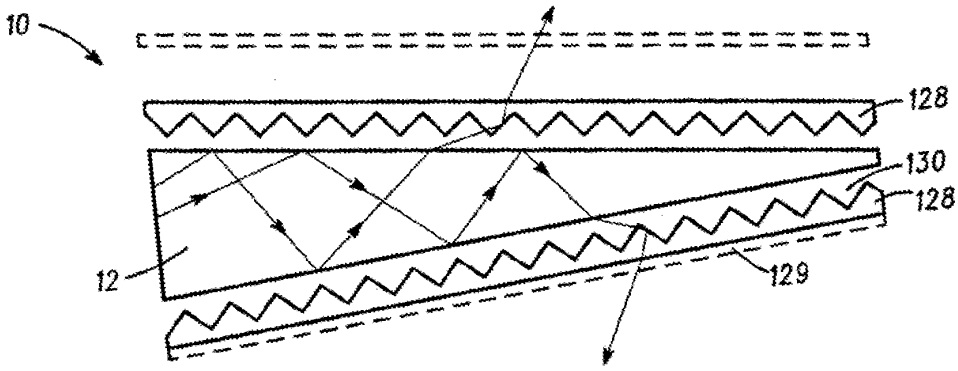
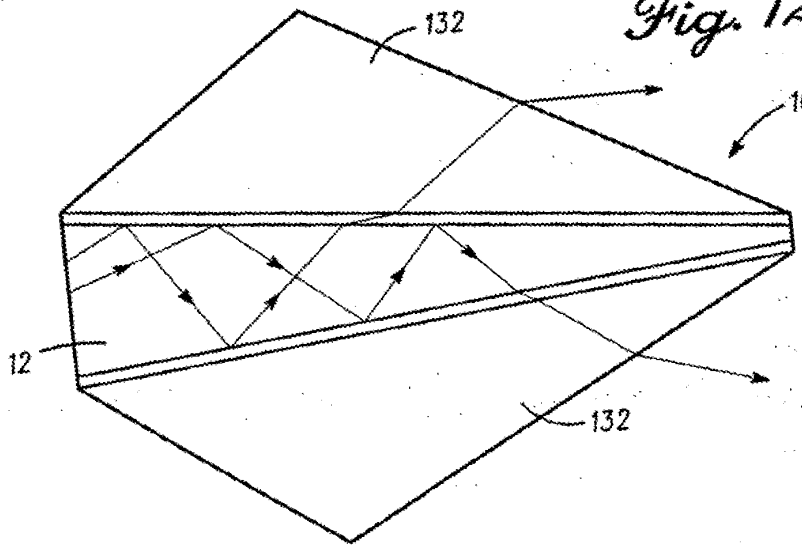


Fig. 12C

Fig. 12D



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Fig. 12E

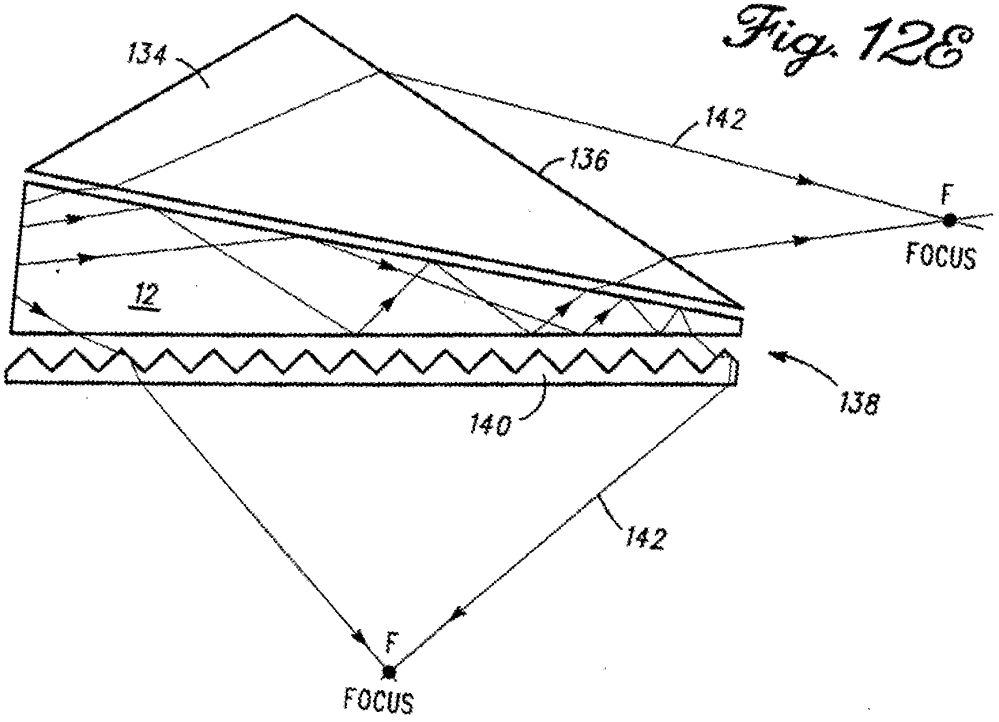
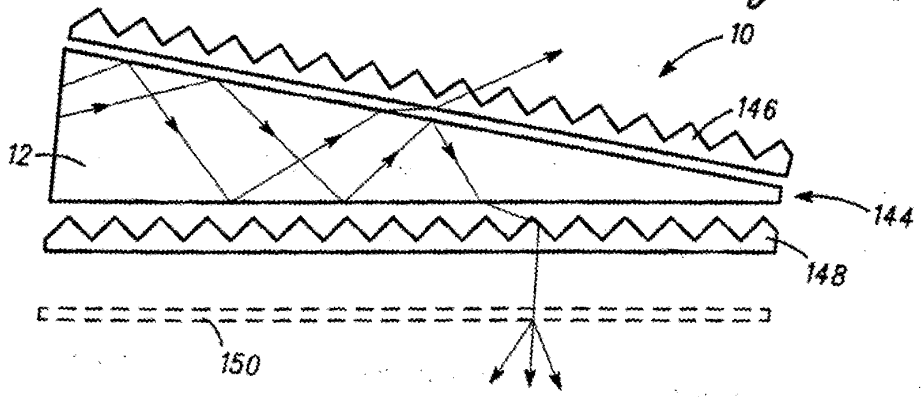


Fig. 12F



RECTIFIED SHEET (RULE 91)

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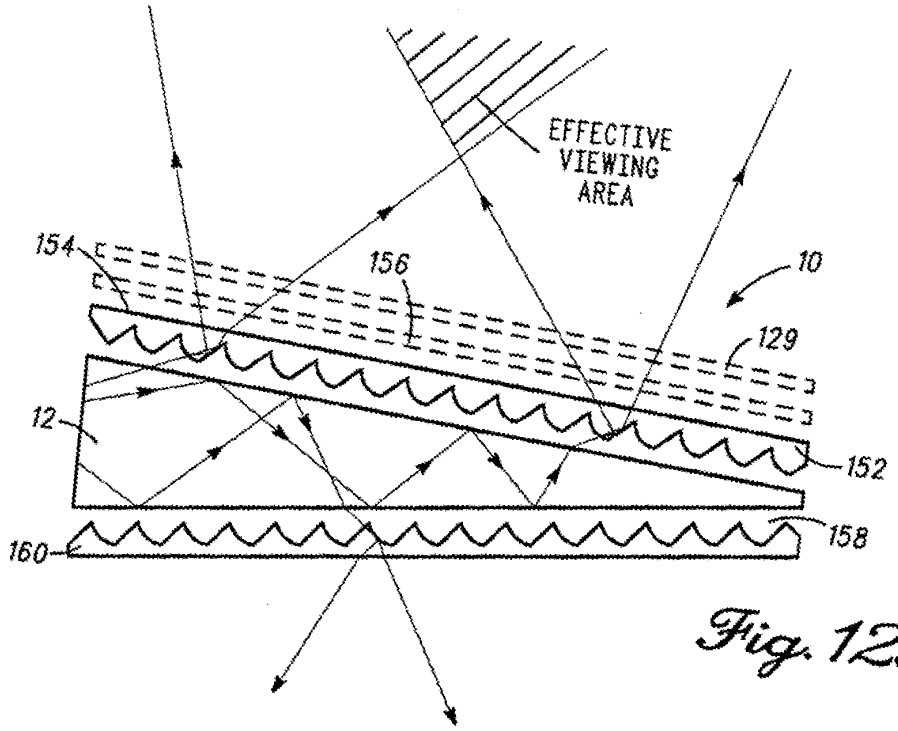
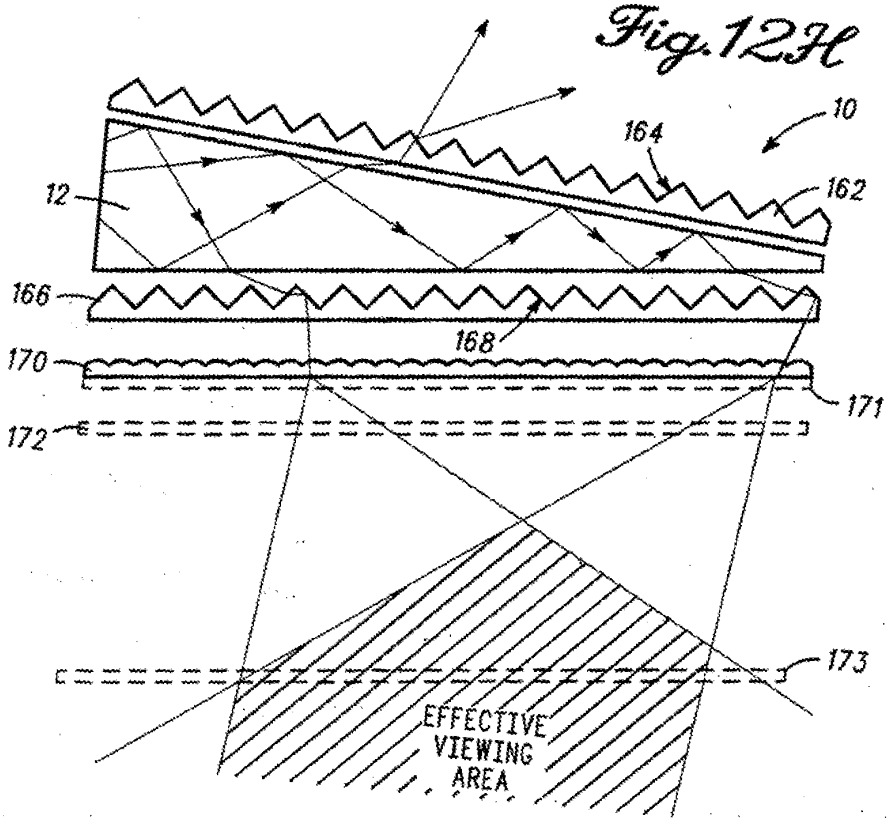


Fig. 12G

Fig. 12H



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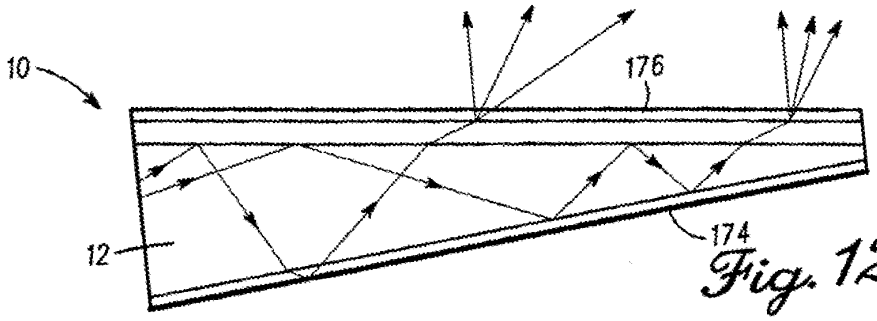


Fig. 12J

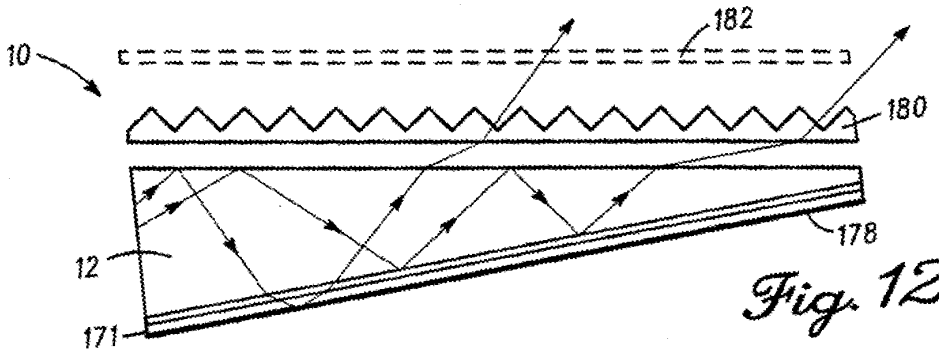


Fig. 12J

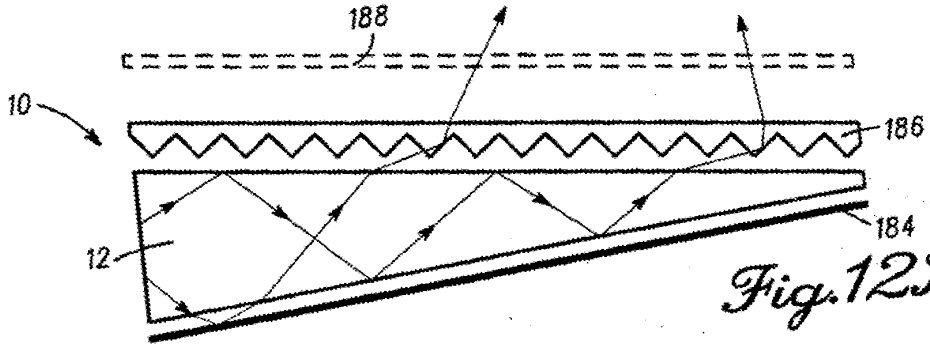


Fig. 12K

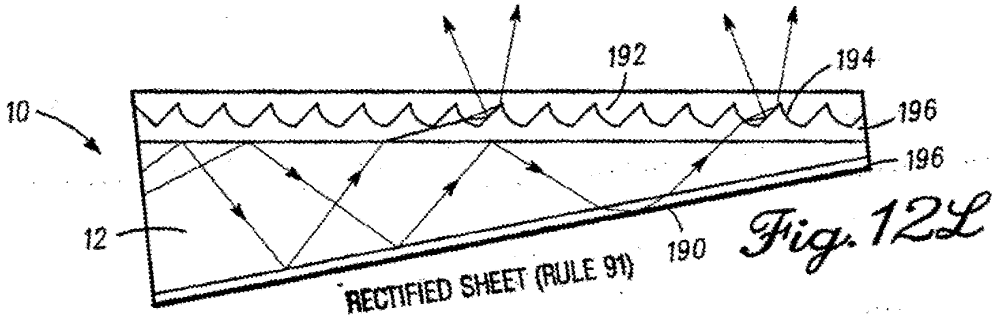


Fig. 12L

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Fig. 12M

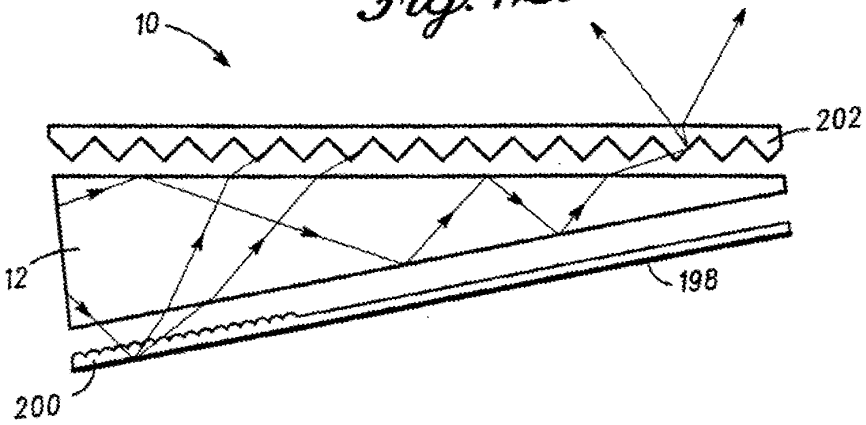
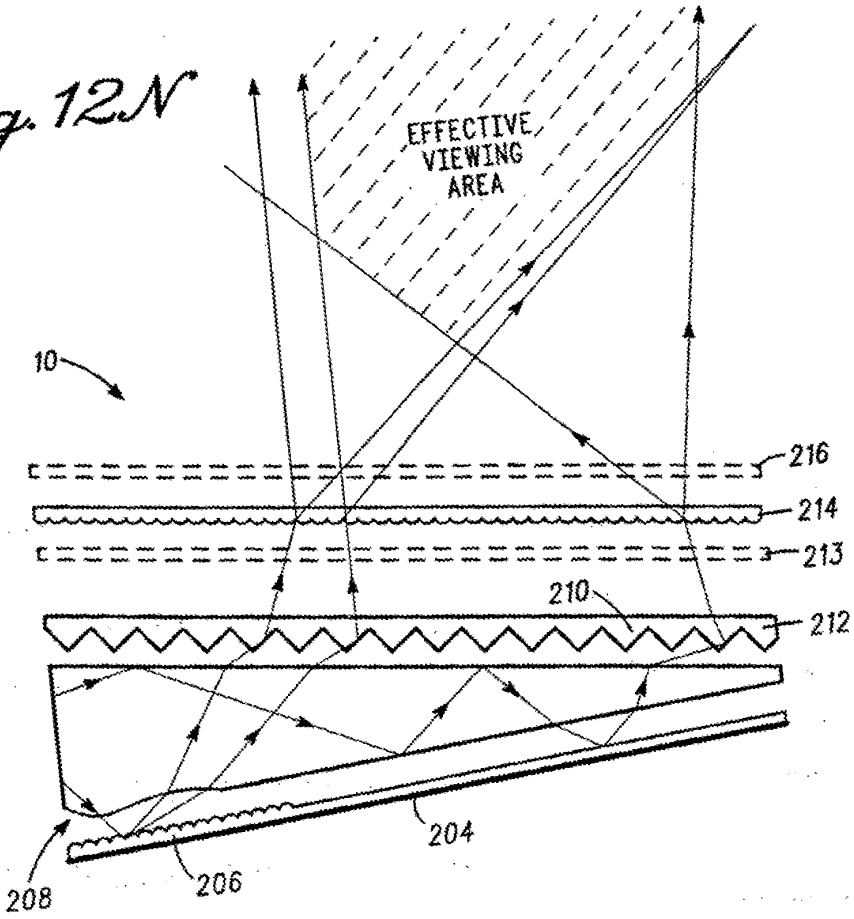


Fig. 12N



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Fig. 12O

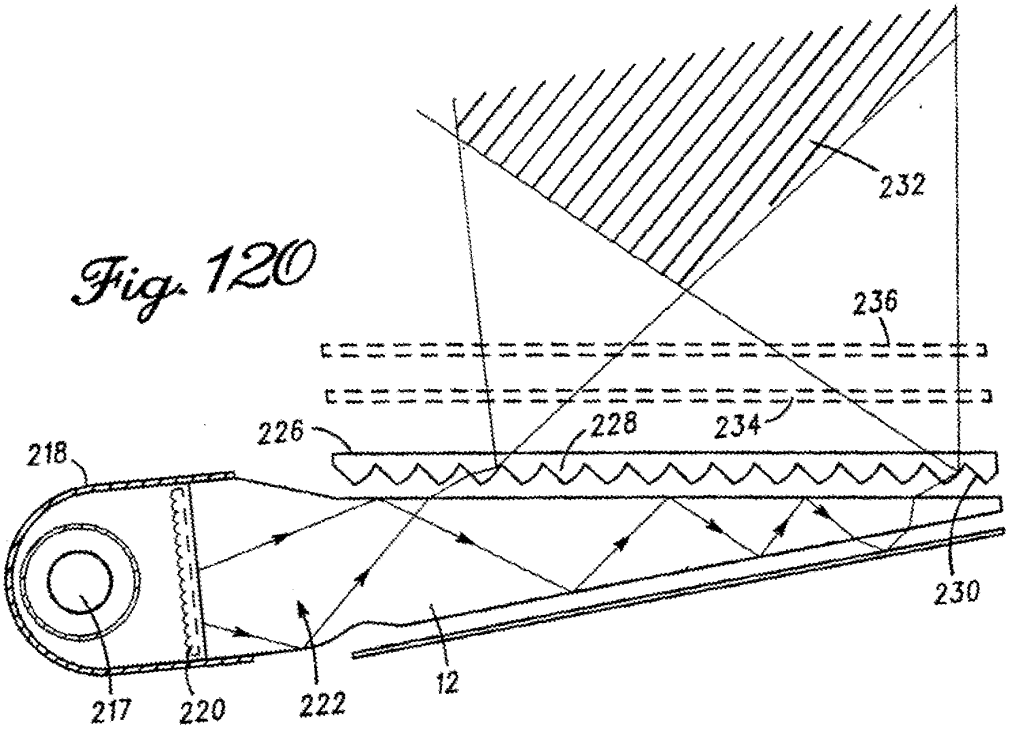
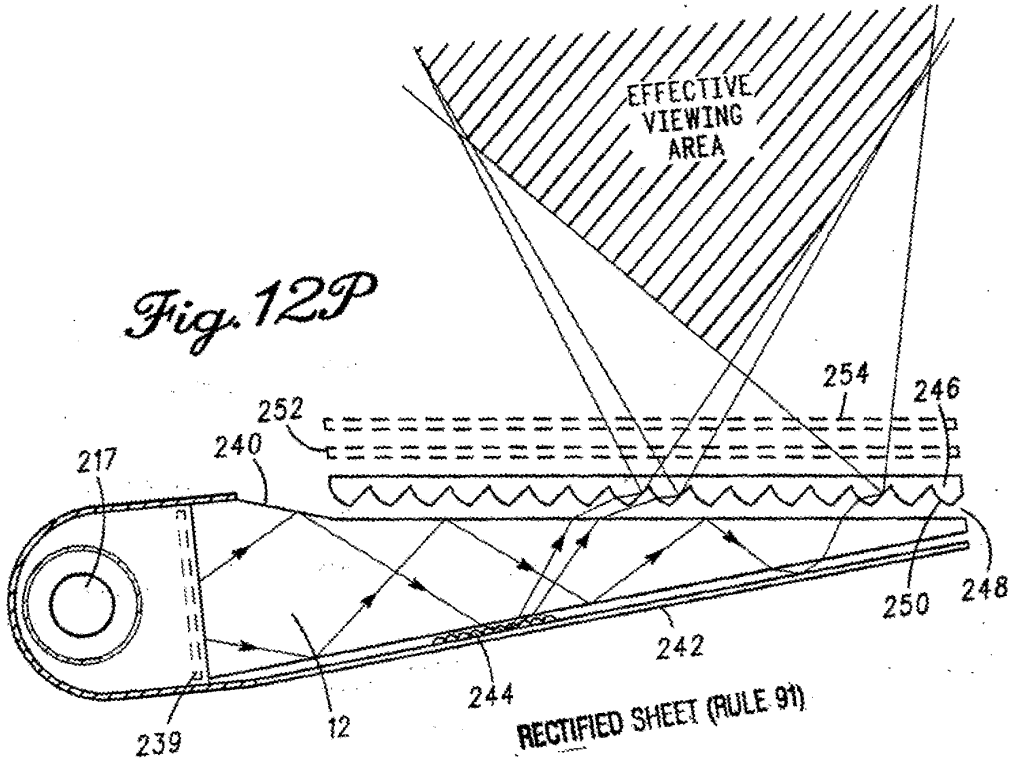


Fig. 12P



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Fig. 12Q

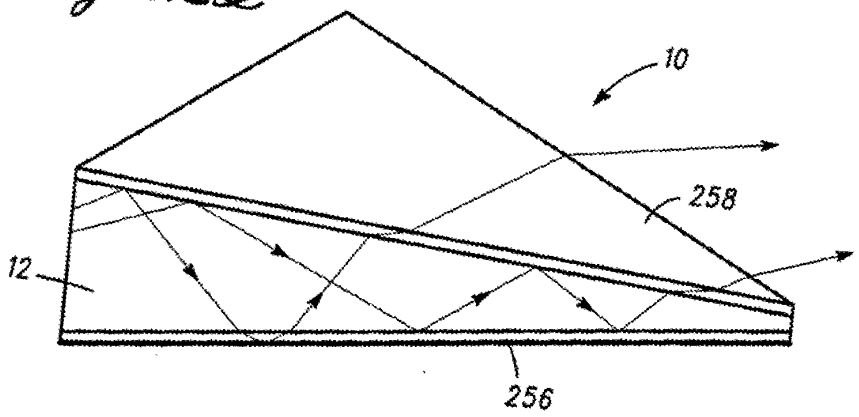


Fig. 12R

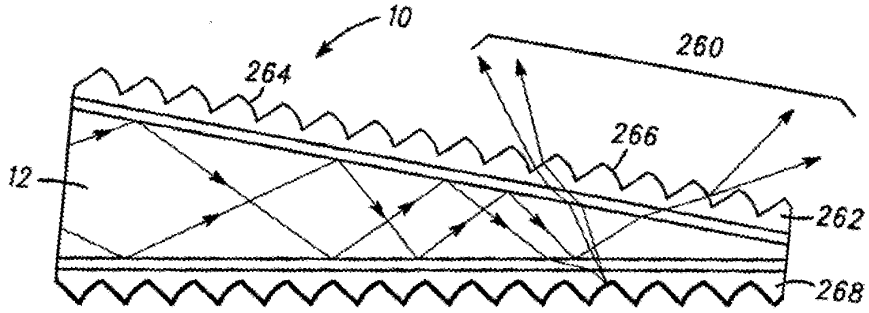
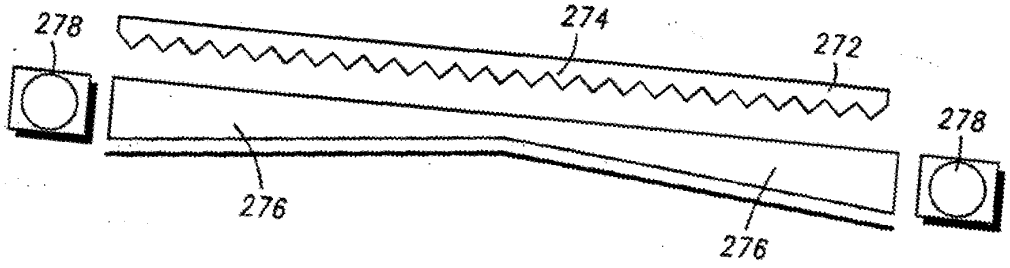


Fig. 13



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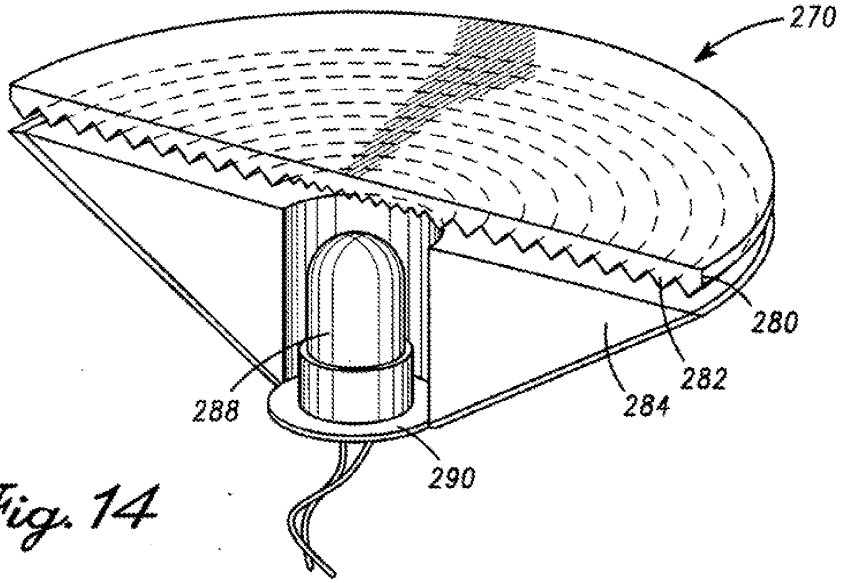


Fig. 14

Fig. 15

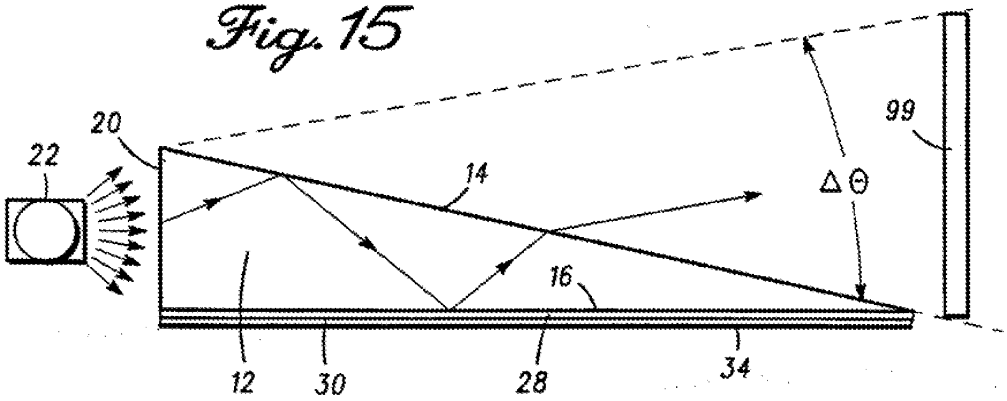


Fig. 16B

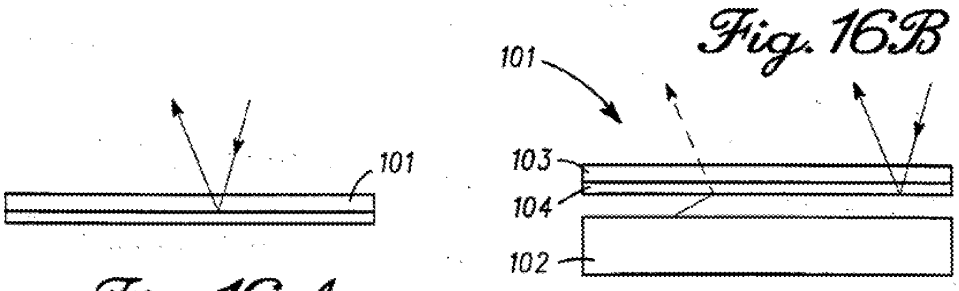


Fig. 16A

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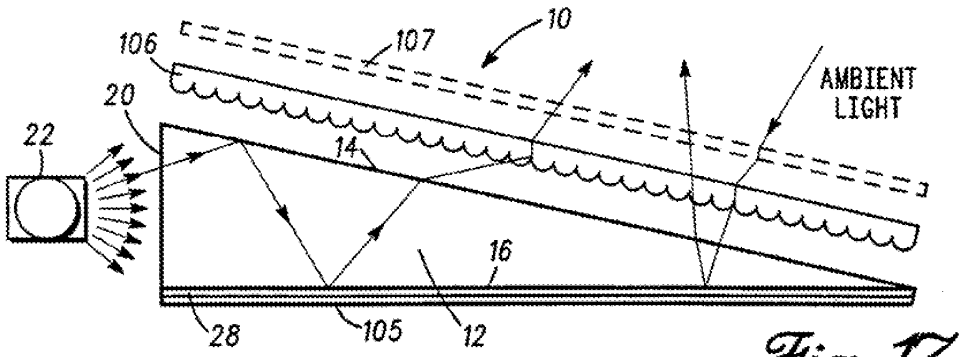


Fig. 17

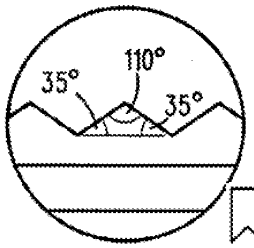
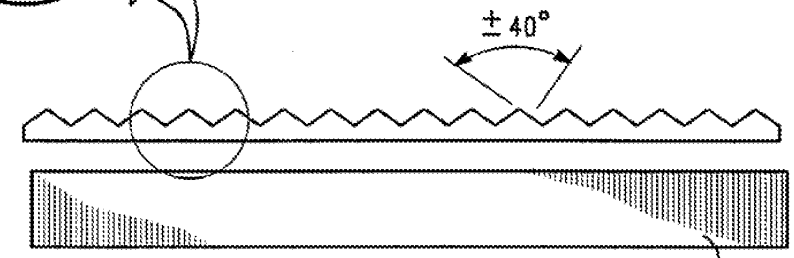
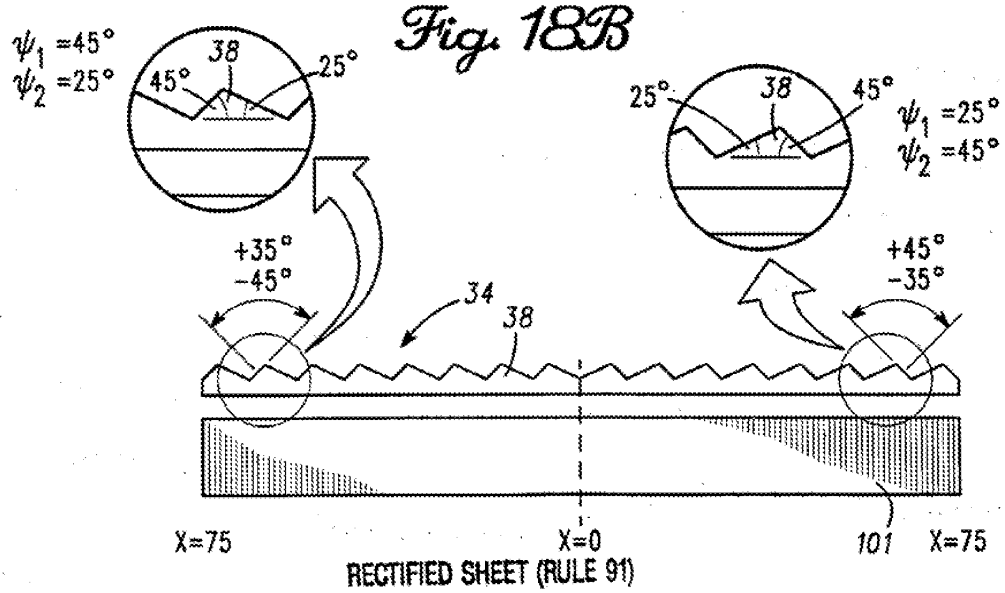


Fig. 18A



$\psi_1 = 35° - (0.133\ \text{DEG/MIN}) \cdot X$
$\psi_2 = 35° + (0.133\ \text{DEG/MIN}) \cdot X$

Fig. 18B



RECTIFIED SHEET (RULE 91)

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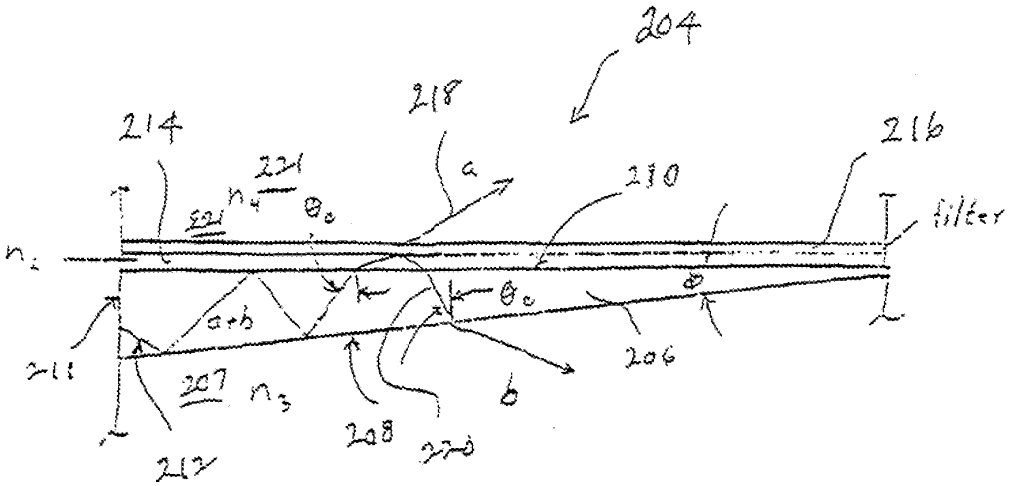


FIG. 19B

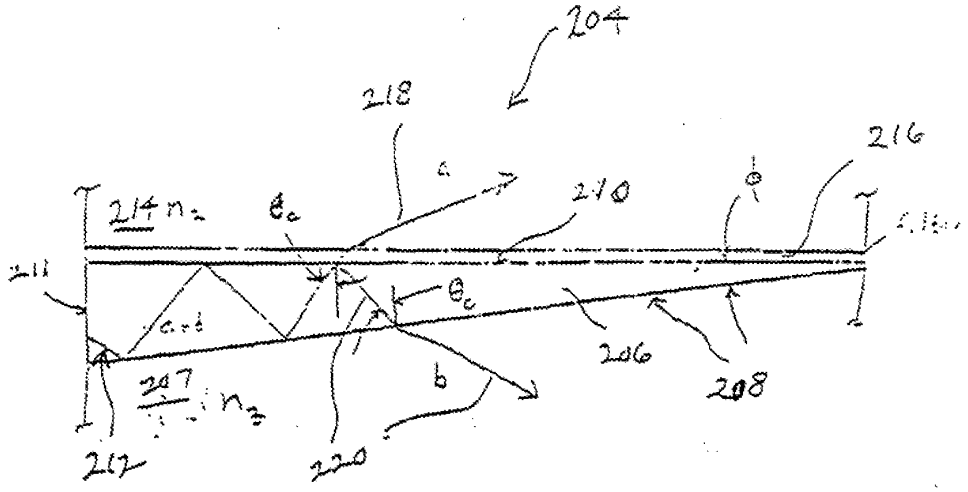


FIG. 19A

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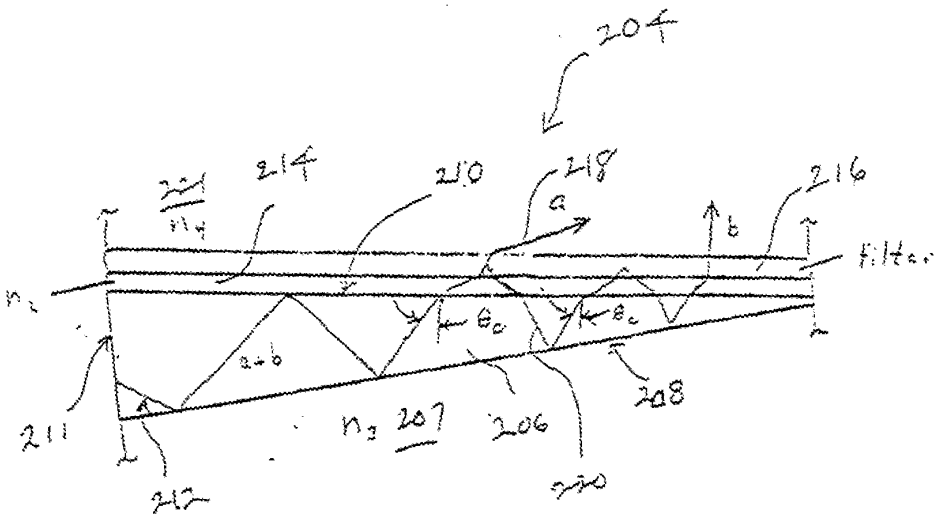


FIG. 19 C

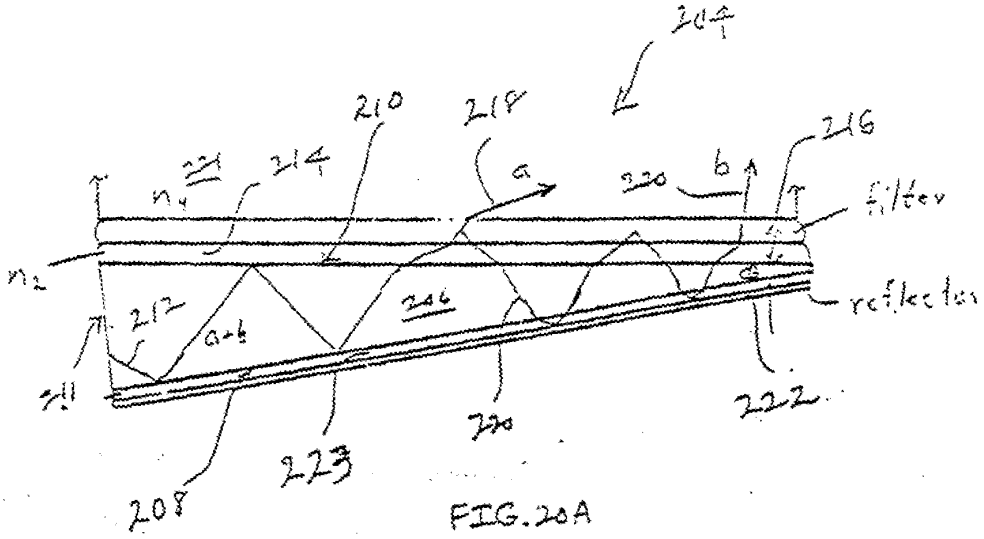


FIG. 20A

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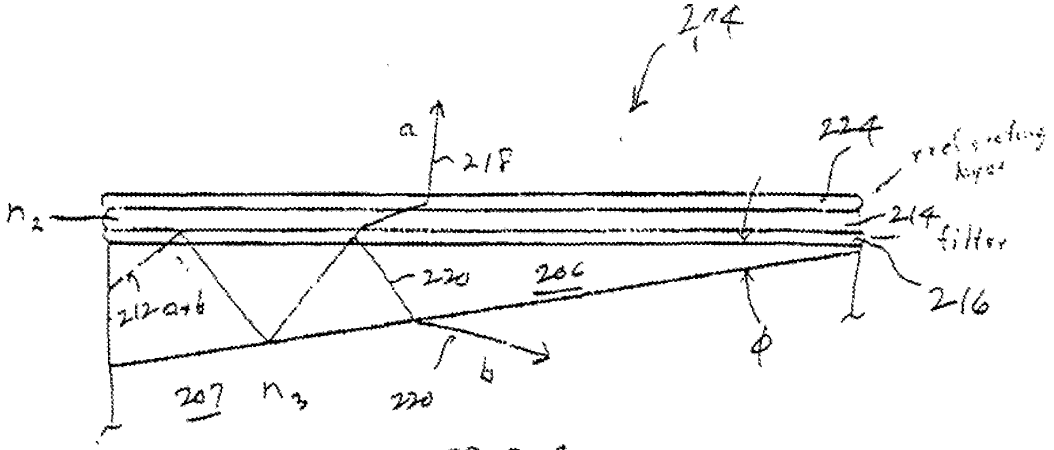


FIG. 20B

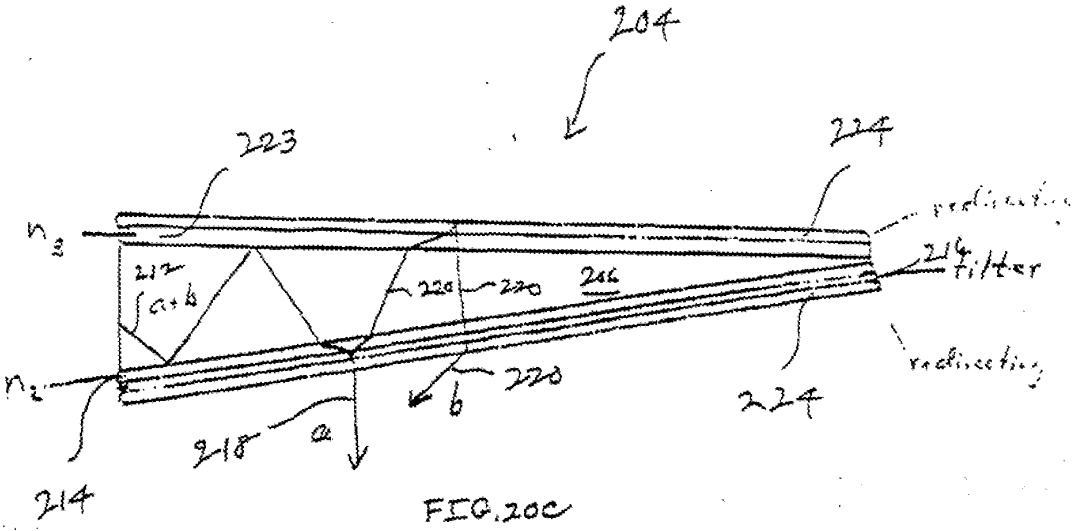


FIG. 20C

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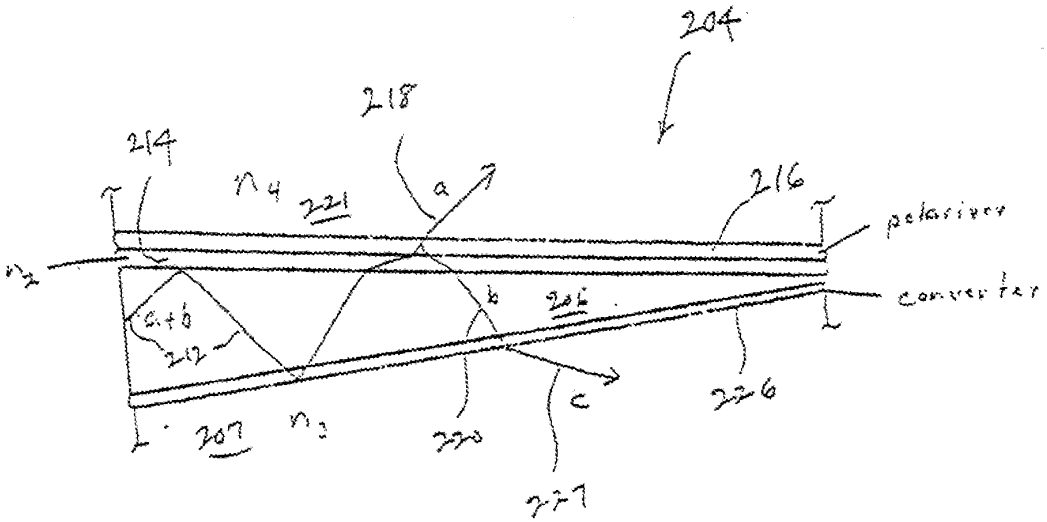


FIG. 2A

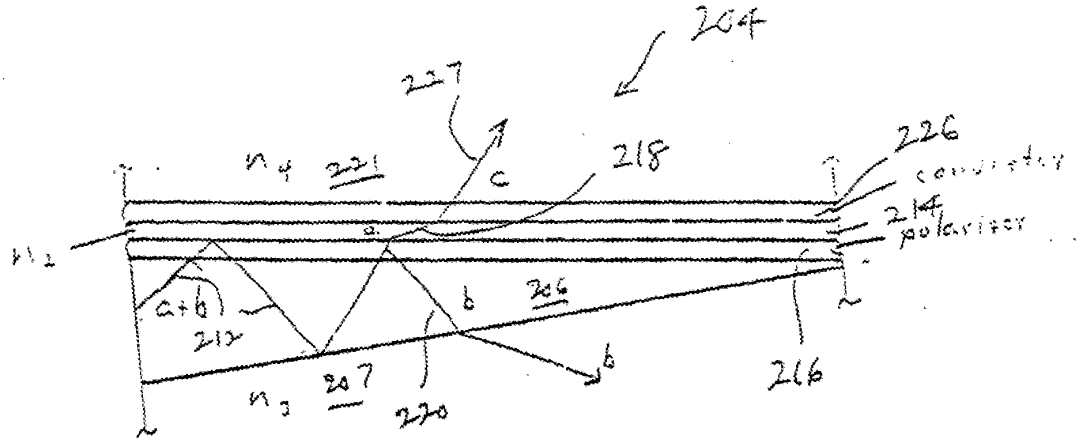


FIG. 2B

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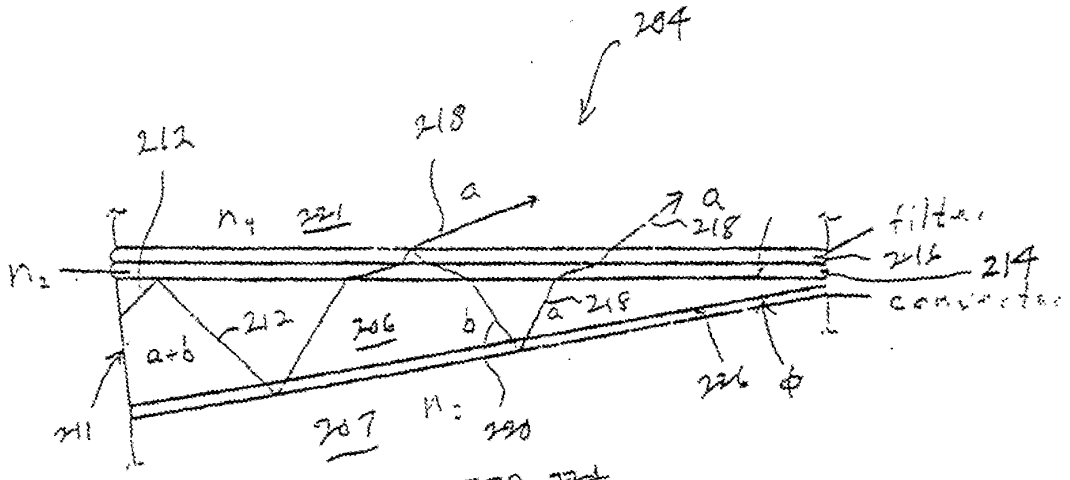


FIG. 2A

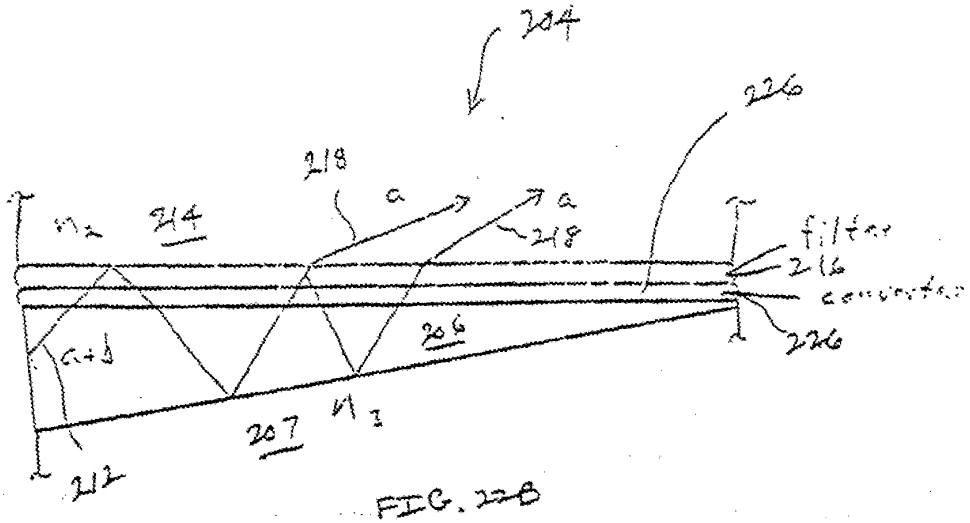


FIG. 2B

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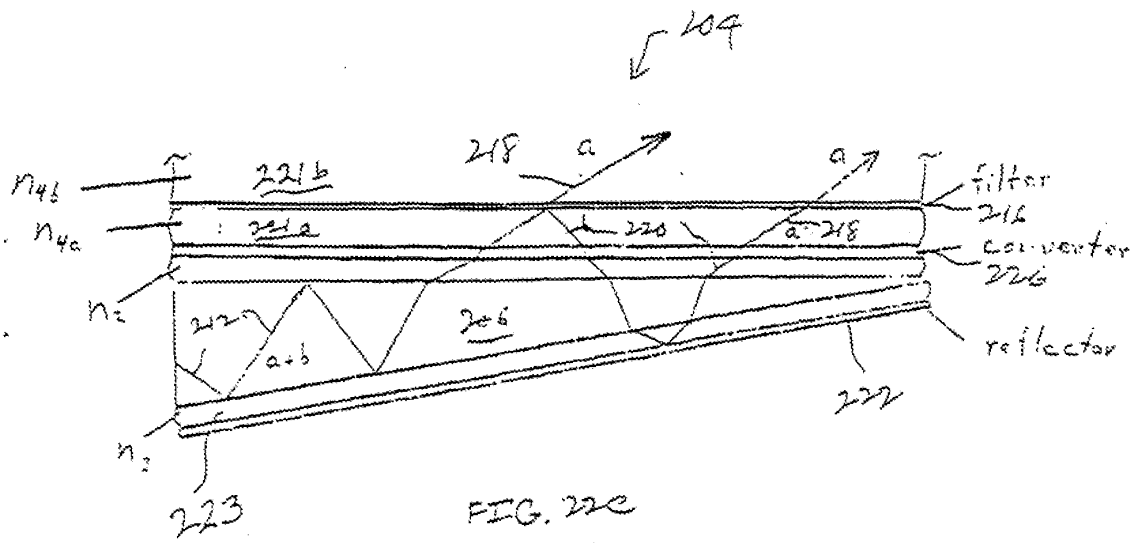


FIG. 22C

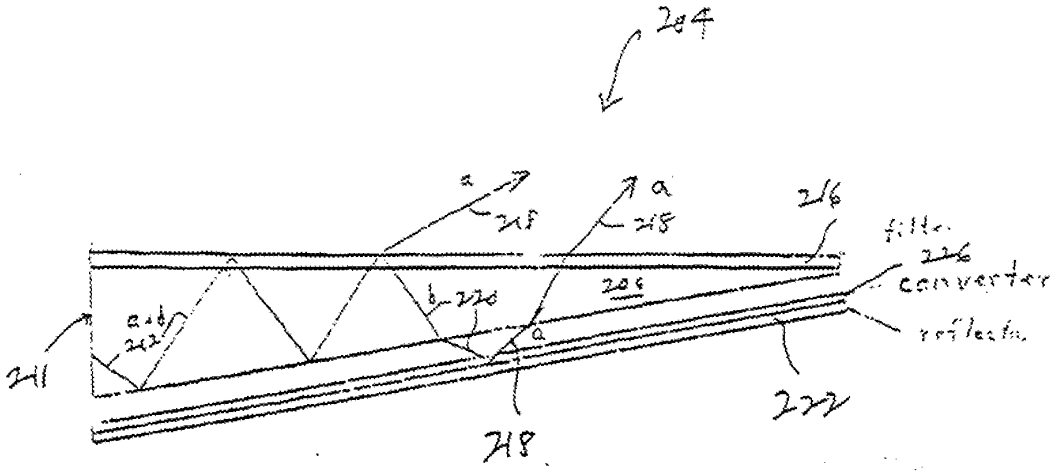


FIG. 22D

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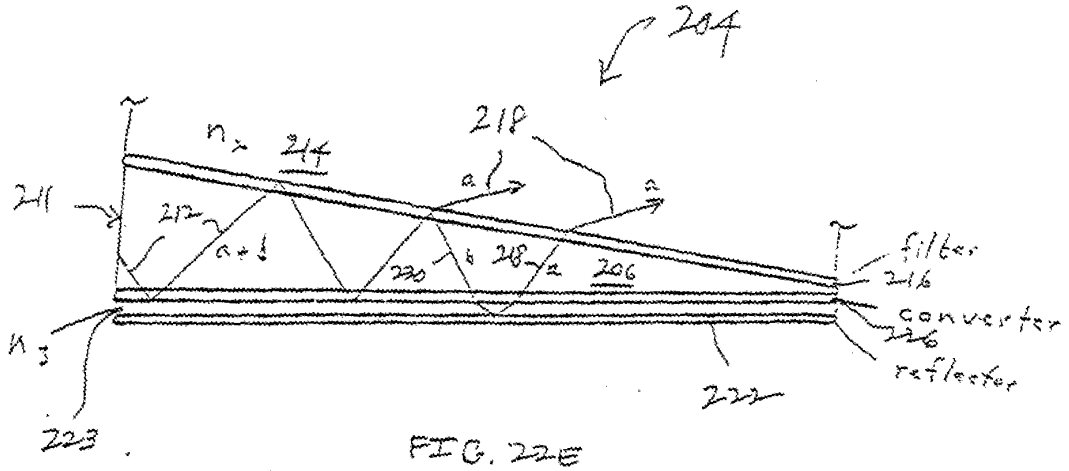

204
218
n_2 24
211
212
a+1
220
b
28
a
206
filter
216
converter
226
reflector
222
n_3
223

FIG. 22E

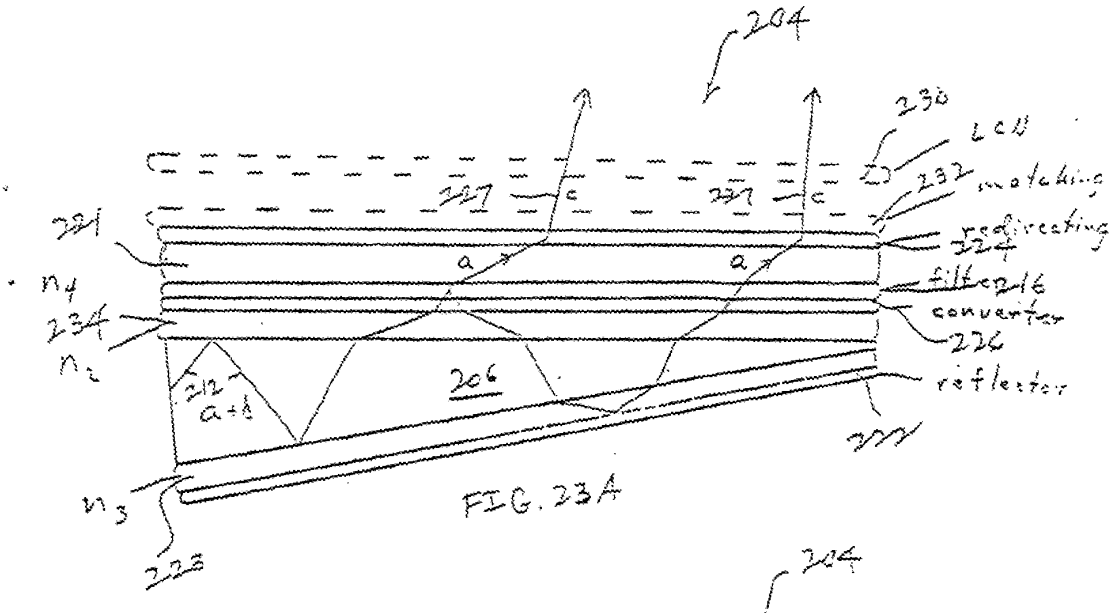


FIG. 23A

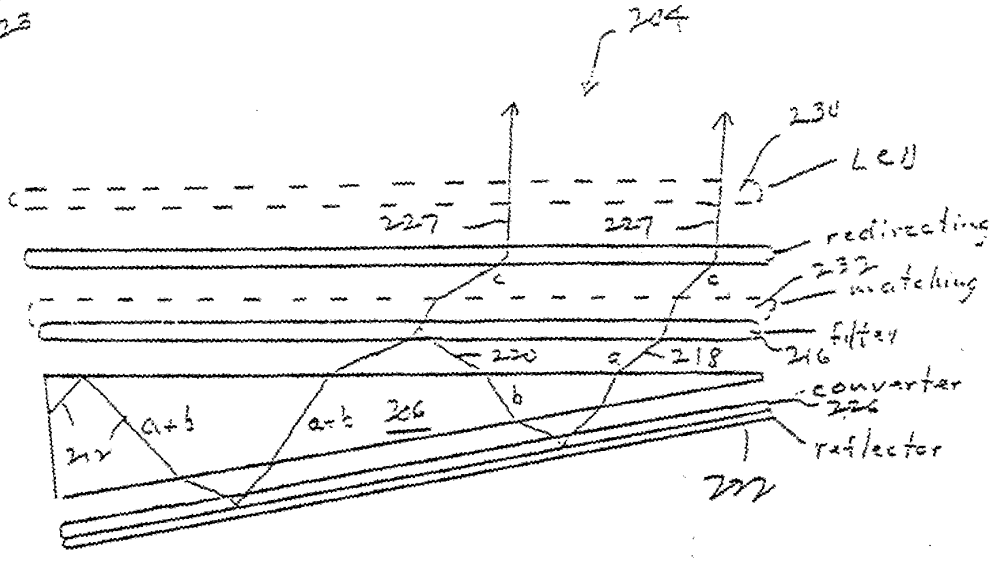


FIG. 23B

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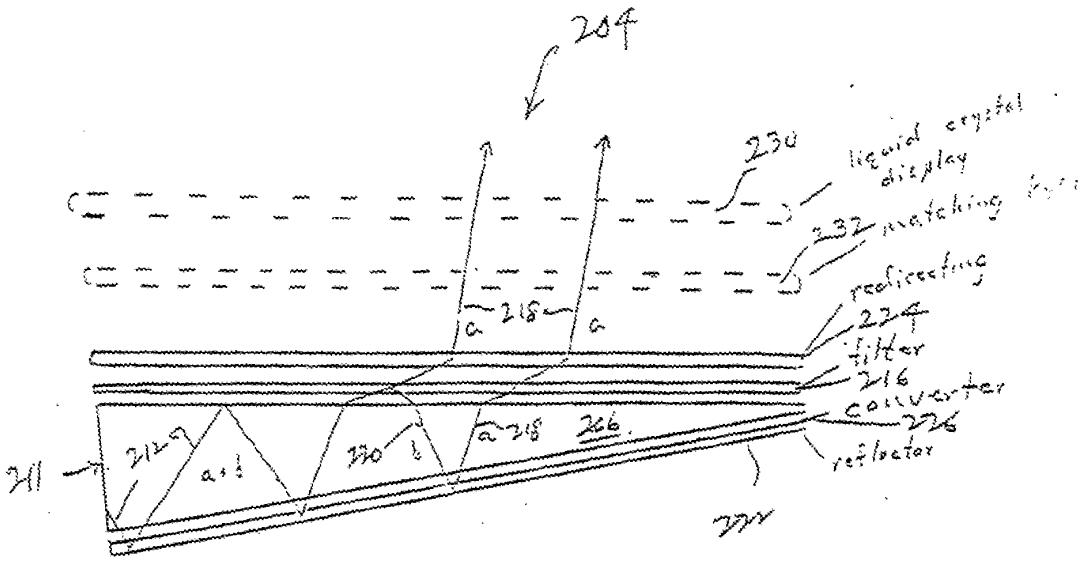


FIG. 23C

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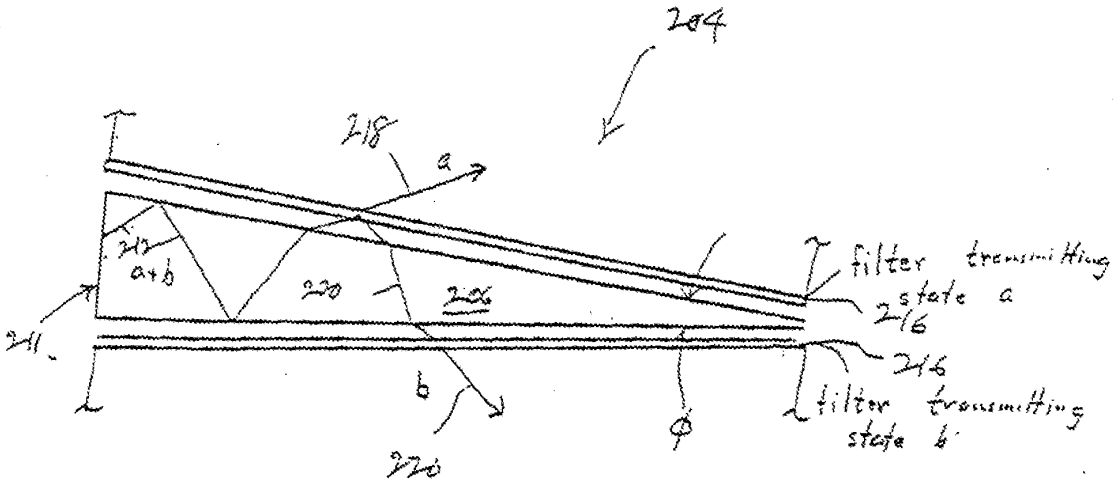


FIG. 24A

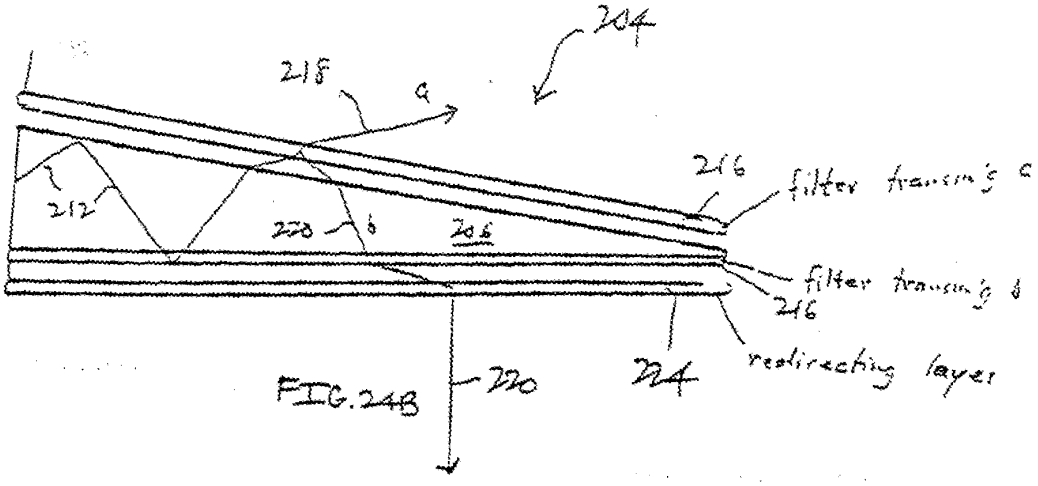


FIG. 24B

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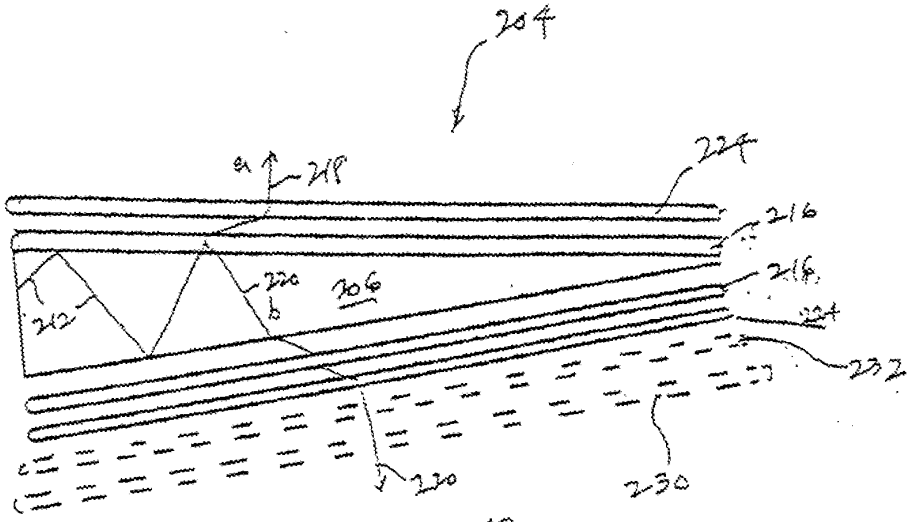


FIG. 24C

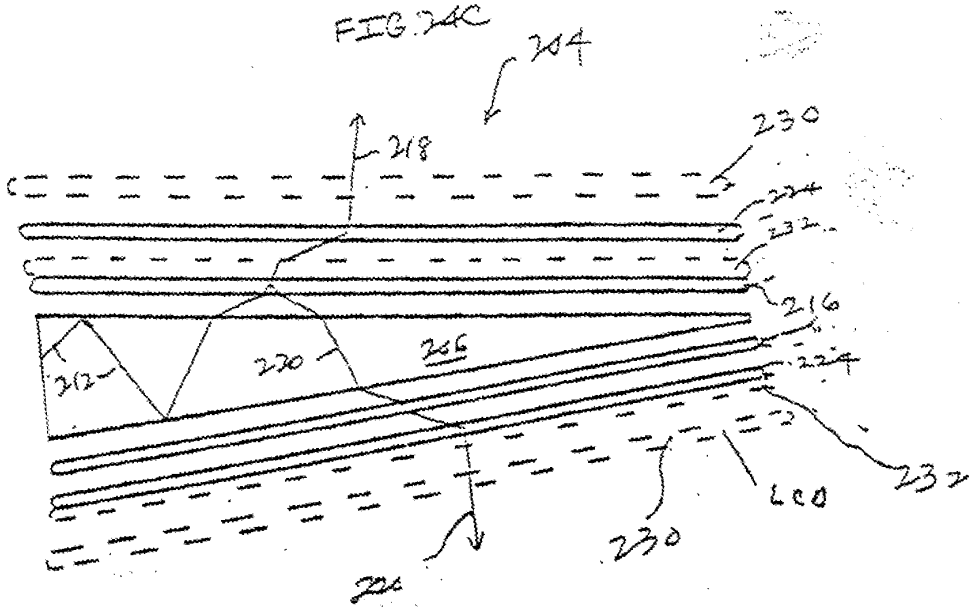


FIG. 24D

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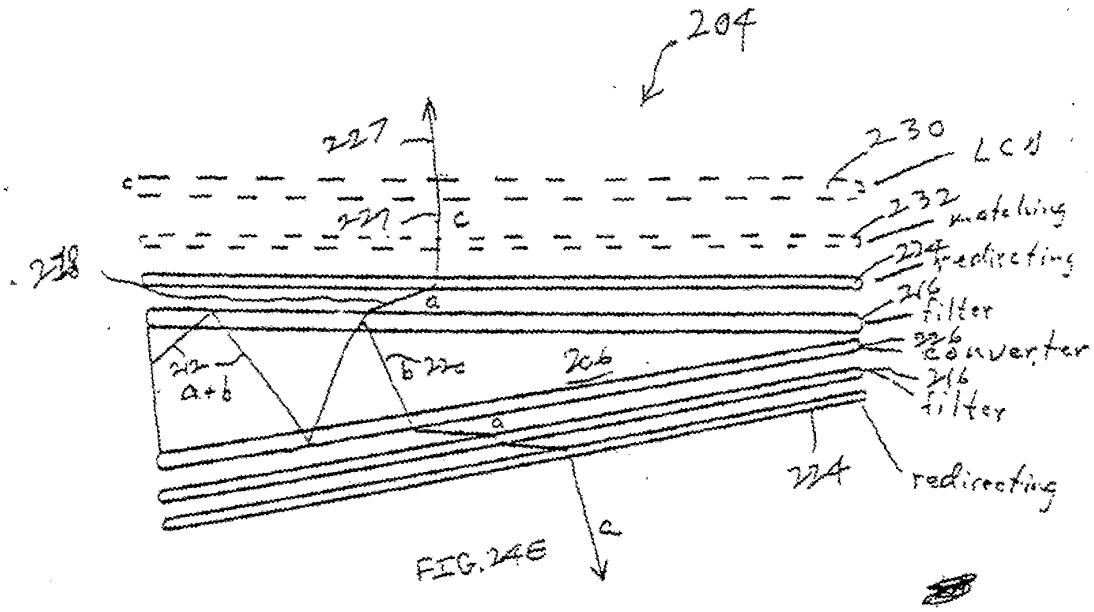


FIG. 2E

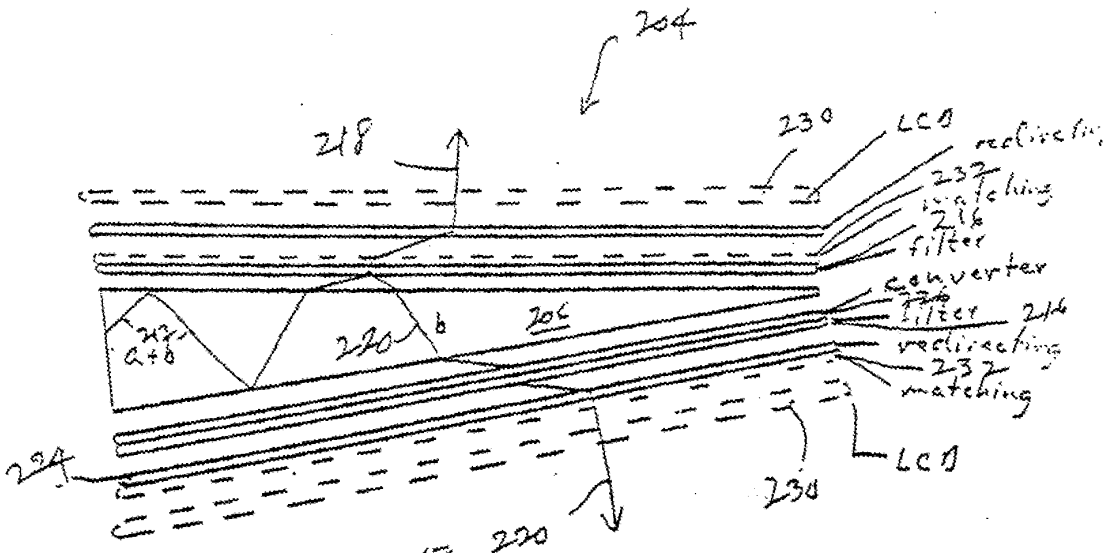


FIG. 2F

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

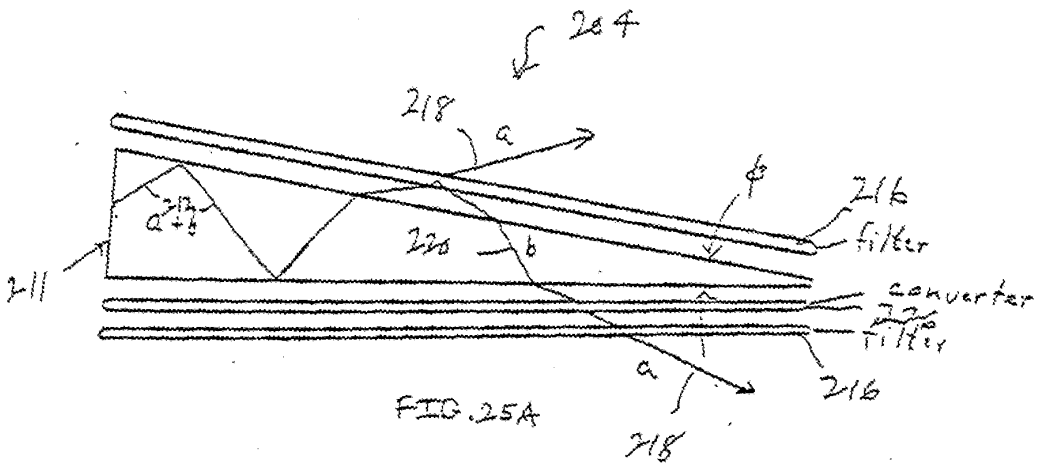


FIG. 25A

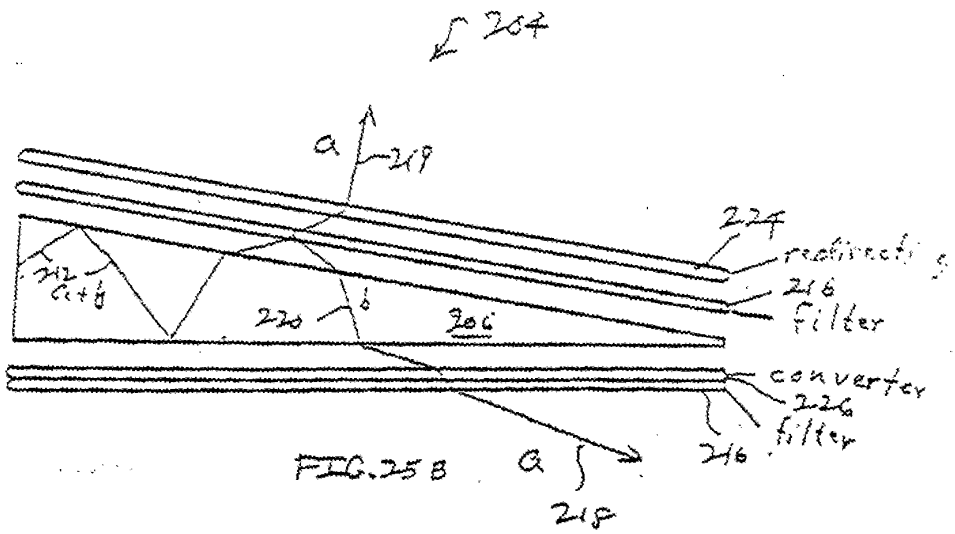


FIG. 25B

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Microsoft Corporation v. RealD Spark, LLC
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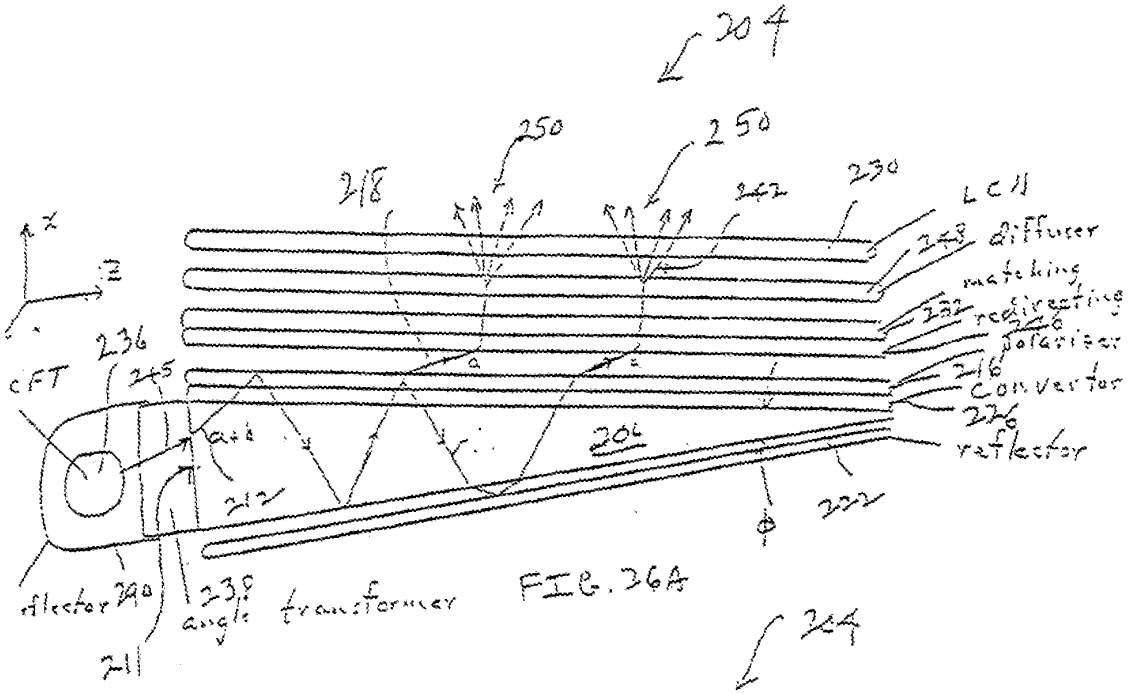


FIG. 2A

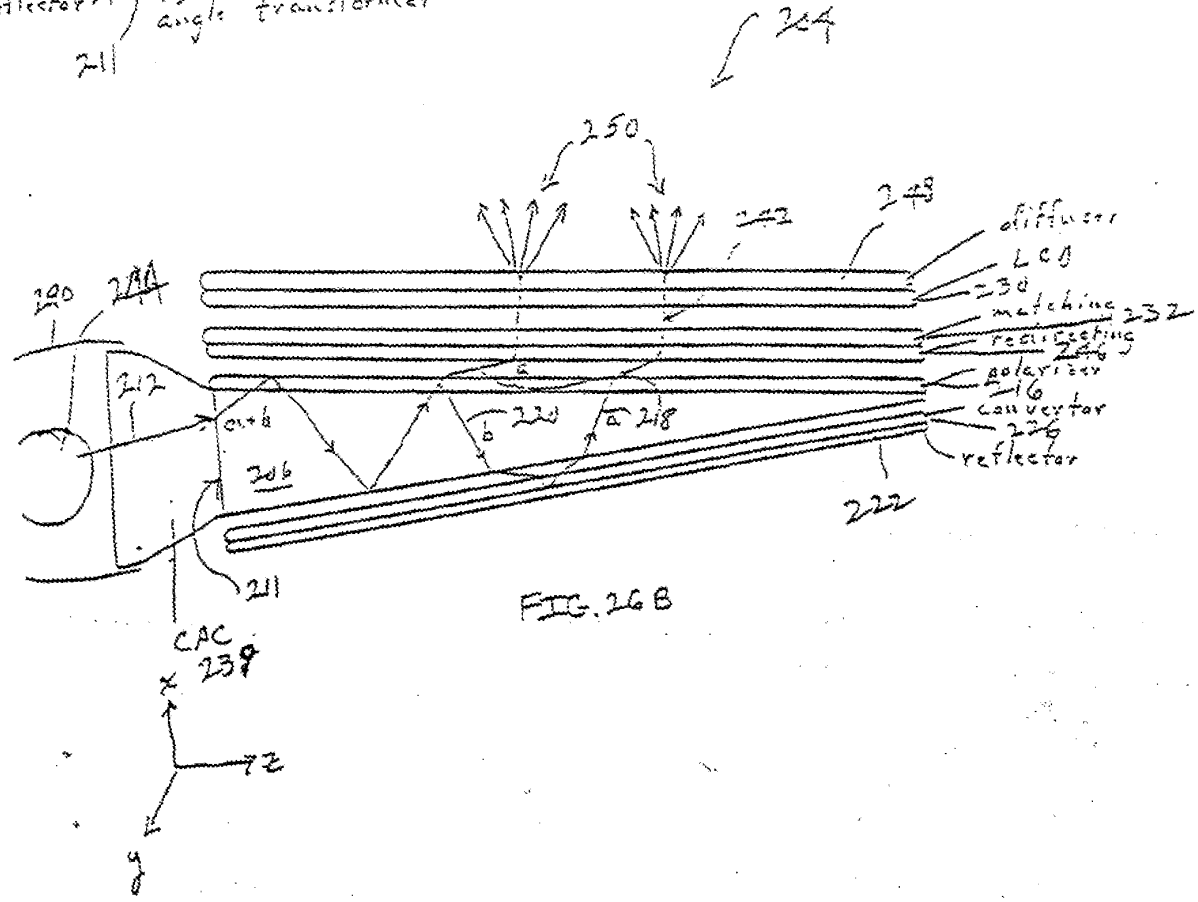


FIG. 2B

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

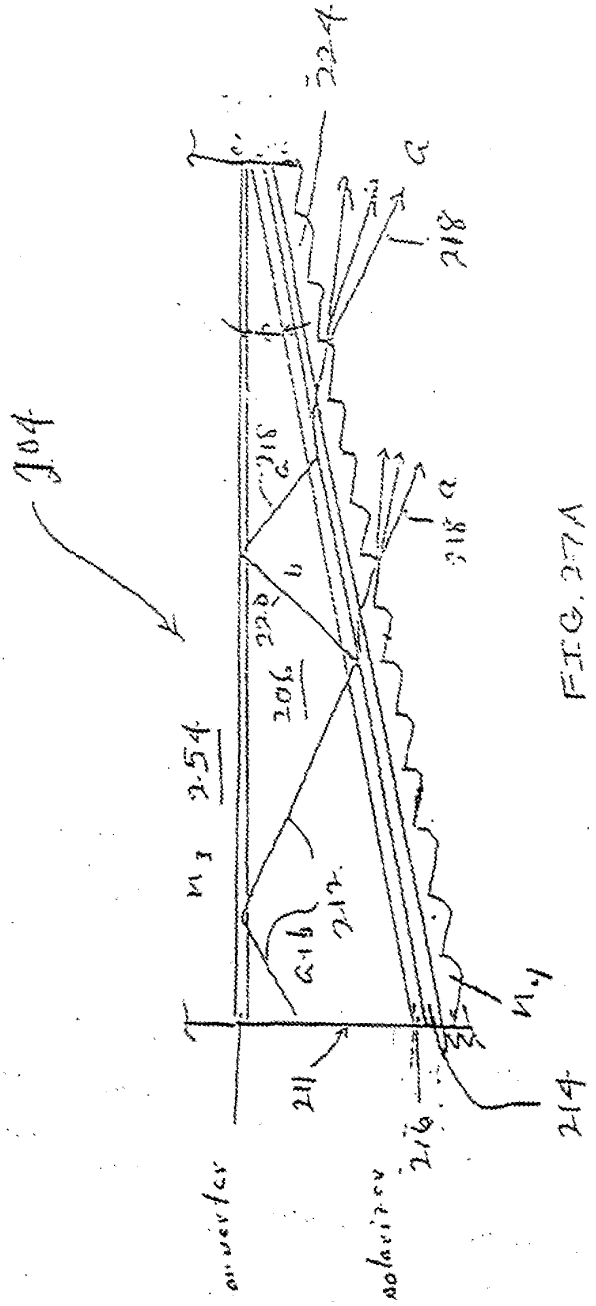
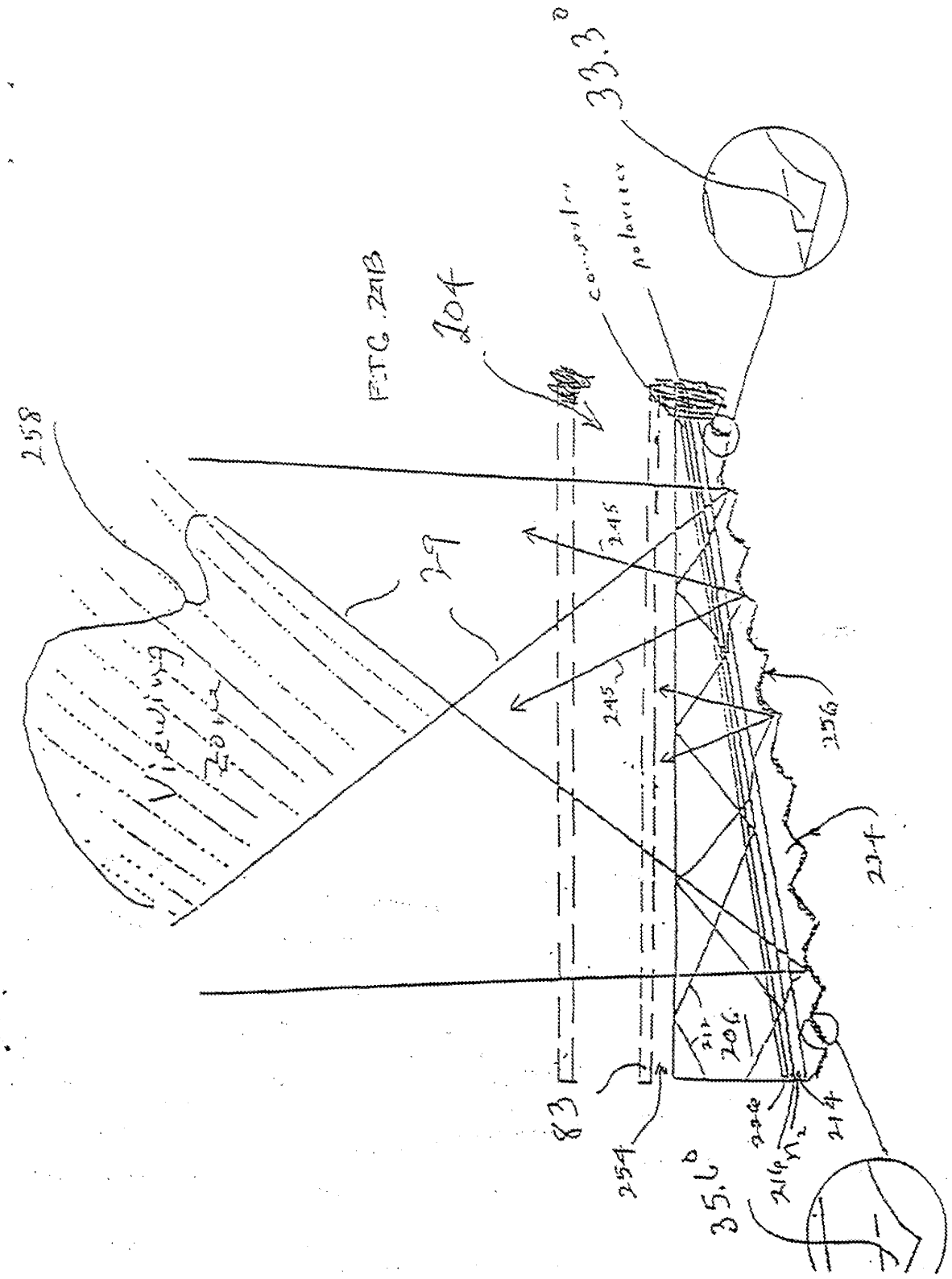


FIG. 27A

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

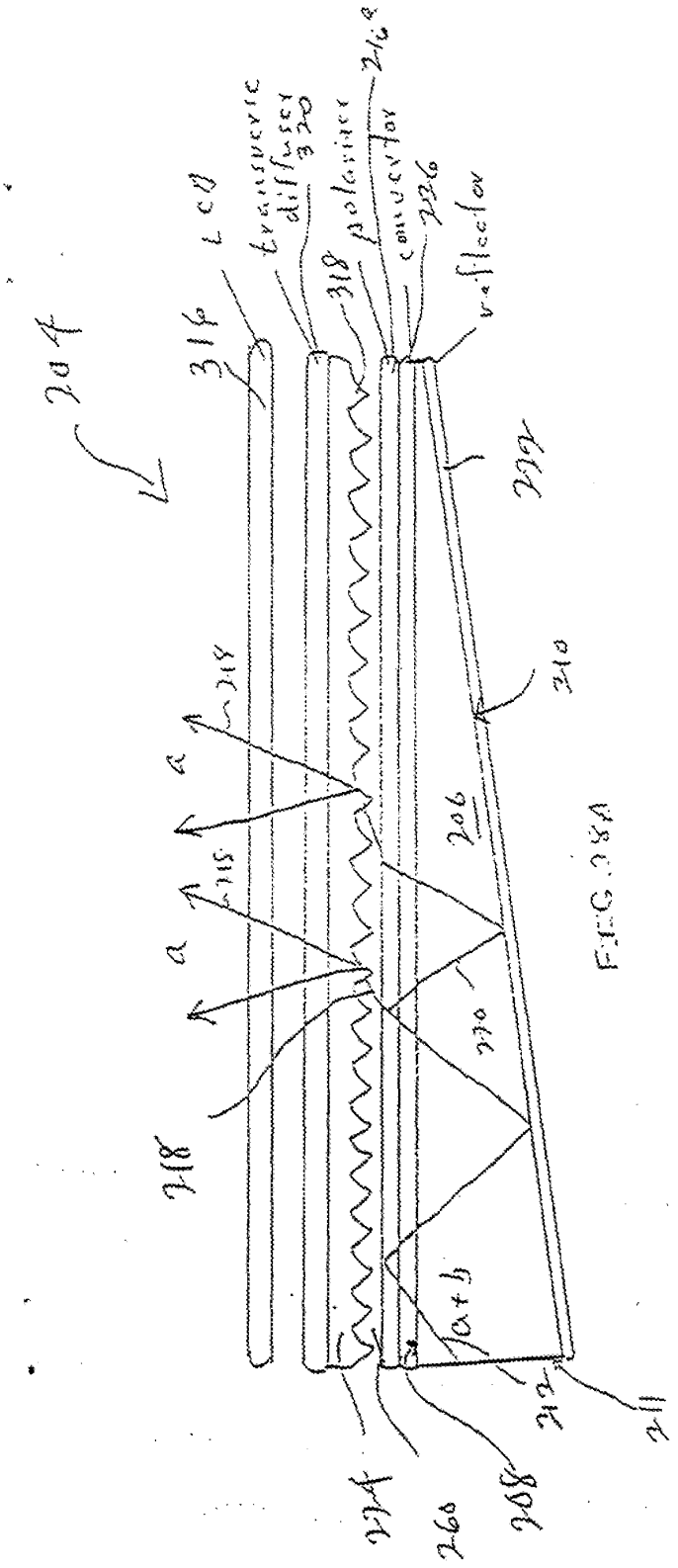


FIG. 2A

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

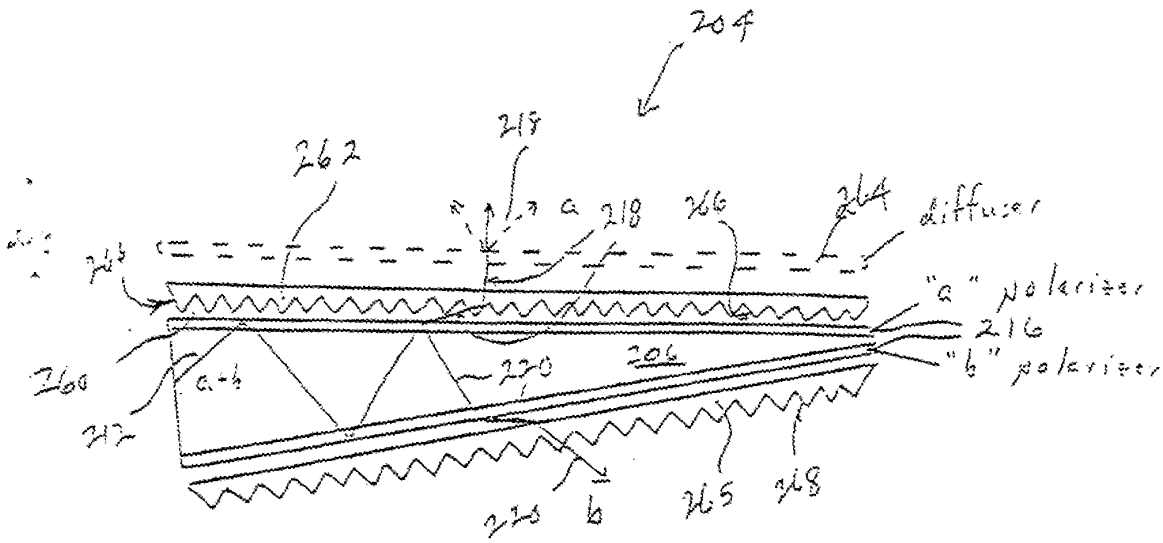


FIG. 25B

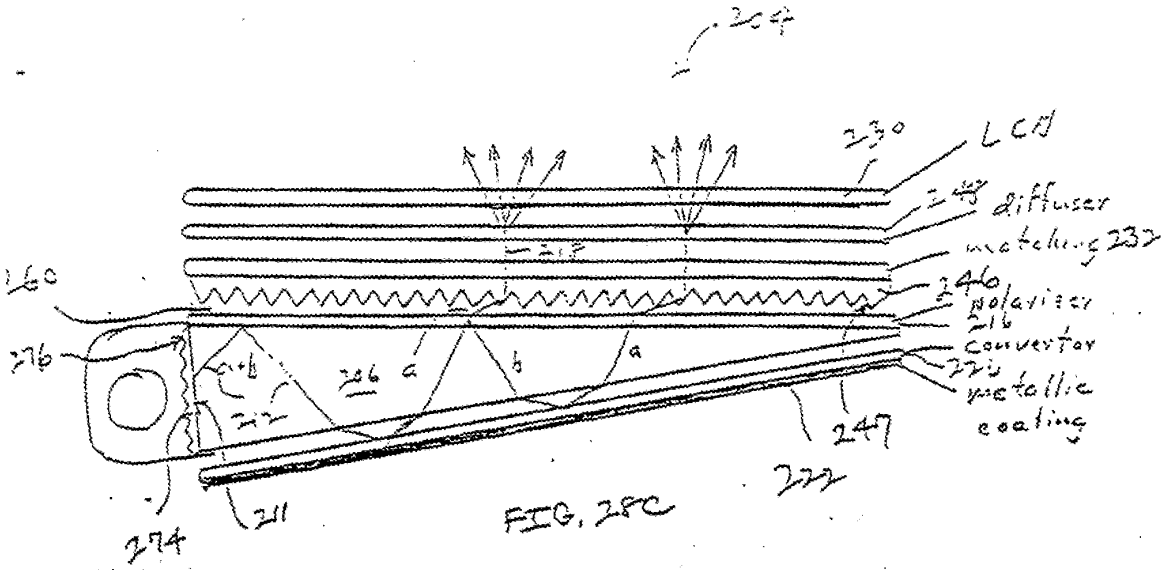


FIG. 25C

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Microsoft Corporation v. RealD Spark, LLC
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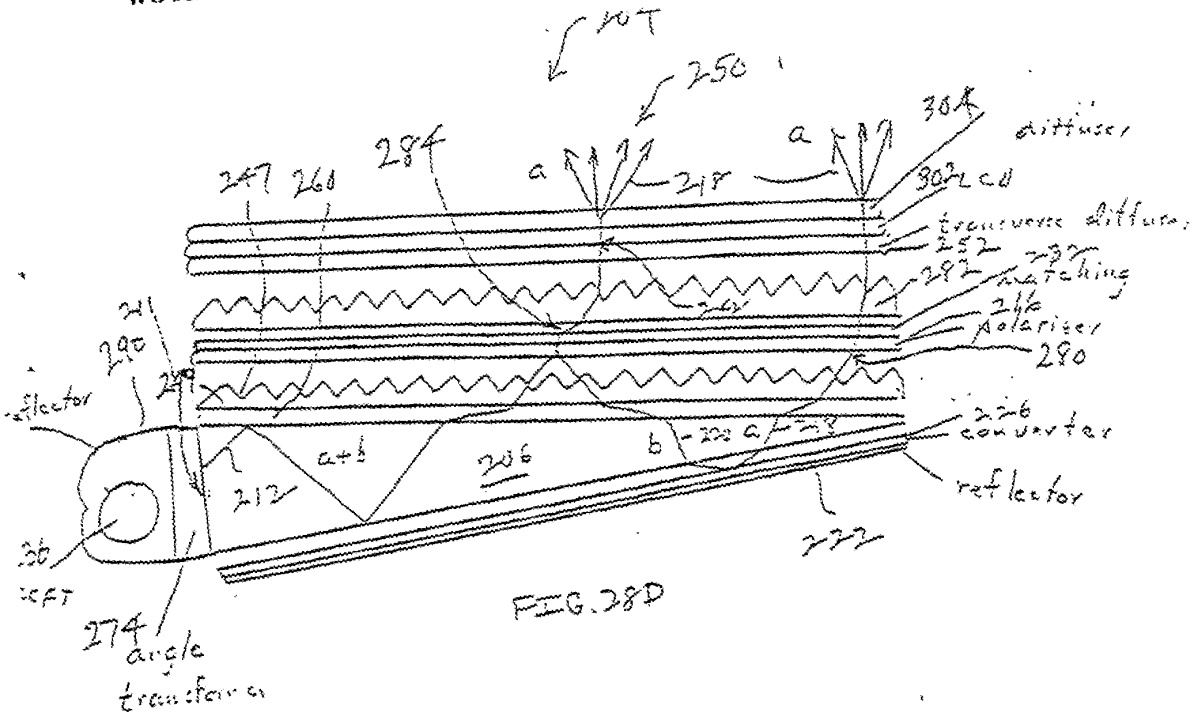


FIG. 28D

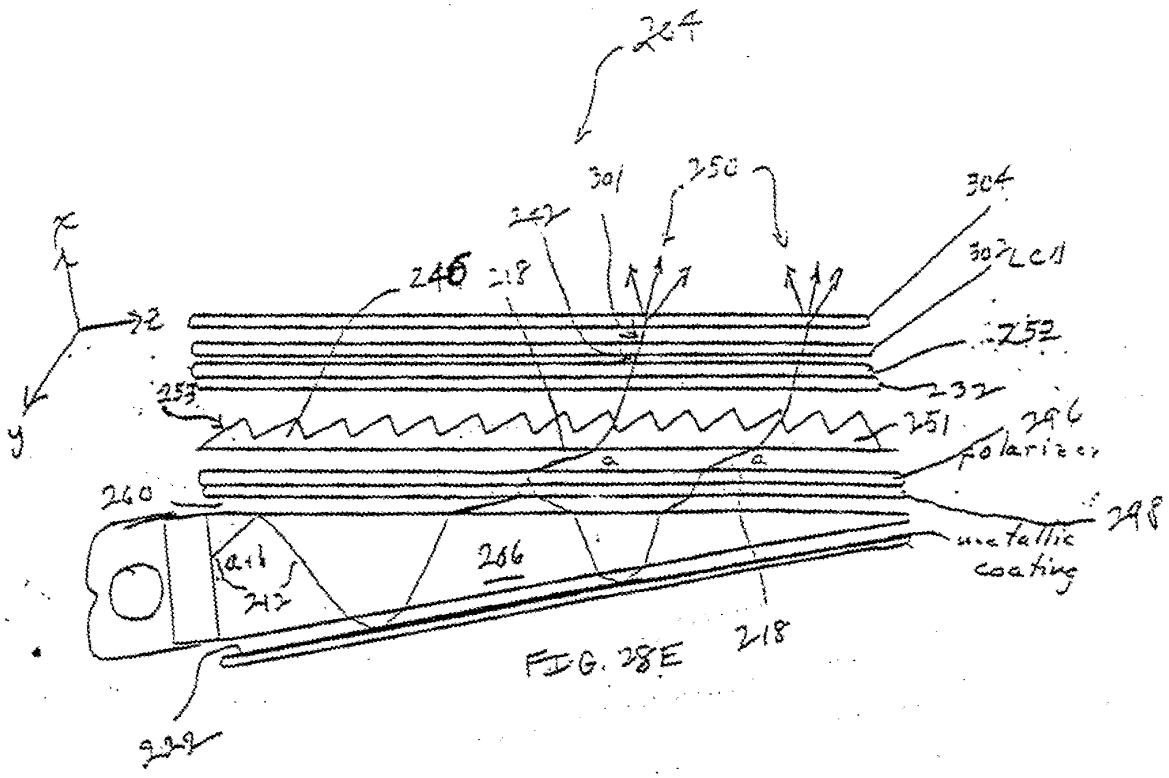


FIG. 28E

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Microsoft Corporation v. RealD Spark, LLC
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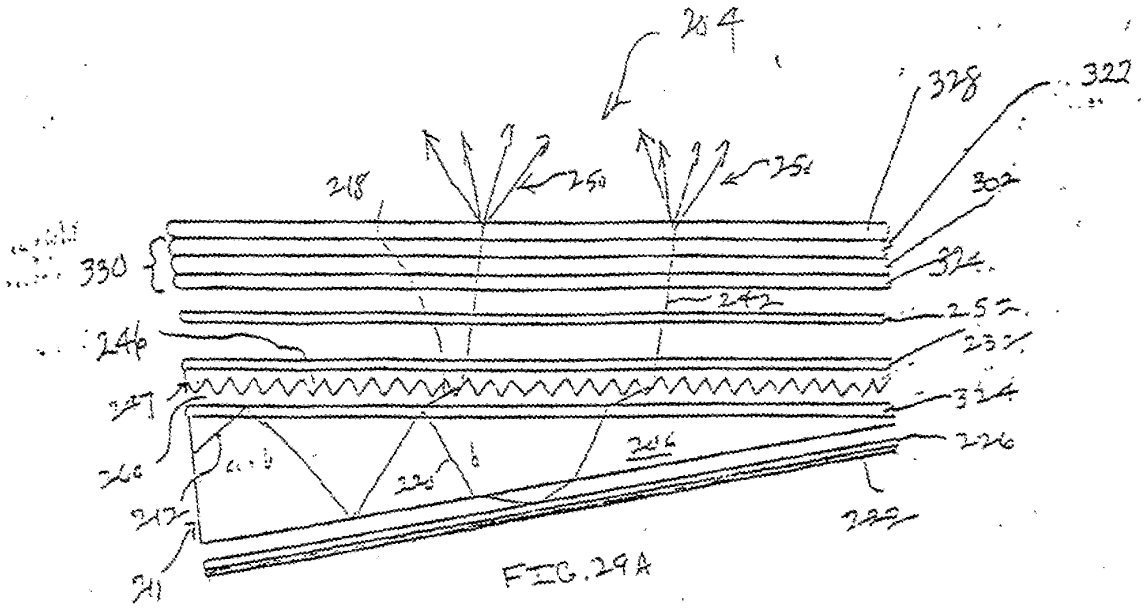


FIG. 29A

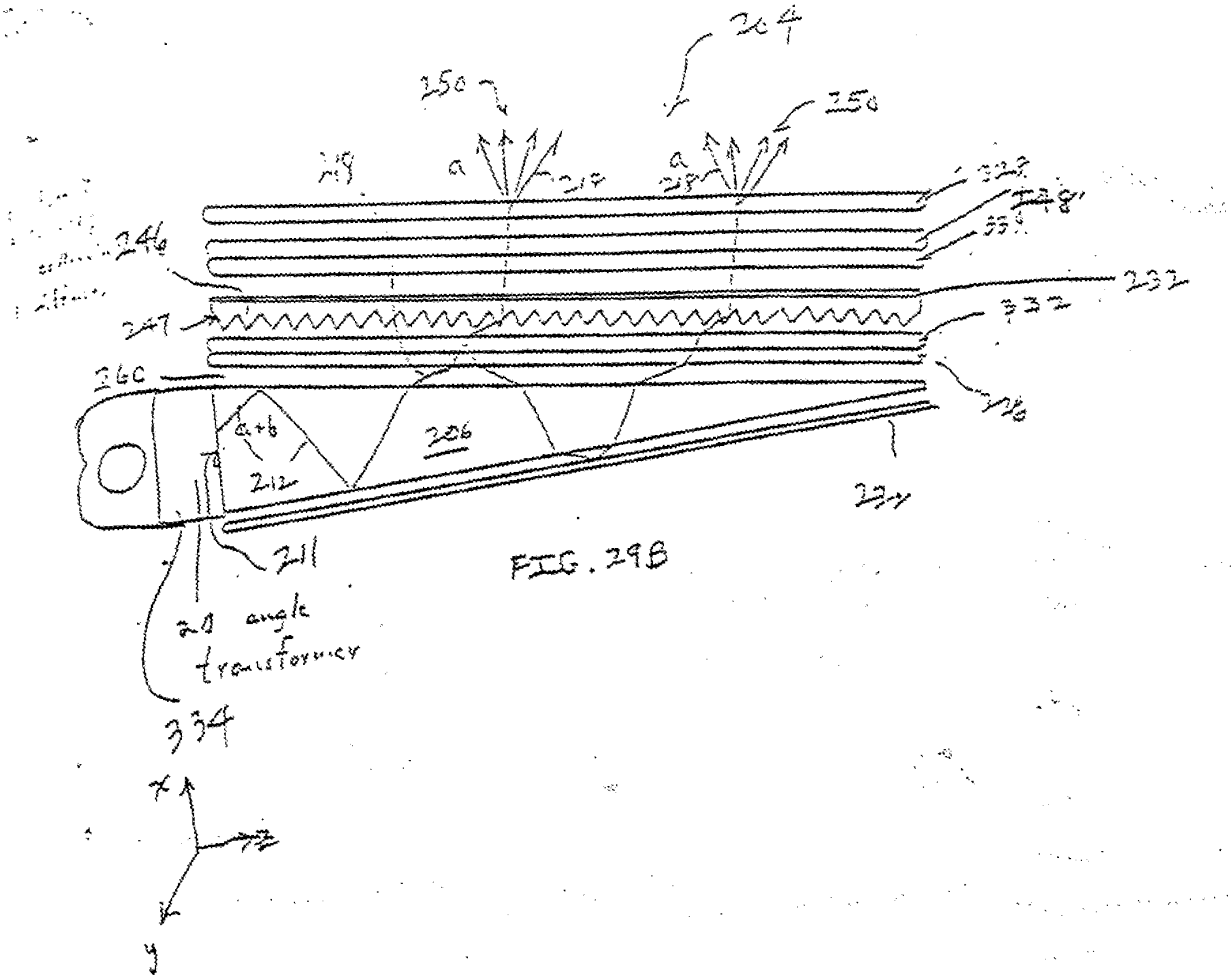


FIG. 29B

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

Prior Art

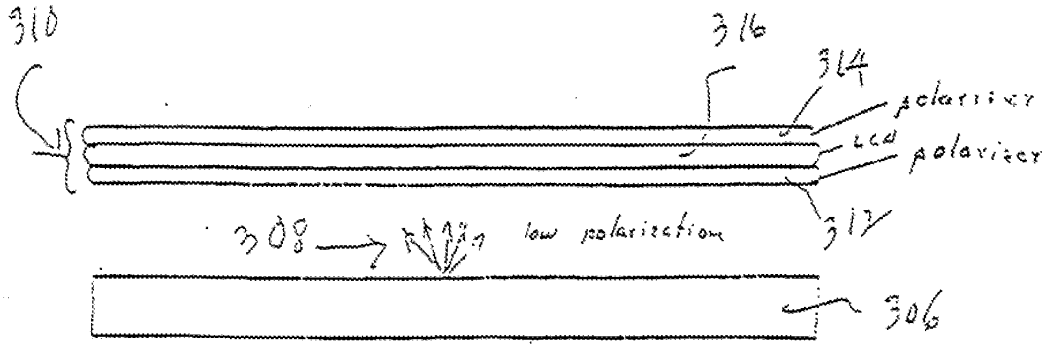


FIG. 30A

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

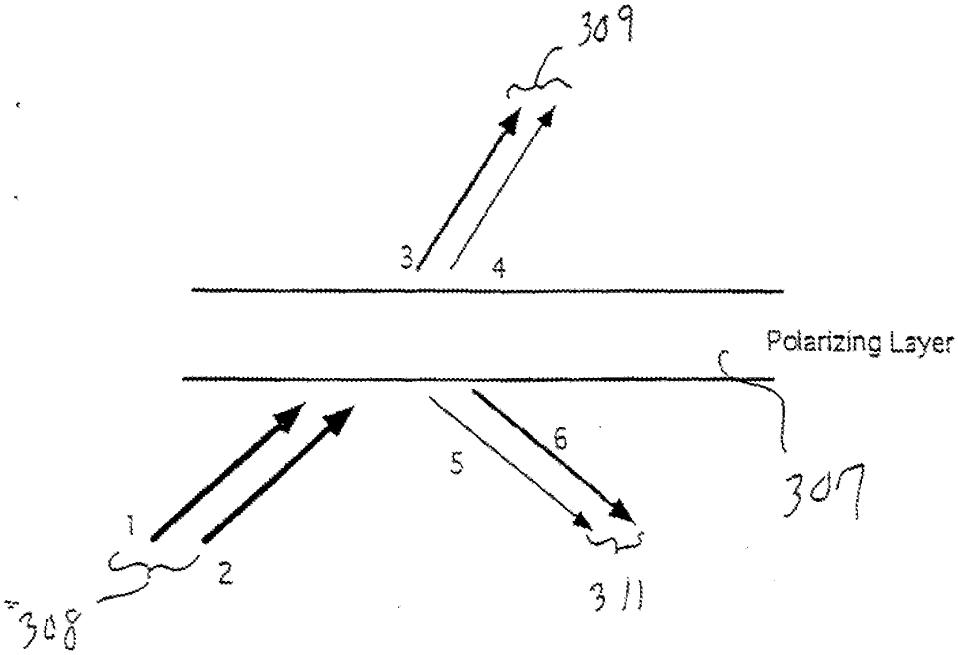


FIG. 30B

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Microsoft Corporation v. RealD Spark, LLC
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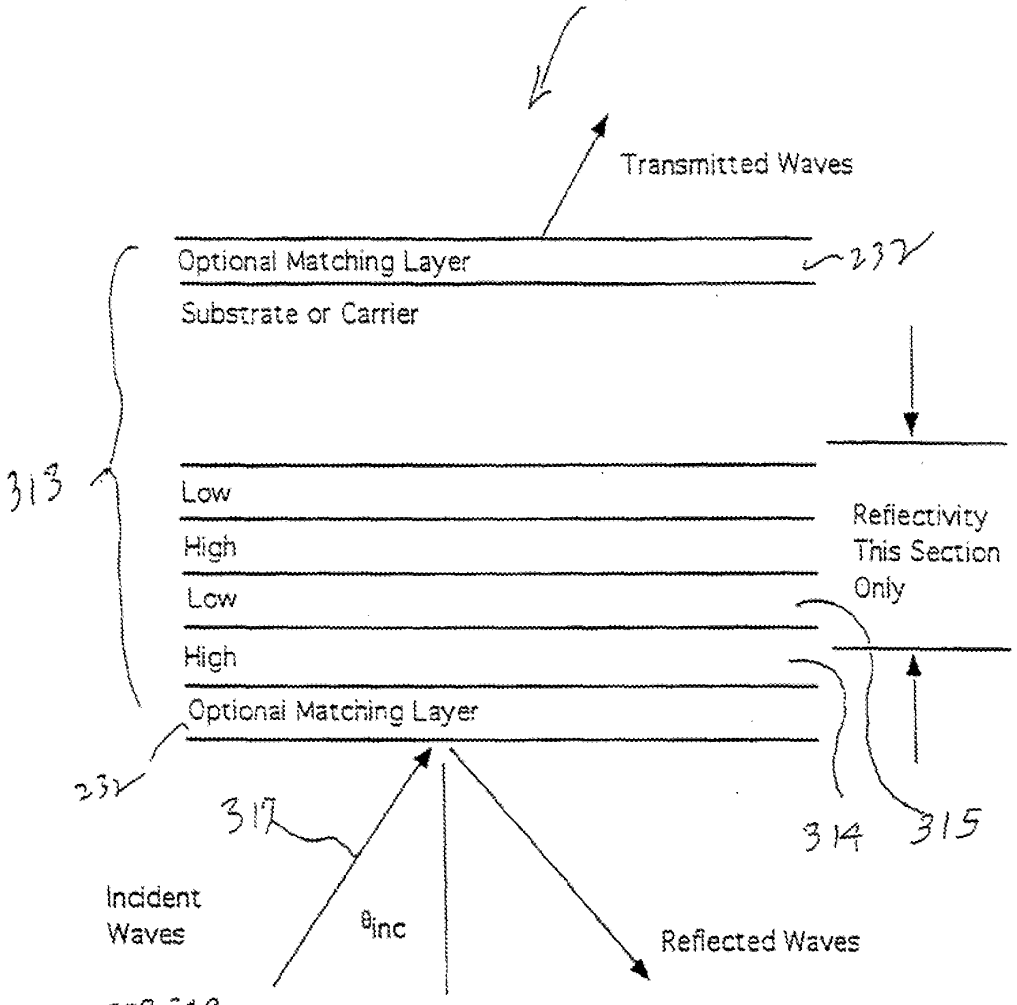


FIG 3d C

~~Figure 3.~~ Depiction of a thin-film design approach. This example has 3 layers in our notation. The substrate and the most frontal high index layer are not counted.

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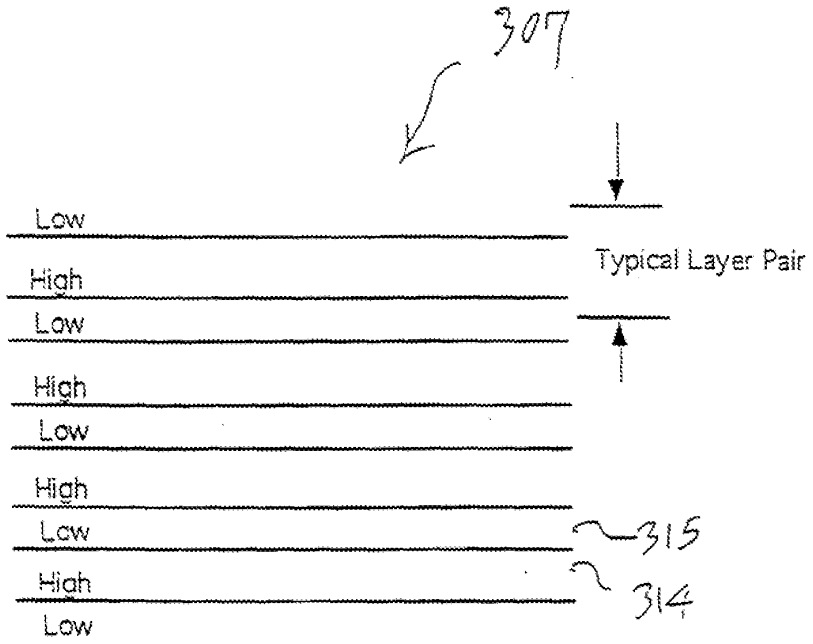


FIG. 3D

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IPR2023-01046 - U.S. Patent No. 10,740,985

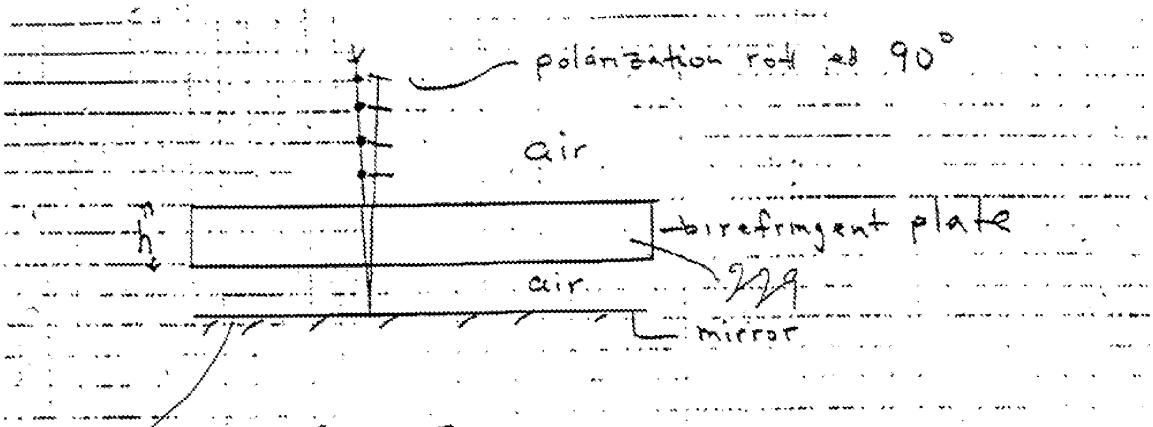


FIG. 30E

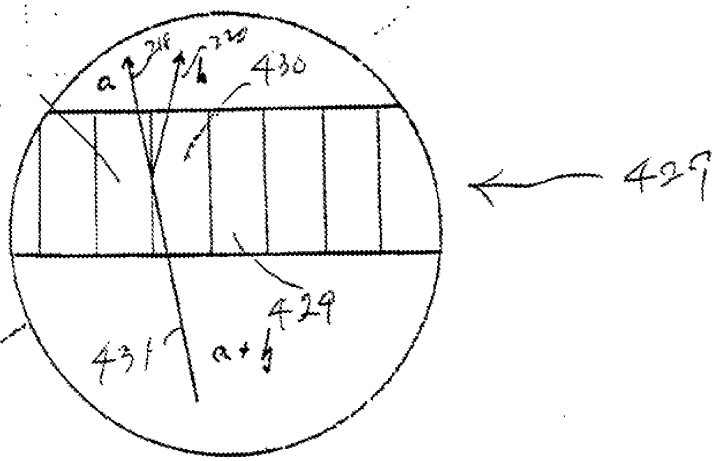


FIG. 30H

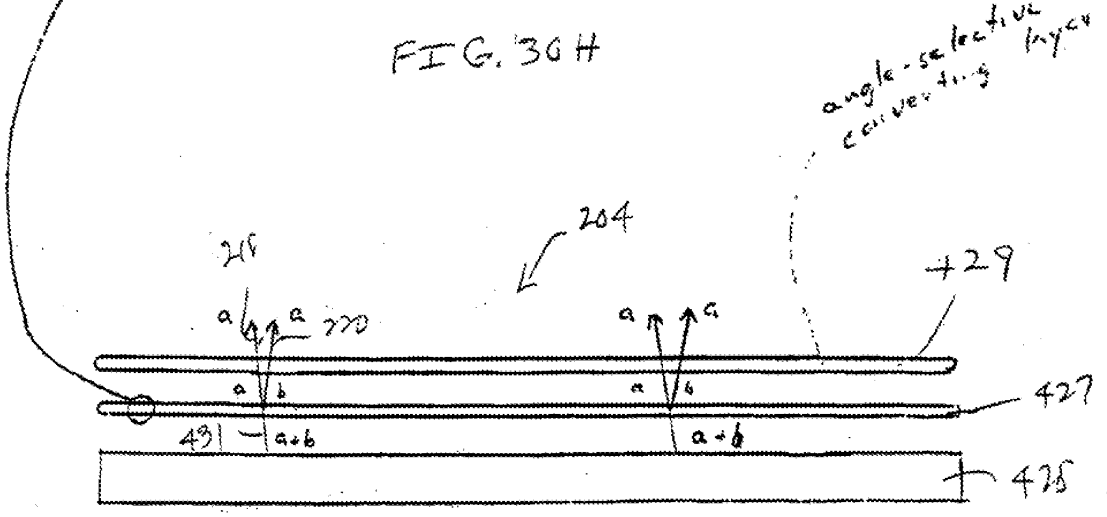
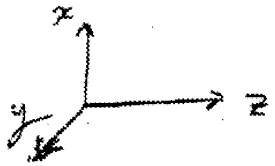


FIG. 30G



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IPR2023-01046 - U.S. Patent No. 10,740,985

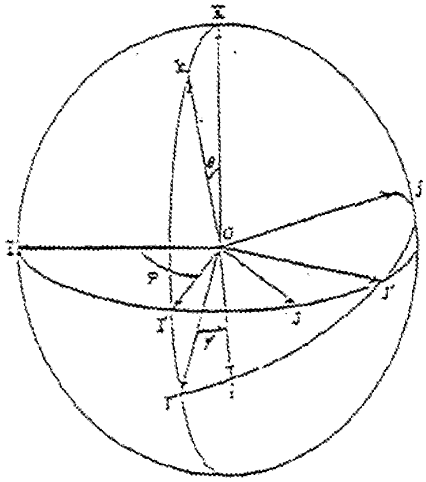


FIG. 30F

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

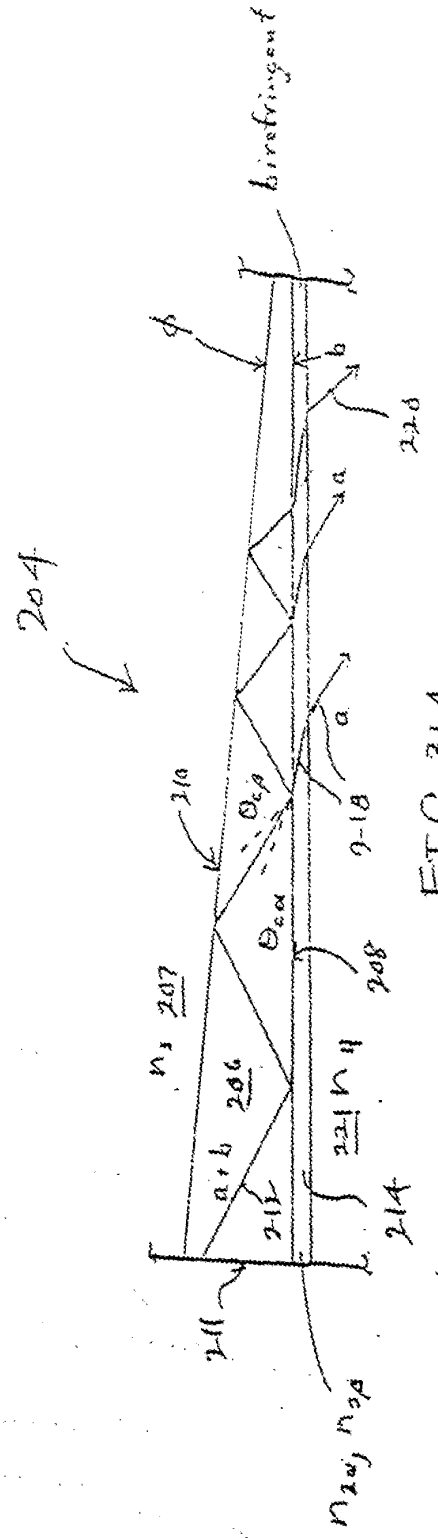


FIG. 31A

FIG. 31B

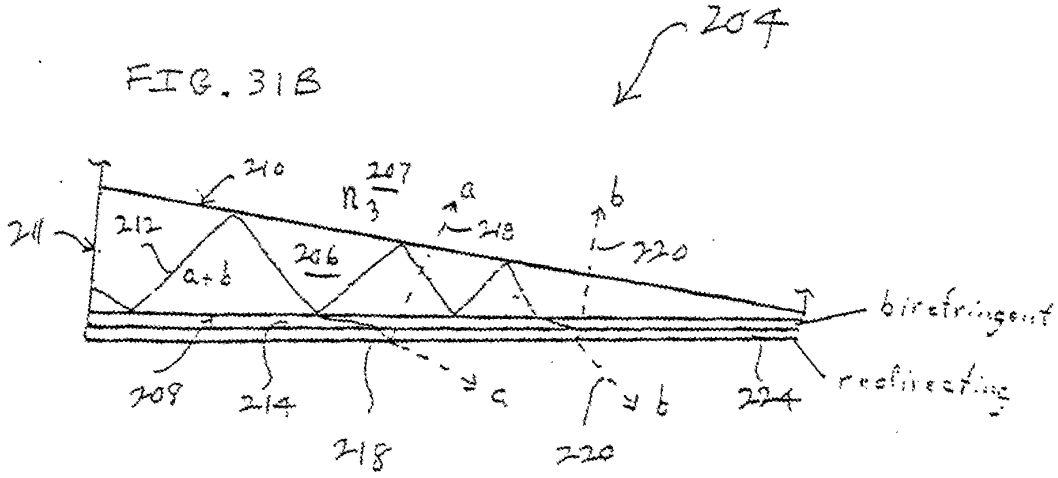
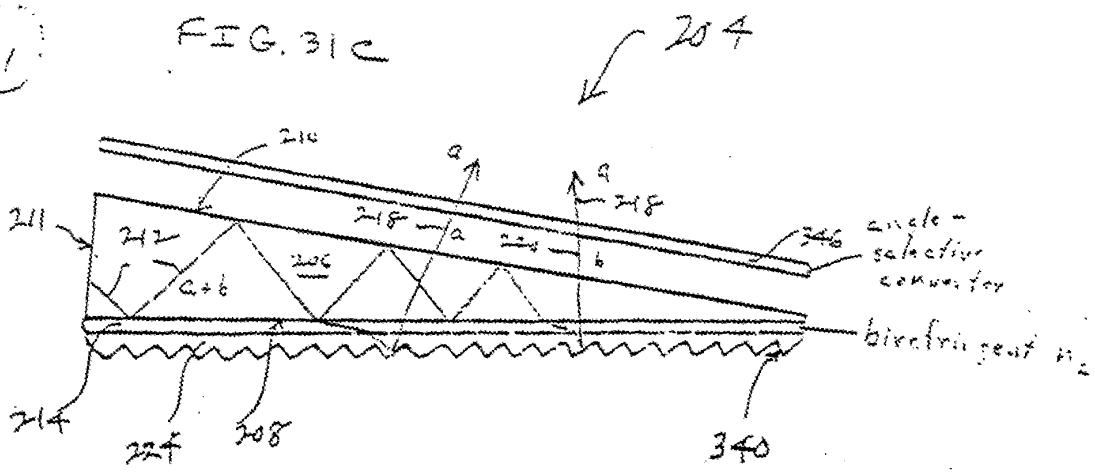


FIG. 31C



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FIG. 31D

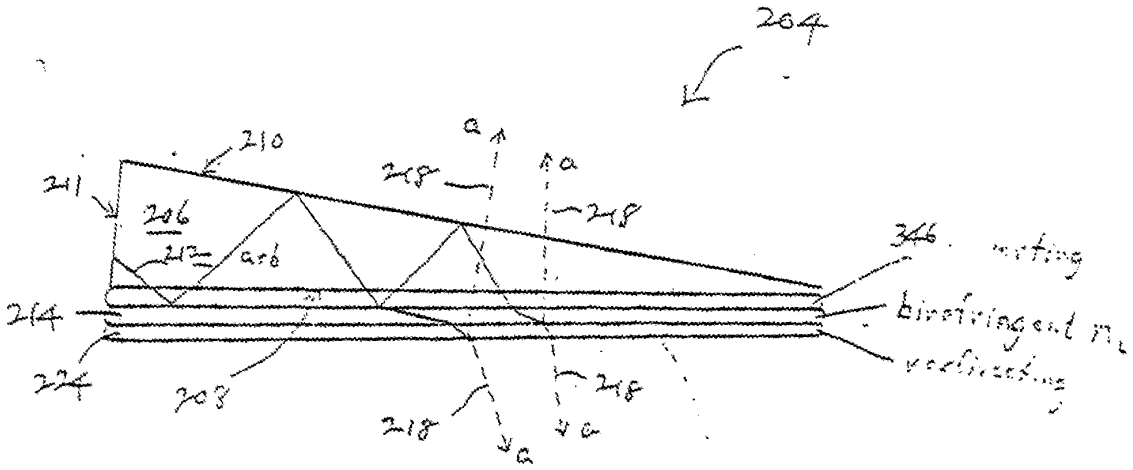
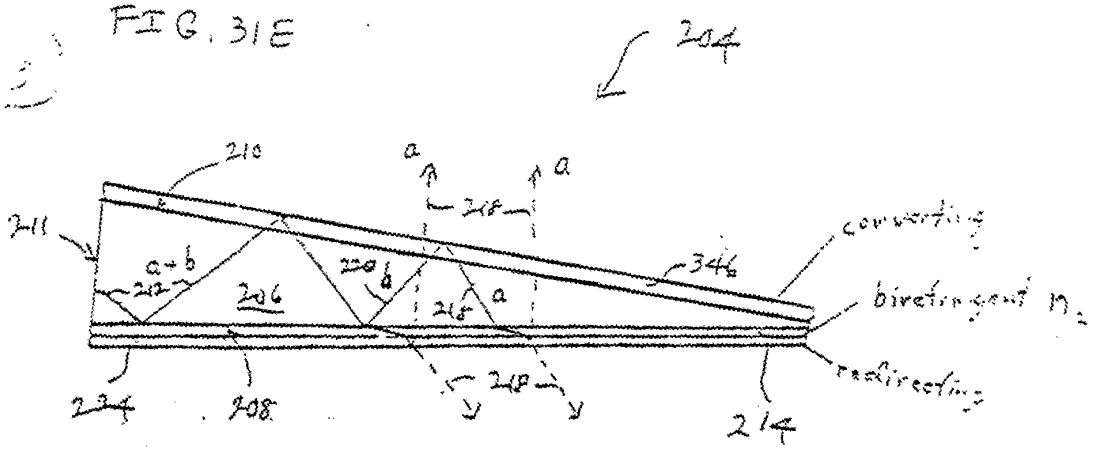
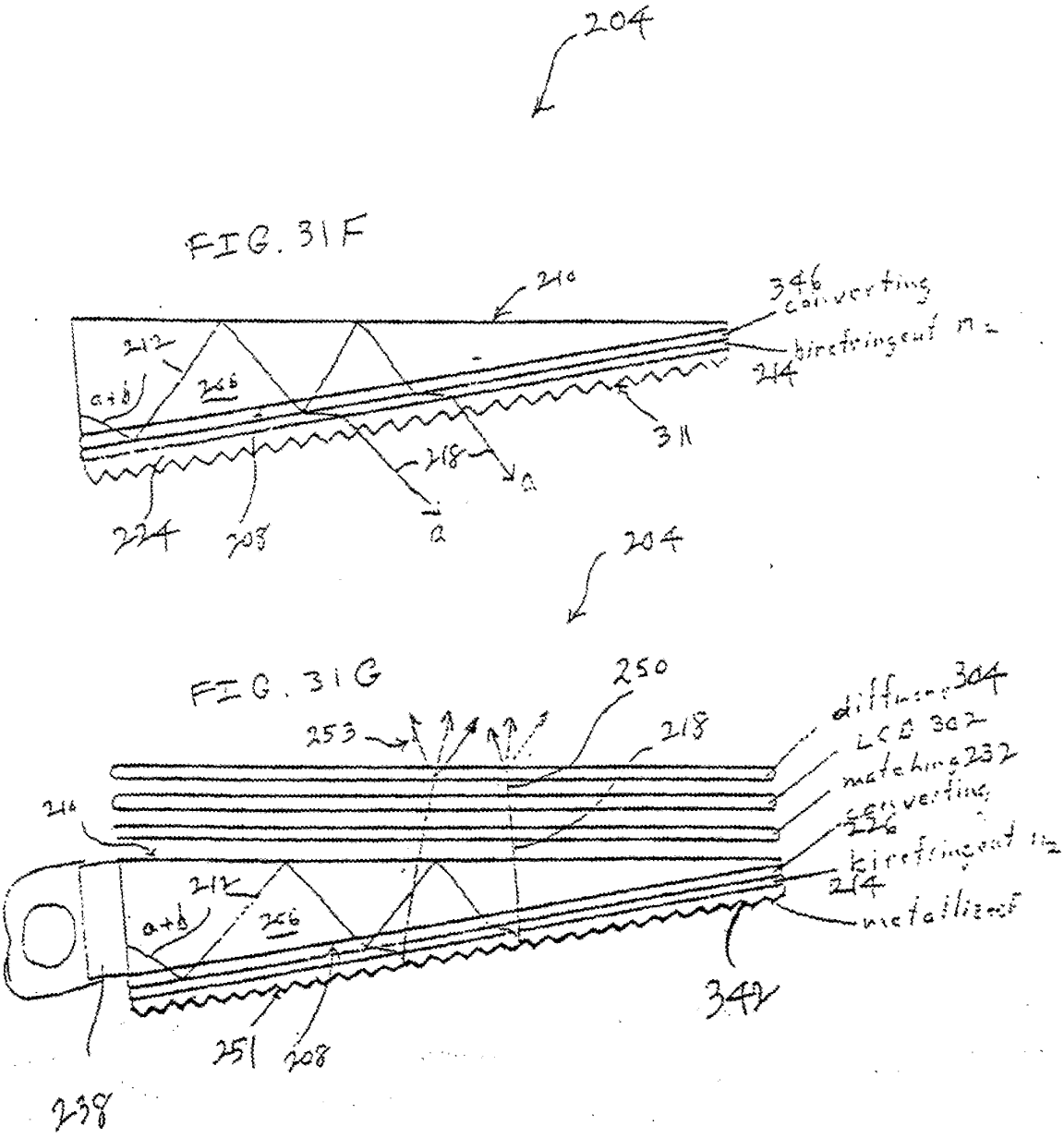


FIG. 31E



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

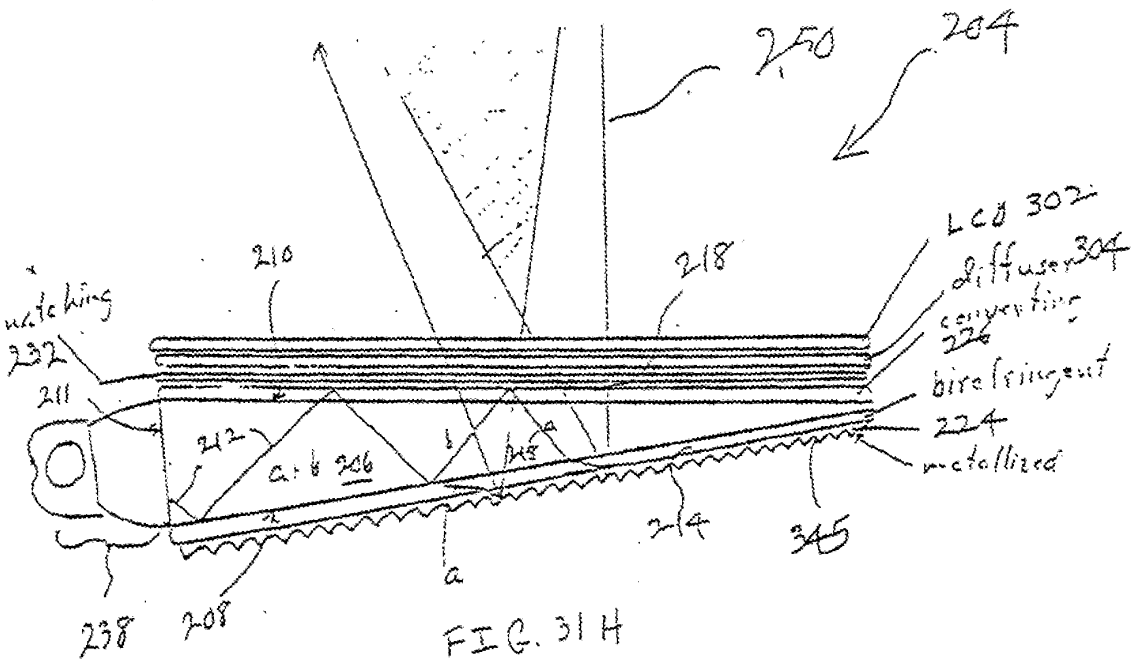

250
204
LCD 302
diffuser 304
converting
226
birefringent
224
metallized
210
218
matching
232
211
242
a+b 246
b
a
214
345
238
208

FIG. 31H

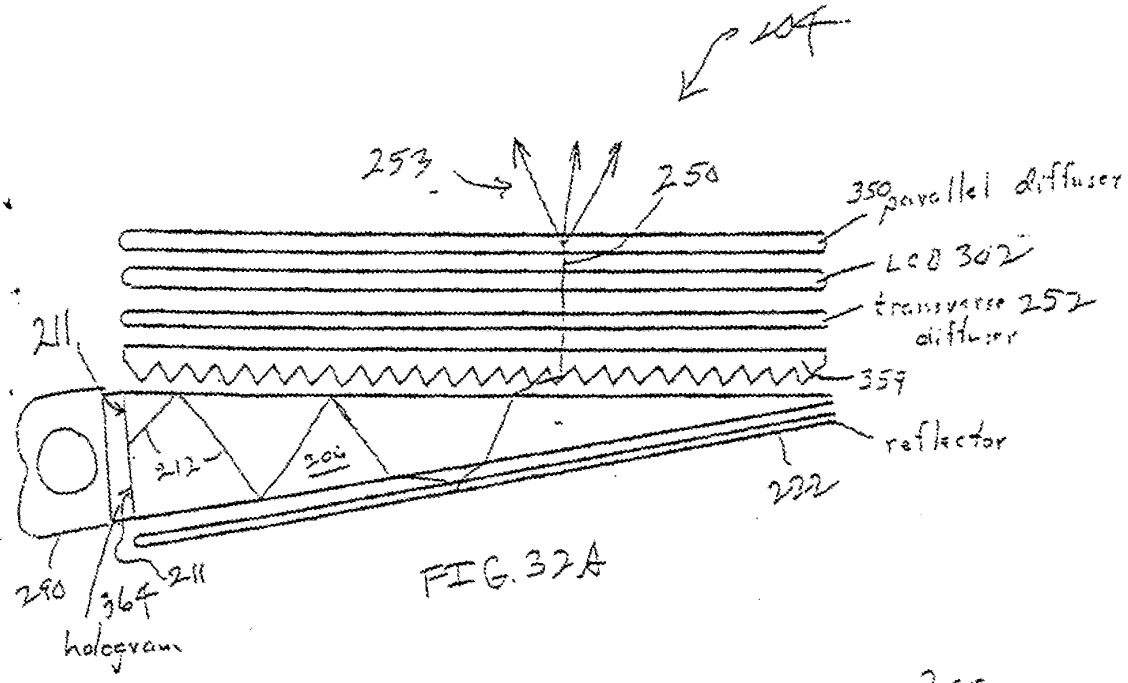


FIG. 32A

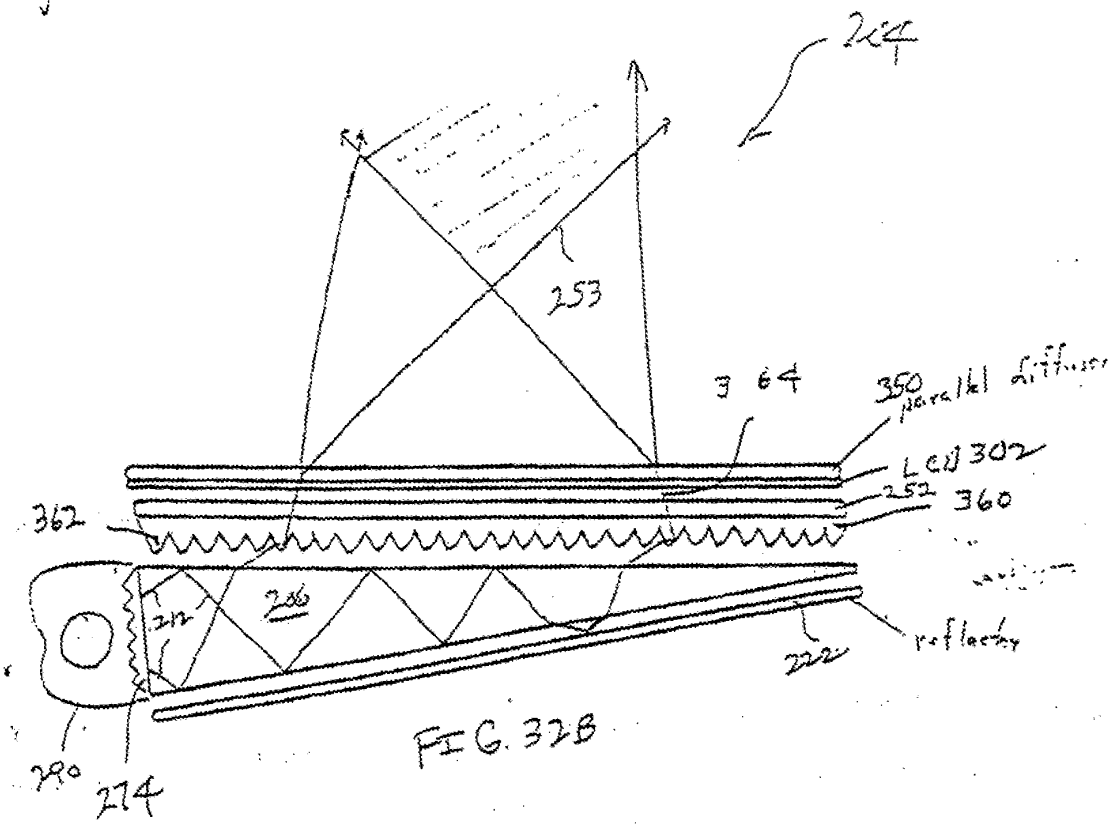


FIG. 32B

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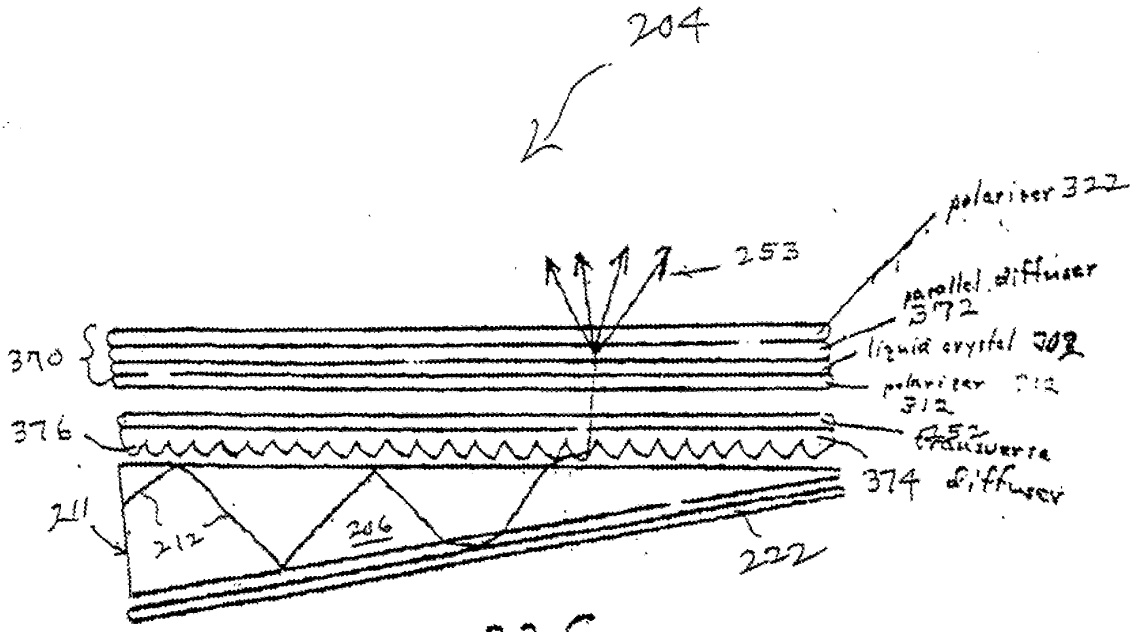


Fig. 32C

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IPR2023-01046 - U.S. Patent No. 10,740,985

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/04424

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :Please See Extra Sheet.
US CL :385/146, 43, 129, 131
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)
U.S. : Please See Extra Sheet.

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5,237,641 (JACOBSON ET AL.) 17 August 1993. Figures 2A and 2B.	
A , P	US, A, 5,303,322 (WINSTON ET AL.) 12 April 1994. Figure 6A	

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

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier document published on or after the international filing date	"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
"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)	"&"	document member of the same patent family
"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		

Date of the actual completion of the international search	Date of mailing of the international search report
06 JULY 1995	17 JUL 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Phan T.H. Palmer Telephone No. (703) 308-4848

Form PCT/ISA/210 (second sheet)(July 1992)*

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IPR2023-01046 - U.S. Patent No. 10,740,985

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/04424

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (5):

G02B 6/26

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

385/146, 43, 129, 131
385/43, 129, 130, 131, 140, 146, 147, 901; 362/19, 31, 32;
395/48, 50, 599, 833, 834, 869

Form PCT/ISA/210 (extra sheet)(July 1992)*

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PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	16057566
Filing Date	2018-08-07
First Named Inventor	Eric Sommerlade
Art Unit	2618
Examiner Name	PRINGLE-PARKER, JASON A
Attorney Docket Number	409001

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	1128979	A	1915-02-16	Hess	Entire Document
	2	1970311	A	1934-08-14	Ives	Entire Document
	3	2133121	A	1938-10-11	Stearns	Entire Document
	4	2247969	A	1941-07-01	Lemuel	Entire Document
	5	2480178	A	1949-08-30	Zinberg	Entire Document
	6	2810905	A	1957-10-22	Barlow	Entire Document
	7	3409351	A	1968-11-05	Winnek	Entire Document
	8	3715154	A	1973-02-06	Bestenreiner	Entire Document

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16057566
	Filing Date	2018-08-07
	First Named Inventor	Eric Sommerlade
	Art Unit	2618
	Examiner Name	PRINGLE-PARKER, JASON A
	Attorney Docket Number	409001

	9	4057323	A	1977-11-08	Robertson Ward	Entire Document
	10	4528617	A	1985-07-09	Blackington	Entire Document
	11	4542958	A	1985-09-24	Young	Entire Document
	12	4804253	A	1989-02-14	Stewart	Entire Document
	13	4807978	A	1989-02-28	Grinberg et al.	Entire Document
	14	4829365	A	1989-05-09	Eichenlaub	Entire Document
	15	4914553	A	1990-04-03	Hamada et al.	Entire Document
	16	5050946	A	1991-09-24	Hathaway et al.	Entire Document
	17	5278608	A	1994-01-11	Taylor et al.	Entire Document
	18	5347644	A	1994-09-13	Sedlmayr	Entire Document
	19	5349419	A	1994-09-20	Taguchi et al.	Entire Document

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16057566
	Filing Date	2018-08-07
	First Named Inventor	Eric Sommerlade
	Art Unit	2618
	Examiner Name	PRINGLE-PARKER, JASON A
	Attorney Docket Number	409001

	20	5459592	A	1995-10-17	Shibatani et al.	Entire Document
	21	5466926	A	1995-11-14	Sasano et al.	Entire Document
	22	5510831	A	1996-04-23	Mayhew	Entire Document
	23	5528720	A	1996-06-18	Winston et al.	Entire Document
	24	5581402	A	1996-12-03	Taylor	Entire Document
	25	5588526	A	1996-12-31	Fantone et al.	Entire Document
	26	5697006	A	1997-12-09	Taguchi et al.	Entire Document
	27	5703667	A	1997-12-30	Ochiai	Entire Document
	28	5727107	A	1998-03-10	Umemoto et al.	Entire Document
	29	5771066	A	1998-06-23	Barnea	Entire Document
	30	5796451	A	1998-08-18	Kim	Entire Document

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16057566
	Filing Date	2018-08-07
	First Named Inventor	Eric Sommerlade
	Art Unit	2618
	Examiner Name	PRINGLE-PARKER, JASON A
	Attorney Docket Number	409001

	31	5808792	A	1998-09-15	Woodgate et al.	Entire Document
	32	5875055	A	1999-02-23	Morishima et al.	Entire Document
	33	5896225	A	1999-04-20	Chikazawa	Entire Document
	34	5903388	A	1999-05-11	Sedlmayr	Entire Document
	35	5933276	A	1999-08-03	Magee	Entire Document
	36	5956001	A	1999-09-21	Sumida et al.	Entire Document
	37	5959664	A	1999-09-28	Woodgate	Entire Document
	38	5969850	A	1999-10-19	Harrold et al.	Entire Document
	39	5971559	A	1999-10-26	Ishikawa et al.	Entire Document
	40	6008484	A	1999-12-28	Woodgate et al.	Entire Document
	41	6014164	A	2000-01-11	Woodgate et al.	Entire Document

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IPR2023-01046 - U.S. Patent No. 10,740,985

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16057566
	Filing Date	2018-08-07
	First Named Inventor	Eric Sommerlade
	Art Unit	2618
	Examiner Name	PRINGLE-PARKER, JASON A
	Attorney Docket Number	409001

	42	6023315	A	2000-02-08	Harrold et al.	Entire Document
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	First Named Inventor	Eric Sommerlade
	Art Unit	2618
	Examiner Name	PRINGLE-PARKER, JASON A
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	Examiner Name	PRINGLE-PARKER, JASON A
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	Attorney Docket Number	409001

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	Examiner Name	PRINGLE-PARKER, JASON A
	Attorney Docket Number	409001

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Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

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See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Brian E. Harris/	Date (YYYY-MM-DD)	2019-03-08
Name/Print	Brian E. Harris	Registration Number	48383

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: PENNY L. LOWRY
5700 FLATIRON PARKWAY
BOULDER, CO 80301

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 409002	Date of mailing *(day/month/year)* 16 OCT 2018 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2018/045648	International filing date *(day/month/year)* 07 August 2018
Applicant REALD SPARK, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2017)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 409002	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2018/045648	International filing date *(day/month/year)* 07 August 2018	(Earliest) Priority Date *(day/month/year)* 08 August 2017
Applicant REALD SPARK, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☒ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 3

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/045648

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 6-19, 22-24, 31, 32
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/045648

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G06F 3/01; G06K 9/00; H04N 5/228; H04N 7/14; H04N 13/00 (2018.01)
CPC - G06F 3/011; G06F 3/013; G06T 5/005; G06T 5/008; G06T 7/11 (2018.08)

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)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 348/222.1; 382/167; 348/E5.024 (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2017/0195662 A1 (REALD SPARK, LLC) 06 July 2017 (06.07.2017) entire document	1-5, 20, 21, 25-30, 33-36
Y	WO 2016/132148 A1 (MAGIC PONY TECHNOLOGY LIMITED et al) 25 August 2016 (25.08.2016) entire document	1-5, 25-30, 33, 34, 36
Y	US 2014/0002586 A1 (NOURBAKHSH) 02 January 2014 (02.01.2014) entire document	5
Y	US 2012/0319928 A1 (RHODES) 20 December 2012 (20.12.2012) entire document	20, 21, 34, 35
Y	US 2005/0104878 A1 (KAYE et al) 19 May 2005 (19.05.2005) entire document	28, 29
A	US 2012/0114201 A1 (LUISI et al) 10 May 2012 (10.05.2012) entire document	1-5, 20, 21, 25-30, 33-36
A	US 2011/0063465 A1 (NANU et al) 17 March 2011 (17.03.2011) entire document	1-5, 20, 21, 25-30, 33-36
A	US 2016/0219258 A1 (REALD INC.) 28 July 2016 (28.07.2016) entire document	1-5, 20, 21, 25-30, 33-36

☐ 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
"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
"P" document published prior to the international filing date but later than the priority date claimed
"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
01 October 2018	16 OCT 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: PENNY L. LOWRY
5700 FLATIRON PARKWAY
BOULDER, CO 80301

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	16 OCT 2018
Applicant's or agent's file reference 409002	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2018/045648	07 August 2018	08 August 2017

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - G06F 3/01; G06K 9/00; H04N 5/228; H04N 7/14; H04N 13/00 (2018.01)
CPC - G06F 3/011; G06F 3/013; G06T 5/005; G06T 5/008; G06T 7/11 (2018.08)

Applicant REALD SPARK, LLC

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☒ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	01 October 2018	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/045648

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

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IPR2023-01046 - U.S. Patent No. 10,740,985

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/045648

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application.

☒ claims Nos. 6-19, 22-24, 31, 32

because:

☐ the said international application, or the said claims Nos. _____ relate to the following subject matter which does not require an international search *(specify)*:

☒ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. 6-19, 22-24, 31, 32 are so unclear that no meaningful opinion could be formed *(specify)*:

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:
Claims 6-19, 22-24, 31, 32 are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

☐ the claims, or said claims Nos. _____ are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no international search report has been established for said claims Nos. 6-19, 22-24, 31, 32

☐ a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

- ☐ furnish a sequence listing in the form of an Annex C/ST.25 text file, and such listing was not available to the International Searching Authority in the form and manner acceptable to it; or the sequence listing furnished did not comply with the standard provided for in Annex C of the Administrative Instructions.
- ☐ furnish a sequence listing on paper or in the form of an image file complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in the form and manner acceptable to it; or the sequence listing furnished did not comply with the standard provided for in Annex C of the Administrative Instructions.
- ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13*ter*.1(a) or (b).

☐ See Supplemental Box for further details.

Form PCT/ISA/237 (Box No. III) (January 2015)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/045648

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-5, 20, 21, 25-30, 33-36	YES
	Claims	None	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-5, 20, 21, 25-30, 33-36	NO
Industrial applicability (IA)	Claims	1-5, 20, 21, 25-30, 33-36	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-4, 25-27, 30, 33, and 36 lack an inventive step under PCT Article 33(3) as being obvious over RealD Spark, LLC (hereinafter RealD) in view of Magic Pony Technology Limited et al. (hereinafter Magic).

Regarding claim 1, RealD discloses a method of generating reference data (The reference data 35 is obtained and analyzed in advance [i.e. generating reference data] using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056) for adjusting a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. adjusting a digital representation of a head region], para 0005), the method comprising:
receiving training data (The capture device 10 includes a display 11 and a camera system 12 comprises two cameras 13 used to capture the stereoscopic pair of images of the head of a source observer 14, para 0030. The training input to the machine learning technique is two sets of images [i.e. receiving training data], which may be stereoscopic pairs of images or monoscopic images, para 0057) comprising:
a set of input patches (in each image of the multi-view images, identifying image patches [i.e. a set of input patches] containing the left and right eyes of the head, respectively, para 0005), each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region (in each image of the multi-view images, identifying image patches containing the left and right eyes of the head, respectively; in respect of the image patches containing the left eyes of the head in each image of the multi-view images, and also in respect of the image patches containing the right eyes of the head in each image of the multi-view images [i.e. input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region], para 0005, the image patches input and output images of each individual are aligned in the normalized coordinate system, para 0062), wherein the target feature is the same for each input patch (image patches containing the left and right eyes of the head, respectively are identified in each image 31 of the stereoscopic pair. FIG. 4 shows the identified image patches 32 of the right eye in each image 31 [i.e. the target feature is the same for each input patch], para 0049, image patches 32 containing the left and right eyes of the head are identified in each image 31 of the stereoscopic pair. This is done by identifying an image patch 39 in each image 31 located around the identified points ("landmarks") corresponding to features of an eye, para 0051); and
a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region (adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field, para 0005, image patches containing the left and right eyes of the head are identified and transformed, para 0006, the image patches input and output images of each individual are aligned in the normalized coordinate system [i.e. a set of output patches in one-to-one correspondence with the input patches], para 0062, From an input and output image of each individual, there is derived a displacement vector field that represents the transformation of the image patch in the input image required to obtain the image patch of the output image [i.e. each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region], para 0063, The displacement vector field F is chosen so that the image patch of the output image O(x,y) is derived from the image patch of the input image I(x,y) [i.e. a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region], para 0064);
using a first machine learning algorithm to generate first reference data using the training data (To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning, para 0006, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The training input to the machine learning technique is two sets of images, which may be stereoscopic pairs of images or monoscopic images [i.e. using a first machine learning algorithm to generate first reference data using the training data], para 0057, In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local image descriptors in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F [i.e. first reference data] to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076), the first reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each

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IPR2023-01046 - U.S. Patent No. 10,740,985

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/045648

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the first reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056); and
using a second machine learning algorithm to generate second reference data (In a second type of machine learning technique, the feature vector may comprise features that are discrete values of the local image descriptors in a continuous space. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with possible discrete values of the feature vector in the continuous space. This allows a displacement vector field F [i.e. second reference data] to be derived from the reference data 35 by interpolation from the reference displacement vector fields based on the relationship between the feature vector 34 derived and the values of the feature vector associated with the reference displacement vector fields [i.e. using a second machine learning algorithm to generate second reference data, para 0083), the second reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the second reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056).
RealD does not specifically disclose the second machine learning algorithm using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm.
However, Magic is in the field of generating hierarchical algorithms using machine learning techniques to enable high quality reconstruction of lower-quality visual data (pg 1 ln 6-8) and discloses the second machine learning algorithm using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm (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, pg 12 ln 13-17, Training hierarchical algorithms can allow enhancement and/or reconstruction models to be developed for enhancing visual data in at least one embodiment, visual data can be image data and/or video data, 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, 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 [i.e. using the same training data as the first machine learning algorithm] 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, pg 12 ln 18-27, 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, 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 [i.e. using the first reference data generated by the first machine learning algorithm] when compared and/or applied to the input data [i.e. the second machine learning algorithm using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm], pg 12 ln 29 to pg 13 ln 10). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Magic for the purpose of allowing 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 (Magic pg 12 ln 18-27).

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Regarding claim 2, RealD further discloses that the first reference data comprise first editing instructions for a range of possible configurations of the target feature and first selection instructions for selecting editing instructions for a particular input patch from the first editing instructions based on the configuration of the target feature of the input patch (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field, para 0005, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The local image descriptors input into the machine learning process are of types expected to provide discrimination between different individuals, although the specific local image descriptors are selected and optimized by the machine learning process itself, para 0070, In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local image descriptors in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076); and
the second reference data comprise second editing instructions for a range of possible configurations of the target feature and second selection instructions for selecting editing instructions for a particular input patch from the second image editing instructions based on the configuration of the target feature of the input patch (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field, para 0005, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The local image descriptors input into the machine learning process are of types expected to provide discrimination between different individuals, although the specific local image descriptors are selected and optimized by the machine learning process itself, para 0070, In the case that the feature vector 34 comprises features that are values in a discrete space and the reference displacement vector fields of the reference data 35 comprise a reference displacement vector field associated with each possible value of the feature vector in the discrete space, then the displacement vector field for the image patch is derived by selecting the reference displacement field associated with the actual value of the derived feature vector 34, para 0095).

Regarding claim 3, RealD further discloses that the configuration of the target feature of each input patch is represented by a feature vector derived from plural local descriptors of the input patch, and the first and second selection instructions define how the feature vector is used to select editing instructions for the input patch (deriving a feature vector from plural local image descriptors of the image patch in at least one image of the multi-view images; and deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector, para 0005, The local image descriptors input into the machine learning process are of types expected to provide discrimination between different individuals, although the specific local image descriptors are selected and optimized by the machine learning process itself, para 0070, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076).

Regarding claim 4, RealD further discloses that the editing instructions comprise a displacement vector field defining how the input patch is to be transformed (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field, para 0005).

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Regarding claim 25, RealD discloses a method of training a machine learning algorithm (The training input to the machine learning technique [i.e. training a machine learning algorithm] is two sets of images, which may be stereoscopic pairs of images or monoscopic images, para 0057, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table, para 0076) to adjust a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. adjusting a digital representation of a head region], para 0005), comprising:
receiving training data (The capture device 10 includes a display 11 and a camera system 12 comprises two cameras 13 used to capture the stereoscopic pair of images of the head of a source observer 14, para 0030, The training input to the machine learning technique is two sets of images [i.e. receiving training data], which may be stereoscopic pairs of images or monoscopic images, para 0057) comprising:
a set of input patches (in each image of the multi-view images, identifying image patches [i.e. a set of input patches] containing the left and right eyes of the head, respectively, para 0005), each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region (in each image of the multi-view images, identifying image patches containing the left and right eyes of the head, respectively; in respect of the image patches containing the left eyes of the head in each image of the multi-view images, and also in respect of the image patches containing the right eyes of the head in each image of the multi-view images [i.e. input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region], para 0005, the image patches input and output images of each individual are aligned in the normalized coordinate system, para 0062), wherein the target feature is the same for each input patch (image patches containing the left and right eyes of the head, respectively are identified in each image 31 of the stereoscopic pair. FIG. 4 shows the identified image patches 32 of the right eye in each image 31 [i.e. the target feature is the same for each input patch], para 0049, image patches 32 containing the left and right eyes of the head are identified in each image 31 of the stereoscopic pair. This is done by identifying an image patch 39 in each image 31 located around the identified points ("landmarks") corresponding to features of an eye, para 0051); and
first reference data generated by a pre-trained first machine learning algorithm (To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning, para 0006, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The training input to the machine learning technique is two sets of images, which may be stereoscopic pairs of images or monoscopic images [i.e. first reference data generated by a pre-trained first machine learning algorithm], para 0057, In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local image descriptors in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076), the first reference data comprising a set of editing instructions in one-to-one correspondence with the input patches, each editing instruction being for adjusting the digital representation of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. each editing instruction being for adjusting the digital representation of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, the image patches input and output images of each individual are aligned in the normalized coordinate system, para 0062, From an input and output image of each individual, there is derived a displacement vector field that represents the transformation of the image patch in the input image required to obtain the image patch of the output image [i.e. a set of editing instructions in one-to-one correspondence with the input patches], para 0063);
a pre-trained second machine learning algorithm trained to generate second reference data (In a second type of machine learning technique, the feature vector may comprise features that are discrete values of the local image descriptors in a continuous space. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with possible discrete values of the feature vector in the continuous space. This allows a displacement vector field F to be derived from the reference data 35 by interpolation from the reference displacement vector fields based on the relationship between the feature vector 34 derived and the values of the feature vector associated with the reference displacement vector fields [i.e. updating a pre-trained second machine learning algorithm trained to generate second reference data], para 0083), the second reference data comprising editing instructions for adjusting the digital representation of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the second reference data comprising editing instructions for adjusting the digital representation of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected,

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thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056).
RealD does not specifically disclose that the input for the updating comprises the training data and the generated first reference data. However, Magic discloses that the input for the updating comprises the training data and the generated first reference data (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, pg 12 ln 13-17, Training hierarchical algorithms can allow enhancement and/or reconstruction models to be developed for enhancing visual data in at least one embodiment, visual data can be image data and/or video data, 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, 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 [i.e. the input for the updating comprises the training data and the generated first reference data], pg 12 ln 18-27). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Magic for the purpose of allowing 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 (Magic pg 12 ln 18-27).

Regarding claim 26, modified RealD discloses the invention above, but RealD did not disclose that the updating of the second machine learning algorithm is performed at or near input data frame rate. However, Magic discloses that the updating of the second machine learning algorithm is performed at or near input data frame rate (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, optionally selecting the lowest frame rate when the network is trained, pg 68 ln 29 to pg 69 ln 5). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Magic for the purpose of training the network (Magic pg 68 ln 29 to pg 69 ln 5).

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Regarding claim 27, RealD discloses a method of training a machine learning algorithm (The training input to the machine learning technique [i.e. training a machine learning algorithm] is two sets of images, which may be stereoscopic pairs of images or monoscopic images, para 0057, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table, para 0076) to adjust a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. adjusting a digital representation of a head region], para 0005), the method comprising:
receiving training data (The capture device 10 includes a display 11 and a camera system 12 comprises two cameras 13 used to capture the stereoscopic pair of images of the head of a source observer 14, para 0030, The training input to the machine learning technique is two sets of images [i.e. receiving training data], which may be stereoscopic pairs of images or monoscopic images, para 0057) comprising a set of input digital representations of a head region (in each image of the multi-view images, identifying image patches containing the left and right eyes of the head, respectively; in respect of the image patches containing the left eyes of the head in each image of the multi-view images, and also in respect of the image patches containing the right eyes of the head in each image of the multi-view images [i.e. a set of input digital representations of a head region], para 0005);
training a first machine learning algorithm using the training data (To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning, para 0006, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The training input to the machine learning technique is two sets of images, which may be stereoscopic pairs of images or monoscopic images [i.e. training a first machine learning algorithm using the training data], para 0057, In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local image descriptors in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076) to perform an adjustment of a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. perform an adjustment of a digital representation of a head region], para 0005);
using the trained first machine learning algorithm to generate first reference data (To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning, para 0006, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The training input to the machine learning technique is two sets of images, which may be stereoscopic pairs of images or monoscopic images [i.e. using the trained first machine learning algorithm to generate first reference data], para 0057, In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local image descriptors in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076), the first reference data comprising an adjusted digital representation of the head region for each of at least a subset of the input digital representations (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the first reference data comprising an adjusted digital representation of the head region for each of at least a subset of the input digital representations], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056), each adjusted digital representation being obtained by performed the adjustment that the first machine learning algorithm was trained to perform (A displacement vector field representing a transformation of an image patch is derived, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector produced by machine learning. The multi-view images are adjusted by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field, abstract, each image 31 of the stereoscopic pair is adjusted by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector fields 37. This produces an adjusted stereoscopic pair of images 38, in which the gaze has been corrected [i.e. each adjusted digital representation being obtained by performed the adjustment that the first machine learning algorithm was trained to perform], para 0116); and
training a second machine learning algorithm (In a second type of machine learning technique, the feature vector may comprise features that are discrete values of the local image descriptors in a continuous space. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with possible discrete values of the feature vector in the continuous space. This allows a displacement vector field F to be derived from the reference data 35 by interpolation from the reference displacement vector fields based on the relationship between the feature vector 34 derived and the values of the feature vector

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associated with the reference displacement vector fields [i.e. training a second machine learning algorithm) to perform the same adjustment of a digital representation of a head region as the first machine learning algorithm (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. perform the same adjustment of a digital representation of a head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056).
RealD does not specifically disclose the second machine learning algorithm using at least a subset of the training data used to train the first machine learning algorithm and the first reference data.
However, Magic discloses the second machine learning algorithm using at least a subset of the training data used to train the first machine learning algorithm and the first reference data (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, pg 12 ln 13-17, Training hierarchical algorithms can allow enhancement and/or reconstruction models to be developed for enhancing visual data in at least one embodiment, visual data can be image data and/or video data, 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, 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 [i.e. the second machine learning algorithm using at least a subset of the training data used to train the first machine learning algorithm and the first reference data], pg 12 ln 18-27). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Magic for the purpose of allowing 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 (Magic pg 12 ln 18-27).

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Regarding Claim 30, RealD fails to explicitly disclose further comprising receiving a further digital representation of the head region and using the updated or trained second machining learning algorithm to adjust the further digital representation.

However, RealD teaches a pre-trained second machine learning algorithm trained to generate second reference data (In a second type of machine learning technique, the feature vector may comprise features that are discrete values of the local image descriptors in a continuous space. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with possible discrete values of the feature vector in the continuous space. This allows a displacement vector field F to be derived from the reference data 35 by interpolation from the reference displacement vector fields based on the relationship between the feature vector 34 derived and the values of the feature vector associated with the reference displacement vector fields [i.e. updating a pre-trained second machine learning algorithm trained to generate second reference data], para 0083) and adjust the digital representation of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the second reference data comprising editing instructions for adjusting the digital representation of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056).

Further, Magic teaches updated algorithm (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, pg 12 ln 13-17, Training hierarchical algorithms can allow enhancement and/or reconstruction models to be developed for enhancing visual data in at least one embodiment, visual data can be image data and/or video data, 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, 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 [i.e. the input for the updating comprises the training data and the generated first reference data], pg 12 ln 18-27).
Furthermore, defining an analysis and training of a learning algorithm to update the representation as taught by RealD and Magic and the specifics [update the second algorithm for head representation] would involve routine skill in the art.

It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Magic for the purpose of allowing 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 (Magic pg 12 ln 18-27).

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Regarding claim 33, RealD discloses a device for generating reference data (The reference data 35 is obtained and analyzed in advance [i.e. generating reference data] using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056) for adjusting a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. adjusting a digital representation of a head region], para 0005), the device comprising a data processing unit (an image processor 30, para 0036) arranged to:
receive training data (The capture device 10 includes a display 11 and a camera system 12 comprises two cameras 13 used to capture the stereoscopic pair of images of the head of a source observer 14, para 0030, The training input to the machine learning technique is two sets of images [i.e. receiving training data], which may be stereoscopic pairs of images or monoscopic images, para 0057) comprising:
a set of input patches (in each image of the multi-view images, identifying image patches [i.e. a set of input patches] containing the left and right eyes of the head, respectively, para 0005), each input patch comprising information about a target feature of a digital representation of the head region prior to adjustment of the digital representation of the head region (in each image of the multi-view images, identifying image patches containing the left and right eyes of the head, respectively; in respect of the image patches containing the left eyes of the head in each image of the multi-view images, and also in respect of the image patches containing the right eyes of the head in each image of the multi-view images [i.e. input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region], para 0005, the image patches input and output images of each individual are aligned in the normalized coordinate system, para 0062), wherein the target feature is the same for each input patch (image patches containing the left and right eyes of the head, respectively are identified in each image 31 of the stereoscopic pair. FIG. 4 shows the identified image patches 32 of the right eye in each image 31 [i.e. the target feature is the same for each input patch], para 0049, image patches 32 containing the left and right eyes of the head are identified in each image 31 of the stereoscopic pair. This is done by identifying an image patch 39 in each image 31 located around the identified points ("landmarks") corresponding to features of an eye, para 0051); and
a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target portion of the digital representation of the head region after adjustment of the digital representation of the head region (adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field, para 0005, image patches containing the left and right eyes of the head are identified and transformed, para 0006, the image patches input and output images of each individual are aligned in the normalized coordinate system [i.e. a set of output patches in one-to-one correspondence with the input patches], para 0062, From an input and output image of each individual, there is derived a displacement vector field that represents the transformation of the image patch in the input image required to obtain the image patch of the output image [i.e. each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region], para 0063, The displacement vector field F is chosen so that the image patch of the output image O(x,y) is derived from the image patch of the input image I(x,y) [i.e. a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region], para 0064);
use a first machine learning algorithm to generate first reference data using the training data (To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning, para 0006, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056, The training input to the machine learning technique is two sets of images, which may be stereoscopic pairs of images or monoscopic images [i.e. using a first machine learning algorithm to generate first reference data using the training data], para 0057, In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local image descriptors in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076); and
use a second machine learning algorithm to generate second reference data (In a second type of machine learning technique, the feature vector may comprise features that are discrete values of the local image descriptors in a continuous space. In this case, the machine learning technique associates a reference displacement vector field F derived from the training input with possible discrete values of the feature vector in the continuous space. This allows a displacement vector field F to be derived from the reference data 35 by interpolation from the reference displacement vector fields based on the relationship between the feature vector 34 derived and the values of the feature vector associated with the reference displacement vector fields [i.e. using a second machine learning algorithm to generate second reference data).
RealD does not specifically disclose the second machine learning algorithm using the same training data as the first machine learning algorithm and the first reference data output by the first machine learning algorithm.
However, Magic discloses the second machine learning algorithm using the same training data as the first machine learning algorithm and the first reference data output by the first machine learning algorithm (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, pg 12 ln 13-17, Training hierarchical algorithms can allow enhancement and/or reconstruction models to be developed for enhancing visual data in at least one embodiment, visual data can be image data and/or video data, 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, 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 [i.e. the second machine learning algorithm using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm], pg 12 ln 18-27). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Magic for the purpose of allowing the hierarchical algorithm to be trained (and/or developed) based on knowledge of both

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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 (Magic pg 12 ln 18-27).

Regarding claim 36, RealD further discloses further comprising a telecommunications interface arranged to transmit the adjusted digital representation over a telecommunications network to a destination device to allow display of the head region thereon (The image processor 30 may be provided in the source device 10, the destination device 10 or in any other device, for example a server on a telecommunications network, which may be suitable in the case that the source device 10 and the destination device 10 communicate over such a telecommunications network, para 0037, the source device 10 and the destination device 10 communicate over such a telecommunications network 50, para 0141, the image processor 30 is provided in the source device 10 and is provided with the stereoscopic pair of images directly from the camera system 12. The telecommunications interface 17 is arranged to transmit the adjusted stereoscopic pair of images 38 over the telecommunications network 50 to the destination device 20 for display thereon, para 0142).

Claim 5 lacks an inventive step under PCT Article 33(3) as being obvious over RealD Spark, LLC (hereinafter RealD) in view of Magic Pony Technology Limited et al. (hereinafter Magic) and Nourbakhsh.

Regarding claim 5, modified RealD discloses the invention above, but RealD did not disclose that the editing instructions comprise a filter field, a brightness adjustment field, or a texture blending field. However, Nourbakhsh is in the field of video calls and meetings (para 0001) and discloses that the editing instructions comprise a filter field (analyzes video frames for the orientations of B's head and gaze direction, and uses image editing software to virtually correct the gaze direction of B's eye upward, toward B's camera, para 0002, The logic calculates 670 the angular correction for the eyes. The logic may then determine 680 filter parameters that set bounds on when eye gaze direction correction will be applied at all, para 0046), a brightness adjustment field, or a texture blending field. It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Nourbakhsh for the purpose of automatically adjusting eye gaze direction in a set of images to simulate eye-contact (Nourbakhsh para 0001).

Claims 20, 21, and 35 lack an inventive step under PCT Article 33(3) as being obvious over RealD Spark, LLC (hereinafter RealD) in view of Rhodes.

Regarding claim 20, RealD discloses a method of adjusting a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. adjusting a digital representation of a head region], para 0005), the method comprising:
identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region (identifying image patches containing the left and right eyes of the head, respectively; in respect of the image patches containing the left eyes of the head in each image of the multi-view images, and also in respect of the image patches containing the right eyes of the head in each image of the multi-view images [i.e. identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region], para 0005);
deriving a feature vector from plural local descriptors of the target patch (deriving a feature vector from plural local image descriptors of the image patch [i.e. deriving a feature vector from plural local descriptors of the target patch] in at least one image of the multi-view images, para 0005);
using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector, para 0005, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived [i.e. using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector], para 0076); and
applying the selected editing instructions to the target patch to adjust the digital representation of the head region (adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. applying the selected editing instructions to the target patch to adjust the digital representation of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed, para 0006, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076).
RealD does not specifically disclose that the editing instructions in the reference data are provided in a compressed representation. However, Rhodes is in the field of transmitting, receiving, and displaying data (abstract) and discloses that the editing instructions in the reference data are provided in a compressed representation (After computing the discrete wavelet transform (DWT), the data can be compressed according to any type of compression technique, such as, a variable thresholding mechanism governed by the embedded zerotree wavelet (EZW) in which coefficients that are larger than a threshold may be selected for transmission, para 0050, The additional data subsequently transmitted can be data compressed using a lower amount of compression, if prioritization instructions (e.g., information indicative of a gaze direction) are provided to the transmitter, the transmitter may encode data representing information about the gaze direction in better quality and less distortion than data representing other areas [i.e. the editing instructions in the reference data are provided in a compressed representation], para 0052). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Rhodes for the purpose of lowering bandwidth (Rhodes abstract).

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Regarding claim 21, modified RealD discloses the invention above, but RealD did not disclose that the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centres. However, Rhodes discloses that the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation (Any type of encoding or compression techniques may be used, such as for example, a wavelet based technique (e.g., such as discrete wavelet transform (DWT) or embedded zerotree wavelet (EZW)), para 0050); Fourier and/or discrete cosine transform components; cluster centres. It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Rhodes for the purpose of lowering bandwidth (Rhodes abstract).

Regarding claim 35, RealD discloses a device for adjusting a digital representation of a head region (adjusting the stereoscopic pair of images, or more generally multi-view images, of a head to correct the perceived gaze, para 0004, adjusting multi-view images of a head to correct gaze [i.e. adjusting a digital representation of a head region], para 0005), the device comprising a data processing unit arranged to process the digital representation of the head region (an image processor 30, para 0036, the image processor 30 is provided in the source device 10 and is provided with the stereoscopic pair of images directly from the camera system 12. The telecommunications interface 17 is arranged to transmit the adjusted stereoscopic pair of images 38 over the telecommunications network 50 to the destination device 20 for display thereon [i.e. a data processing unit arranged to process the digital representation of the head region], para 0142) by:
identifying a target patch in the digital representation of the head region, the target patch comprising information about a target feature of the digital representation of the head region (identifying image patches containing the left and right eyes of the head, respectively; in respect of the image patches containing the left eyes of the head in each image of the multi-view images, and also in respect of the image patches containing the right eyes of the head in each image of the multi-view images [i.e. identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region], para 0005);
deriving a feature vector from plural local descriptors of the target patch (deriving a feature vector from plural local image descriptors of the image patch [i.e. deriving a feature vector from plural local descriptors of the target patch] in at least one image of the multi-view images, para 0005);
using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector, para 0005, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived [i.e. using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector], para 0076); and
applying the selected editing instructions to the target patch to adjust the digital representation of the head region (adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. applying the selected editing instructions to the target patch to adjust the digital representation of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed, para 0006, the machine learning technique associates a reference displacement vector field F derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 is essentially a look-up table. This allows a reference displacement vector field F to be simply selected from the reference data 35 on the basis of the feature vector 34 derived, para 0076).
RealD does not specifically disclose that the editing instructions in the reference data are provided in a compressed representation. However, Rhodes discloses that the editing instructions in the reference data are provided in a compressed representation (After computing the discrete wavelet transform (DWT), the data can be compressed according to any type of compression technique, such as, a variable thresholding mechanism governed by the embedded zerotree wavelet (EZW) in which coefficients that are larger than a threshold may be selected for transmission, para 0050, The additional data subsequently transmitted can be data compressed using a lower amount of compression, if prioritization instructions (e.g., information indicative of a gaze direction) are provided to the transmitter, the transmitter may encode data representing information about the gaze direction in better quality and less distortion than data representing other areas [i.e. the editing instructions in the reference data are provided in a compressed representation], para 0052). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Rhodes for the purpose of lowering bandwidth (Rhodes abstract).

Claims 28 and 29 lack an inventive step under PCT Article 33(3) as being obvious over RealD Spark, LLC (hereinafter RealD) in view of Magic Pony Technology Limited et al. (hereinafter Magic) and Kaye et al. (hereinafter Kaye).

Regarding claim 28, modified RealD discloses the invention above, but RealD did not disclose that the adjustment of the digital representation comprises converting from a two-dimensional digital representation to a three-dimensional digital representation. However, Kaye is in the field of reconstructing a hidden surface area in an image (abstract) and discloses that the adjustment of the digital representation comprises converting from a two-dimensional digital representation to a three-dimensional digital representation (converting two-dimensional images into three-dimensional images, para 0037). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Kaye for the purpose of converting two-dimensional (2D) motion picture images into three-dimensional (3D) motion picture images and to be able reduce or eliminate image artifacts that occur in the process of applying depth to objects during the conversion of 2D images into 3D images (Kaye para 0002, 0008).

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Regarding claim 29, modified RealD discloses the invention above, but RealD did not disclose that the training of the first machine learning algorithm comprises iteratively using a rendering process to generate a two-dimensional digital representation from a three-dimensional digital representation generated by the first machine learning algorithm and comparing the generated digital representation with a corresponding digital representation in the training data. However, Kaye discloses that the training of the first machine learning algorithm comprises iteratively using a rendering process to generate a two-dimensional digital representation from a three-dimensional digital representation generated by the first machine learning algorithm and comparing the generated digital representation with a corresponding digital representation in the training data (An image region comparison technique is used to determine if an image region in an alternate frame contains missing image information hidden in the original frame, an image region is represented as a 2-dimensional topological set. Basic point-set topological operations then facilitate the pertinent region comparisons in the reconstruction process, para 0045, a region of image discrepancy caused by the shift of the object is determined quantitatively. This region is compared with the object's original region of definition in alternate frames to determine if any portion of the area of discrepancy is uncovered in those frames, para 0046, comparing image regions to determine if an image region in an alternate image contains information missing from the image due to the separation pixel gap. In one embodiment, the step of comparing image regions further includes the steps of: representing the image regions as a two-dimensional topological sets; and employing point-set topological operations for pertinent image region comparisons, para 0051). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Kaye for the purpose of determining if an image region in an alternate frame contains missing image information hidden in the original frame (Kaye para 0045).

Claim 34 lacks an inventive step under PCT Article 33(3) as being obvious over RealD Spark, LLC (hereinafter RealD) in view of Magic Pony Technology Limited et al. (hereinafter Magic) and Rhodes.

Regarding claim 34, modified RealD discloses the invention above, and RealD further discloses that the first reference data comprises editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the first reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056); and the second reference data comprises editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region (deriving a displacement vector field representing a transformation of an image patch, using the derived feature vector to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector; and adjusting each image of the multi-view images by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector field [i.e. the second reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region], para 0005, image patches containing the left and right eyes of the head are identified and transformed. To derive a displacement vector field that represents the transformation, a feature vector is derived from plural local image descriptors of the image patch in at least one image of the multi-view images and used to look up reference data comprising reference displacement vector fields associated with possible values of the feature vector. The form of the feature vector may be derived in advance from the reference data using machine learning. This method allows the gaze to be corrected, thereby reducing the disconcerting effect of incorrect gaze when the multi-view images are subsequently displayed, para 0006, The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 comprising reference displacement vector fields that represent transformations of the image patch and are associated with possible values of the feature vector, para 0055, The reference data 35 is obtained and analyzed in advance using a machine learning technique which derives the form of the feature vectors 34 and associates the reference displacement vector fields with the possible values of the feature vector, para 0056), but RealD did not disclose that the second editing instructions in the second reference data are provided in a compressed representation. However, Rhodes discloses that the second editing instructions in the second reference data are provided in a compressed representation (After computing the discrete wavelet transform (DWT), the data can be compressed according to any type of compression technique, such as, a variable thresholding mechanism governed by the embedded zerotree wavelet (EZW) in which coefficients that are larger than a threshold may be selected for transmission, para 0050, The additional data subsequently transmitted can be data compressed using a lower amount of compression, if prioritization instructions (e.g., information indicative of a gaze direction) are provided to the transmitter, the transmitter may encode data representing information about the gaze direction in better quality and less distortion than data representing other areas [i.e. the editing instructions in the reference data are provided in a compressed representation], para 0052). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify RealD with the teachings of Rhodes for the purpose of lowering bandwidth (Rhodes abstract).

Claims 1-5, 20, 21, 25-30, and 33-36 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

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Search History:

Limited Classification Search

The Patent Analyst performed a limited classification search within the following US, IPC, CPC, ECLA, or F-Term classification areas:

CPC Class/Subclass(es): G06F 3/011; G06F 3/013; G06T 5/005; G06T 5/008; G06T 7/11 (2018.08)

IPC (8) Class/Subclass(es): G06F 3/01; G06K 9/00; H04N 5/228; H04N 7/14; H04N 13/00 (2018.01)

U.S. Class/Subclass(es): 348/222.1; 382/167

See Global Search Results.

Global Patent Literature Text Search

The Patent Analyst performed the following global text search, which was not limited by classification but may or may not have been limited by other criteria:

Questel Orbit: https://www.orbit.com

#	Search query	Results
1	(("REALD SPARK")/NPAN) AND PD <= 2017-08-08	42
2	(ADJUST+ AND DIGITAL+ AND REPRESENT+ AND HEAD+ AND (REGION+ OR AREA+ OR SECTION+))/TI/AB/IW/OBJ/ADB/ICLM/TX AND PD <= 2017-08-08	453783
3	(ADJUST+ AND DIGITAL+ AND REPRESENT+ AND HEAD+ AND (REGION+ OR AREA+ OR SECTION+) AND (GENERAT+ OR CREAT+))/TI/AB/IW/OBJ/ADB/ICLM/TX AND PD <= 2017-08-08	433210
4	3 AND REFERENCE+	88283
5	4 AND DATA+	49334
6	5 AND RECEIV+	31118
7	6 AND TRAIN+	2401
8	7 AND INPUT+	1405
9	8 AND PATCH+	11
10	8 AND TARGET+	300
11	8 AND (FEATURE+ OR CHARACTERISTIC+)	748
12	8 AND OUTPUT+	1109
13	8 AND (MACHINE+ W LEARN+)	24
14	8 AND RANGE+	526
15	8 AND POSSIBLE+	740

16	(382167)/PCLM AND PD <= 2017-08-08	1391
17	(348222100)/PCLM AND PD <= 2017-08-08	2178
18	(3480E5024)/PCLM AND PD <= 2017-08-08	0
19	(G06F-003/01)/IPC AND PD <= 2017-08-08	46242
20	(G06K-009/00)/IPC AND PD <= 2017-08-08	109444
21	(H04N-005/228)/IPC AND PD <= 2017-08-08	9199
22	(H04N-007/14)/IPC AND PD <= 2017-08-08	18982
23	(H04N-013/00)/IPC AND PD <= 2017-08-08	20850
24	(H04N-013/04)/IPC AND PD <= 2017-08-08	16986
25	(G06F-003/011)/CPC AND PD <= 2017-08-08	8486
26	(G06F-003/013)/CPC AND PD <= 2017-08-08	4221
27	(G06T-005/005)/CPC AND PD <= 2017-08-08	1121
28	(G06T-005/008)/CPC AND PD <= 2017-08-08	1203
29	(G06T-007/11)/CPC AND PD <= 2017-08-08	4752
30	(G06T-007/136)/CPC AND PD <= 2017-08-08	1049
31	(G06T-007/90)/CPC AND PD <= 2017-08-08	2126
32	(G06T-2207/10024)/CPC AND PD <= 2017-08-08	5033
33	(G06T-2207/30216)/CPC AND PD <= 2017-08-08	172
34	(H04N-001/624)/CPC AND PD <= 2017-08-08	156
35	(H04N-005/2256)/CPC AND PD <= 2017-08-08	3948
36	(H04N-005/23206)/CPC AND PD <= 2017-08-08	2195
37	(H04N-005/23219)/CPC AND PD <= 2017-08-08	2680
38	(H04N-007/144)/CPC AND PD <= 2017-08-08	476
39	(H04N-013/117)/CPC AND PD <= 2017-08-08	342
40	(H04N-013/122)/CPC AND PD <= 2017-08-08	915
41	(H04N-013/128)/CPC AND PD <= 2017-08-08	2053
42	(H04N-013/194)/CPC AND PD <= 2017-08-08	1580
43	(H04N-013/344)/CPC AND PD <= 2017-08-08	1160

Google Patents: https://patents.google.com

#	Search query	Results
1	adjust digital representation of head region	543,000
2	"REALD SPARK"	157

3	inassignee:"REALD SPARK" adjust digital representation of head region	10
4	generate reference data for adjusting digital representation of head region	445,000
5	generate reference data for adjusting digital representation of head region receive training data	116,000
6	generate reference data for adjusting digital representation of head region receive training data input patches	47,500
7	generate reference data for adjusting digital representation of head region receive training data input patches comprising target feature prior to adjustment	33,500
8	generate reference data for adjusting digital representation of head region receive training data input patches comprising target feature prior to adjustment output patches comprising target feature after adjustment	22,000
9	adjust digital representation of head region machine learning algorithm generate reference data using training data	32,700
10	adjust digital representation of head region machine learning algorithm generate reference data using training data adjust range of possible digital representations	13,900
11	adjust digital representation of head region editing instructions comprise filter field	45,600
12	gaze correction editing instructions comprise filter field	5,740
13	gaze correction editing instructions in reference data provided in compressed representation	4,400
14	gaze correction compress editing instructions reduce data storage bandwidth	4,200
15	compress image editing instructions	118,000
16	compressed instructions for editing image	122,000
17	send compressed instructions to edit image	46,100
18	send compressed instructions to correct gaze	7,830
19	second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm	133,000
20	image correction second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm	80,800
21	image correction second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm update near input data frame rate	67,000
22	second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm update near input data frame rate	96,100
23	update machine learning algorithm near input data frame rate	275,000
24	update machine learning algorithm near input data "frame rate"	16,800
25	convert from two-dimensional digital representation to three-dimensional digital representation machine learning comparing	85,900

	reverse generated two-dimensional digital representation from three-dimensional digital representation	

Computer Accessed Text Databases Searched

The Patent Analyst searched the following computer accessed text databases:

Google: https://www.google.com/

#	Search query	Results
1	adjust digital representation of head region	33,100,000
2	"REALD SPARK"	6,970
3	"REALD SPARK" adjust digital representation of head region	274
4	generate reference data for adjusting digital representation of head region	36,400,000
5	generate reference data for adjusting digital representation of head region receive training data	29,100,000
6	generate reference data for adjusting digital representation of head region receive training data input patches	14,000,000
7	generate reference data for adjusting digital representation of head region receive training data input patches comprising target feature prior to adjustment	6,470,000
8	generate reference data for adjusting digital representation of head region receive training data input patches comprising target feature prior to adjustment output patches comprising target feature after adjustment	2,540,000
9	adjust digital representation of head region machine learning algorithm generate reference data using training data	5,290,000
10	adjust digital representation of head region machine learning algorithm generate reference data using training data adjust range of possible digital representations	915,000
11	adjust digital representation of head region editing instructions comprise filter field	5,690,000
12	gaze correction editing instructions comprise filter field	610,000
13	gaze correction editing instructions in reference data provided in compressed representation	596,000
14	gaze correction compress editing instructions reduce data storage bandwidth	475,000
15	compress image editing instructions	29,300,000
16	compressed instructions for editing image	29,000,000
17	send compressed instructions to edit image	5,230,000
18	send compressed instructions to correct gaze	732,000
19	second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm	32,700,000
20	image correction second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm	18,200,000
21	image correction second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm update near input data frame rate	7,570,000

22	second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm update near input data frame rate	64,100,000
23	update machine learning algorithm near input data frame rate	24,400,000
24	update machine learning algorithm near input data "frame rate"	360,000
25	convert from two-dimensional digital representation to three-dimensional digital representation machine learning comparing reverse generated two-dimensional digital representation from three-dimensional digital representation	13,500,000

Google Scholar: https://scholar.google.com/

#	Search query	Results
1	adjust digital representation of head region	96,500
2	"REALD SPARK"	0
3	"REALD SPARK" adjust digital representation of head region	0
4	generate reference data for adjusting digital representation of head region	45,800
5	generate reference data for adjusting digital representation of head region receive training data	27,300
6	generate reference data for adjusting digital representation of head region receive training data input patches	19,500
7	generate reference data for adjusting digital representation of head region receive training data input patches comprising target feature prior to adjustment	17,400
8	generate reference data for adjusting digital representation of head region receive training data input patches comprising target feature prior to adjustment output patches comprising target feature after adjustment	15,500
9	adjust digital representation of head region machine learning algorithm generate reference data using training data	28,200
10	adjust digital representation of head region machine learning algorithm generate reference data using training data adjust range of possible digital representations	19,400
11	adjust digital representation of head region editing instructions comprise filter field	18,400
12	gaze correction editing instructions comprise filter field	17,400
13	gaze correction editing instructions in reference data provided in compressed representation	15,000
14	gaze correction compress editing instructions reduce data storage bandwidth	2,970
15	compress image editing instructions	27,500
16	compressed instructions for editing image	39,400
17	send compressed instructions to edit image	23,500
18	send compressed instructions to correct gaze	19,400
19	second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm	620,000
20	image correction second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm	56,700

21	image correction second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm update near input data frame rate	23,300
22	second machine learning algorithm use same training data as first machine learning algorithm and reference data generated by first machine learning algorithm update near input data frame rate	38,500
23	update machine learning algorithm near input data frame rate	61,800
24	update machine learning algorithm near input data "frame rate"	18,600
25	convert from two-dimensional digital representation to three-dimensional digital representation machine learning comparing reverse generated two-dimensional digital representation from three-dimensional digital representation	19,000

Date search was completed: 01 October 2018

EH/MP

Electronic Acknowledgement Receipt

EFS ID:	35372198
Application Number:	16057566
International Application Number:	
Confirmation Number:	5211
Title of Invention:	Adjusting a digital representation of a head region
First Named Inventor/Applicant Name:	Eric Sommerlade
Customer Number:	145234
Filer:	Brian Edward Harris/Kristal Veliz
Filer Authorized By:	Brian Edward Harris
Attorney Docket Number:	409001
Receipt Date:	08-MAR-2019
Filing Date:	07-AUG-2018
Time Stamp:	18:49:52
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	Dalal__2005__histograms.pdf	456138 1d5bb54035efbb85c2af35fdbbb7147239da449e	no	8

Warnings:

Microsoft Exhibit 1002 - Page 2264
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

Information:					
2	Non Patent Literature	drucker__1996__support_vector_regression_machines_reprint.pdf	3017502 58242783047e866e4498f55ce9c8ba44c913d183	no	7
Warnings:					
Information:					
3	Non Patent Literature	ho__1995__random_odt.pdf	167865 11cc86fdd7674014a2b9411f03222213a6e5b94c	no	5
Warnings:					
Information:					
4	Non Patent Literature	Ian_Sexton_ET_AL_Stereoscopic_and_autostereoscopic_display-systems.pdf	4820982 25054af46971348d078734f34009895e11750747	no	15
Warnings:					
Information:					
5	Non Patent Literature	Kalantar_2004.pdf	817951 92322685c0d619d386f2c2b1bc61f185dc3ed13a	no	9
Warnings:					
Information:					
6	Non Patent Literature	Kononenko__2015__Learning_To_Look_2015_CVPR_paper.pdf	1048549 9c2a18691e28a6112cced694564247f56f5c97f3	no	9
Warnings:					
Information:					
7	Non Patent Literature	Languy_2011.pdf	350933 66ea2b6de7b3b546c8ab9a51519381f38e125561	no	3
Warnings:					
Information:					
8	Non Patent Literature	LIPTON_Stereographics_Developers_Handbook_1997_1-33.pdf	7846158 c52fa3eda884a3a6cba7bd5015e42b7844994197	no	33
Warnings:					
Information:					

9	Non Patent Literature	LIPTON_Stereographics_Developers_Handbook_1997_34-end.pdf	6557793 81b3b078907842922a2a0ad867c0e78617ca53c4	no	33
Warnings:					
Information:					
10	Non Patent Literature	LIPTON_Stereographic_Composition_2009.pdf	2208080 e7f99723e38ba5d91e8121f8095fdd8a52c95607	no	7
Warnings:					
Information:					
11	Non Patent Literature	lowe__2004__distinctive__ijcv.pdf	455074 90ed33f616d5e3c34445b705e3af9270f4d3568f	no	28
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Information:					
12	Non Patent Literature	LUCIO_2012_RGBD_Camera_Effects.pdf	1410596 b6f14bd9efa5f74ffb9d90dc5633430e2e18de5b	no	4
Warnings:					
Information:					
13	Non Patent Literature	Marjanovic_Matthew_Interlace_Interleave_and_Field_Dominance.pdf	97371 e61ef6a98c7def21376284680e4e84a3e615da78	no	3
Warnings:					
Information:					
14	Non Patent Literature	ozuysal__2007__fast__10_1_1_92_6299.pdf	1392039 8747f8a3ceaa0802922631ddb7f503674a3f6ca3	no	8
Warnings:					
Information:					
15	Non Patent Literature	Tabiryan_2010.pdf	1259623 f33ef431a0f8bee75a4ed7d0ca08b9384a816ec3	no	6
Warnings:					
Information:					

16	Non Patent Literature	Travis_Backlight.pdf	2799452 019f96ab53488340656efa302b4d13560066578c	no	25
Warnings:					
Information:					
17	Non Patent Literature	Travis_Collimated.pdf	453768 18b0cf4438e8d4c0799709c69bf87e020206cf57	no	6
Warnings:					
Information:					
18	Non Patent Literature	viola_cvpr_01.pdf	199114 6dde3da12d1a10bd38e56032ed26c2eac50c3063	no	9
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Information:					
19	Non Patent Literature	WILLIAMS_New_Computational_Control_Techniques.pdf	3095433 72bca9dd4c67686f36468272a21e9c0c427856b4	no	10
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Information:					
20	Non Patent Literature	zach__2007__duality39.pdf	851025 0f6bbe9afab5fd61f36de5461e9e6a30ca462c7c	no	10
Warnings:					
Information:					
21	Non Patent Literature	SAHOO_2017_Online_Deep_Learning.pdf	543800 f04a198a8c38853c02bc681c9fac32a460c20e6e	no	9
Warnings:					
Information:					
22	Non Patent Literature	SAFFARI_OnlineRandomForests_2009.pdf	1920508 344139f86951a890e42a858673fa22db439777eb	no	8
Warnings:					
Information:					

23	Non Patent Literature	PCTUS2018-45648-ISR-WO.pdf	1002506 99fa3a2d15b718f5ec3d3e6b5a0ea98cee3cd40a	no	25
Warnings:					
Information:					
			Total Files Size (in bytes):	42772260	

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/057,566	08/07/2018	Eric Sommerlade	409001

CONFIRMATION NO. 5211

145234
RealD Spark, LLC
100 North Crescent Drive
Suite 200
Beverly Hills, CA 90210

PUBLICATION NOTICE

OC000000105913163

Title: Adjusting a digital representation of a head region

Publication No.US-2019-0051057-A1
Publication Date:02/14/2019

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

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Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Microsoft Exhibit 1002 - Page 2269
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/057,566

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	36 minus 20 =	* 16	x 50 =	800	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	6 minus 3 =	* 3	x 230 =	690			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	2275		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/057,566	08/07/2018	2688	2355	409001	36	6

CONFIRMATION NO. 5211

UPDATED FILING RECEIPT

145234
RealD Spark, LLC
100 North Crescent Drive
Suite 200
Beverly Hills, CA 90210

OC000000103514172

Date Mailed: 11/02/2018

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Eric Sommerlade, Oxford, UNITED KINGDOM;
Alexandros Neophytou, Oxford, UNITED KINGDOM;

Applicant(s)

RealD Spark, LLC, Beverly Hills, CA;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 62/542,661 08/08/2017
and claims benefit of 62/543,587 08/10/2017

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 08/24/2018

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

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/057,566**

Projected Publication Date: 02/14/2019

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

Adjusting a digital representation of a head region

Preliminary Class

360

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/057,566	08/07/2018	Eric Sommerlade	409001

CONFIRMATION NO. 5211

145234
RealD Spark, LLC
100 North Crescent Drive
Suite 200
Beverly Hills, CA 90210

INFORMAL NOTICE

OC000000103514173

Date Mailed: 11/02/2018

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  Eric Sommerlade
  Alexandros Neophytou

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/yteferra/

Microsoft Exhibit 1002 - Page 2274
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/057,566

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	36 minus 20 =	* 16	x 50 =	800	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	6 minus 3 =	* 3	x 230 =	690			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	2275		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/057,566	08/07/2018	Eric Sommerlade	409001

CONFIRMATION NO. 5211

145234
RealD Spark, LLC
100 North Crescent Drive
Suite 200
Beverly Hills, CA 90210

FORMALITIES LETTER

OC000000103440581

Date Mailed: 10/30/2018

NOTICE OF INCOMPLETE REPLY (NONPROVISIONAL)

Filing Date Granted

The U.S. Patent and Trademark Office has received your reply on 10/26/2018 to the Notice to File Missing Parts (Notice) mailed 08/27/2018 and it has been entered into the nonprovisional application. The reply, however, does not include the following items required in the Notice. A complete reply must be timely filed to prevent ABANDONMENT of the above-identified application. Replies should be mailed to: Mail Stop Missing Parts, Commissioner for Patents, P.O. Box 1450, Alexandria VA 22313-1450.

Applicant is given **TWO MONTHS** from the date of the Notice to File Missing Parts (Notice) mailed 08/27/2018 within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

Items Required to Avoid Abandonment:

The required items noted below SHOULD be filed along with any items required above. The filing date of this nonprovisional application will be the date of receipt of the items required above.

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
  - The drawings are not in compliance with 37 CFR 1.84 because figures 4# contain figure or view numbers that have incorrect orientation. Reference characters, sheet numbers, and view numbers must be oriented in the same direction as the view. See 37 CFR 1.84(p)(1).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

Microsoft Exhibit 1002 - Page 2276
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

• A properly executed inventor's oath or declaration has not been received for the following inventor(s):
Eric Sommerlade
Alexandros Neophytou

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web, including a copy of this Notice and selecting the document description "Applicant response to Pre-Exam Formalities Notice". https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/yteferra/

Microsoft Exhibit 1002 - Page 2277
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	RealD Spark, LLC		
Title:	Adjusting a digital representation of a head region		
Application No.:	16/057,566	Filed:	August 7, 2018
Examiner:	TBD	Group Art Unit:	2688
Atty. Docket No.:	409001	Conf. No.:	5211

Mail Stop Amendment
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

CERTIFICATE OF FILING ELECTRONICALLY VIA EFS
37 CFR 1.8

I HEREBY CERTIFY THAT I HAVE A REASONABLE BASIS FOR BELIEF THAT THIS CORRESPONDENCE IS BEING SUBMITTED TO THE UNITED STATES PATENT AND TRADEMARK OFFICE VIA EFS (ELECTRONICALLY) ON THE DATE INDICATED BELOW, AND IS ADDRESSED TO:

MAIL STOP AMENDMENT
COMMISSIONER FOR PATENTS
PO BOX 1450
ALEXANDRIA, VA 22313-1450

/Penny L Lowry/_____
Penny L. Lowry, Reg. No. 57186

DATE OF SUBMISSION: OCTOBER 30, 2018
ELECTRONIC FILING (EFS)

RESPONSE TO NOTICE TO FILE MISSING PARTS OF A NON-PROVISIONAL APPLICATION

In response to the Notice to File Missing Parts of Non-provisional Application mailed August 27, 2018, Applicants hereby respectfully submit the following:

1. **Replacement drawing sheets (1/12 thru 12/12; and**
2. **Fees due.**

Microsoft Exhibit 1002 - Page 2278
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

REMARKS

Applicant notes that the replacement drawing sheets contain no new subject matter.

The Examiner is requested to contact the undersigned Attorney of Record if such would expedite the prosecution of the present Application. If the Commissioner determines that any additional fees are due, the Examiner is requested to contact the undersigned Attorney of Record for any such fees, referencing Attorney Docket Number 409001.

Respectfully submitted,

/Penny L Lowry/

Date: October 30, 2018

Penny L. Lowry
Reg. No. 57186

RealD Inc.
5700 Flatiron Parkway
Boulder, CO 80301
Tel: (303) 500-6030

Microsoft Exhibit 1002 - Page 2279
Microsoft Corporation v. RealD Spark, LLC
IPR2023-01046 - U.S. Patent No. 10,740,985

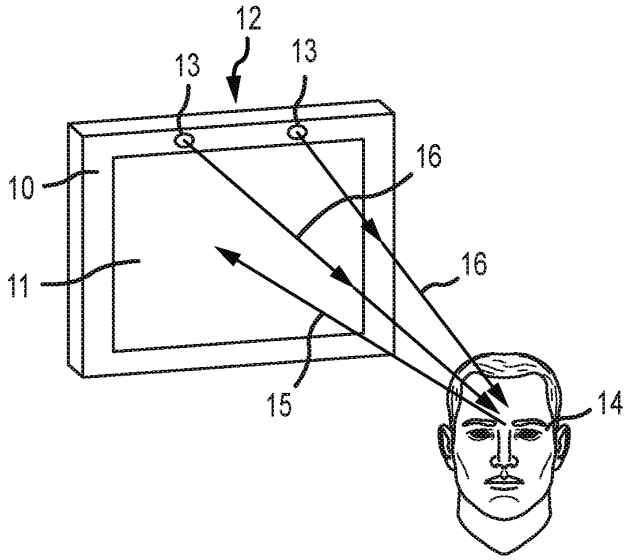


FIG.1

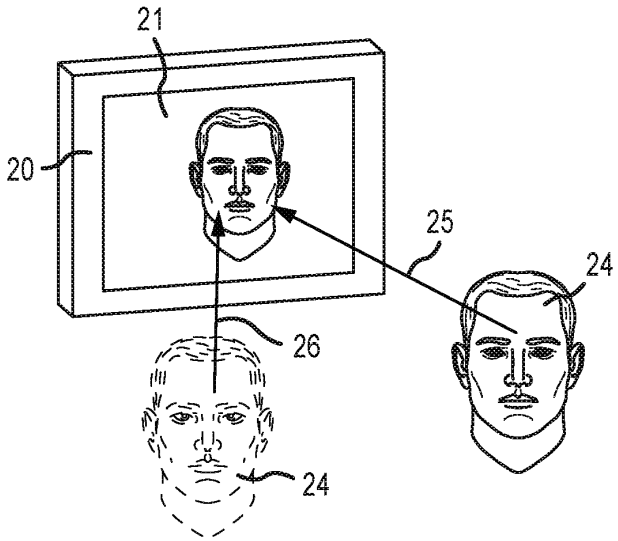


FIG.2

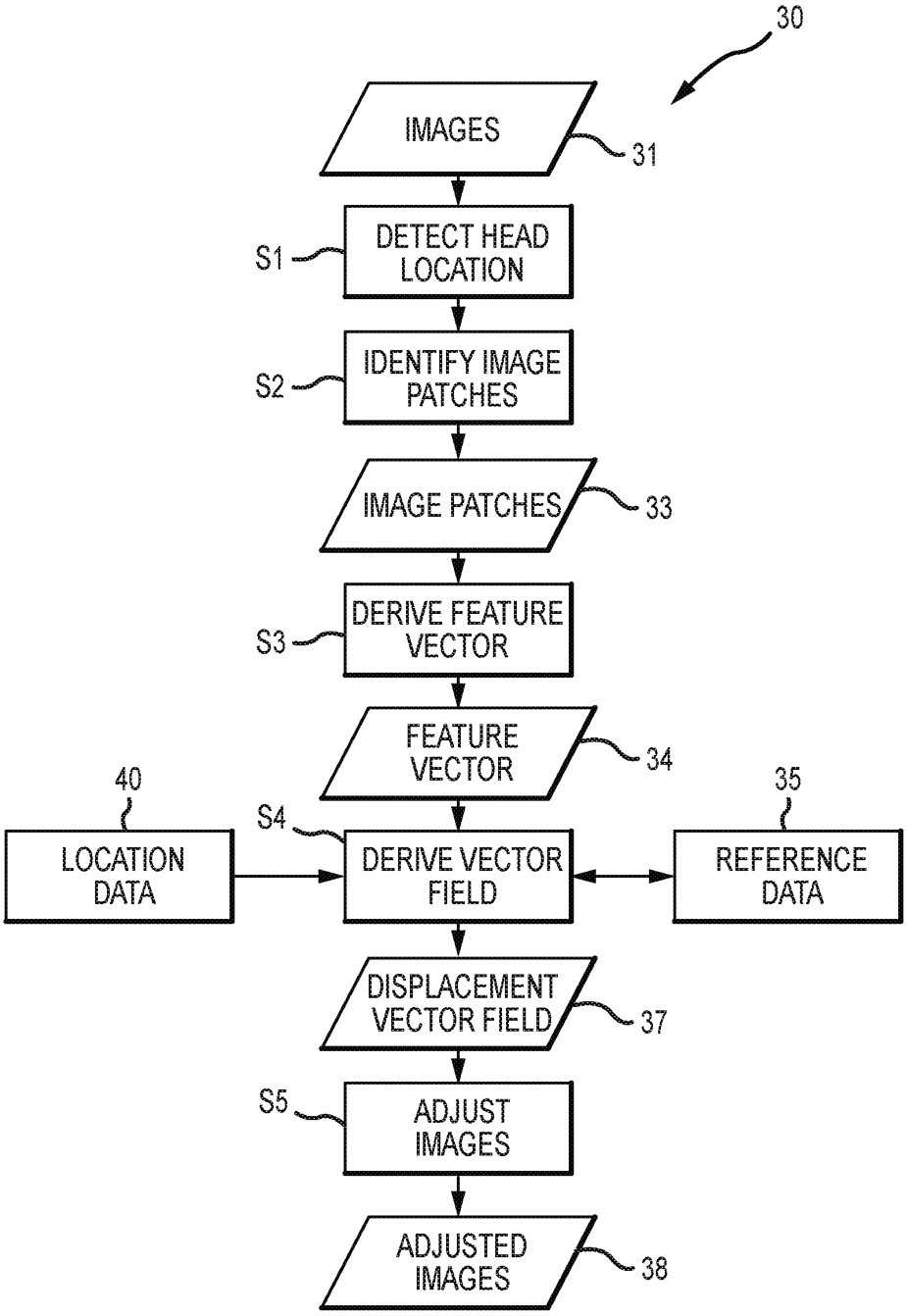

30
IMAGES
31
S1
DETECT HEAD LOCATION
S2
IDENTIFY IMAGE PATCHES
IMAGE PATCHES
33
S3
DERIVE FEATURE VECTOR
FEATURE VECTOR
34
40
LOCATION DATA
S4
DERIVE VECTOR FIELD
35
REFERENCE DATA
DISPLACEMENT VECTOR FIELD
37
S5
ADJUST IMAGES
ADJUSTED IMAGES
38

FIG.3

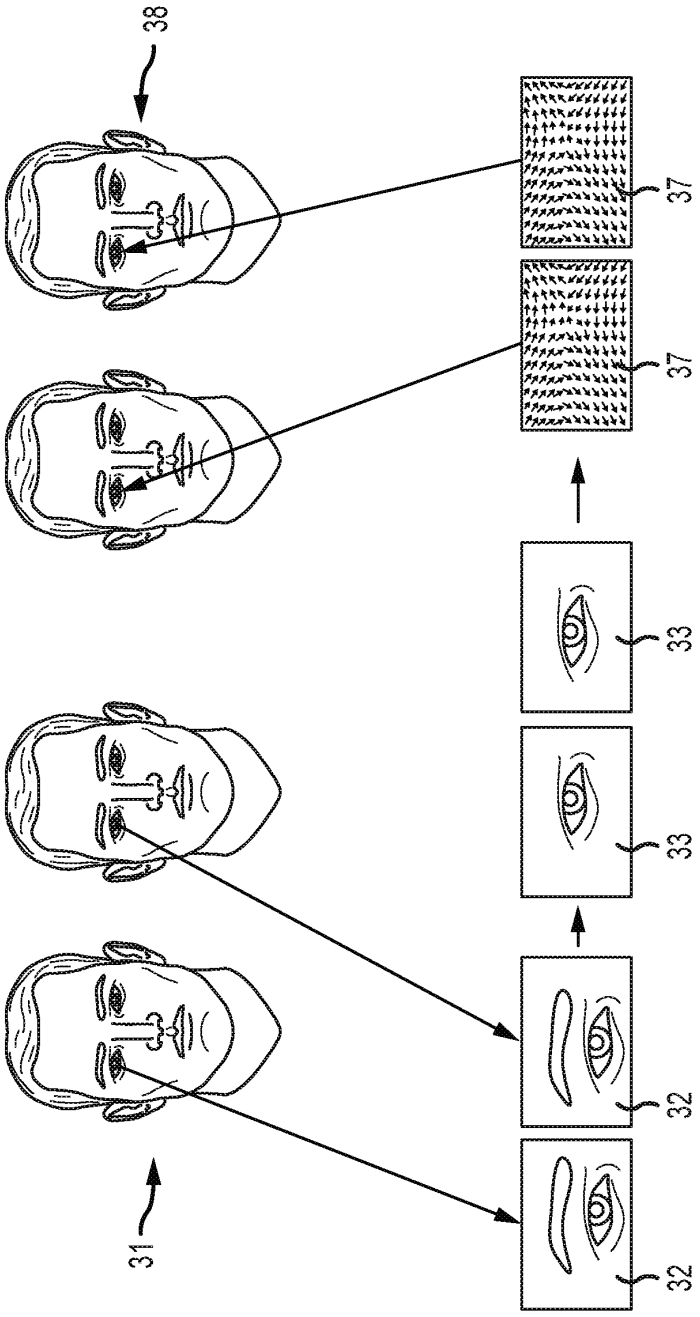


FIG.4

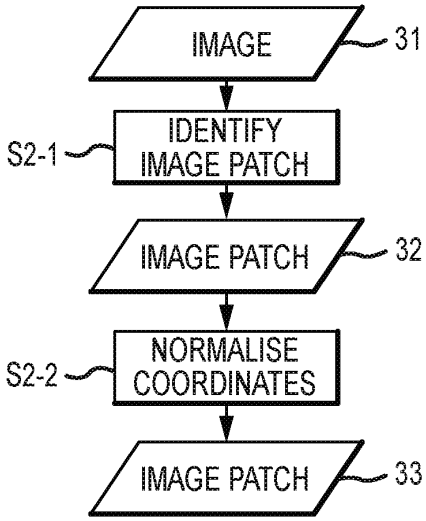

IMAGE
31
S2-1
IDENTIFY IMAGE PATCH
IMAGE PATCH
32
S2-2
NORMALISE COORDINATES
IMAGE PATCH
33

FIG.5

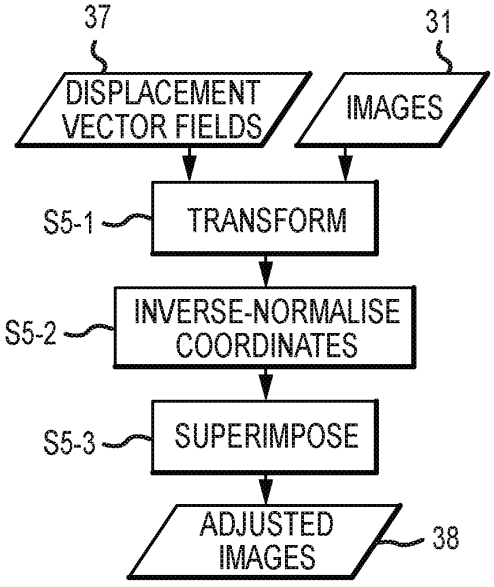

37
31
DISPLACEMENT VECTOR FIELDS
IMAGES
S5-1
TRANSFORM
S5-2
INVERSE-NORMALISE COORDINATES
S5-3
SUPERIMPOSE
ADJUSTED IMAGES
38

FIG.6

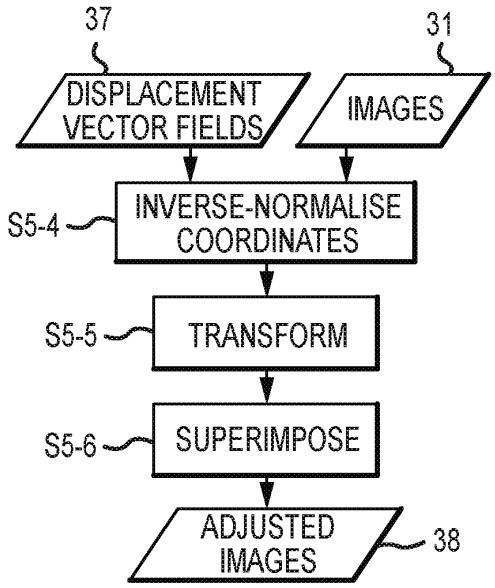

37
31
DISPLACEMENT VECTOR FIELDS
IMAGES
S5-4
INVERSE-NORMALISE COORDINATES
S5-5
TRANSFORM
S5-6
SUPERIMPOSE
ADJUSTED IMAGES
38

FIG.7

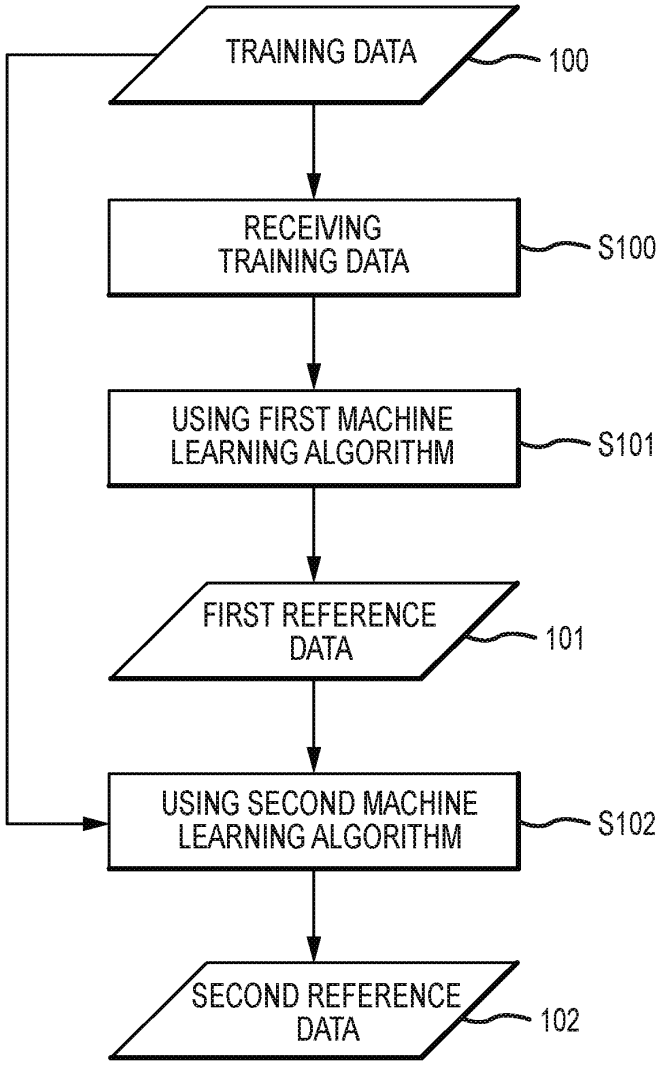

TRAINING DATA
100
RECEIVING TRAINING DATA
S100
USING FIRST MACHINE LEARNING ALGORITHM
S101
FIRST REFERENCE DATA
101
USING SECOND MACHINE LEARNING ALGORITHM
S102
SECOND REFERENCE DATA
102

FIG.8

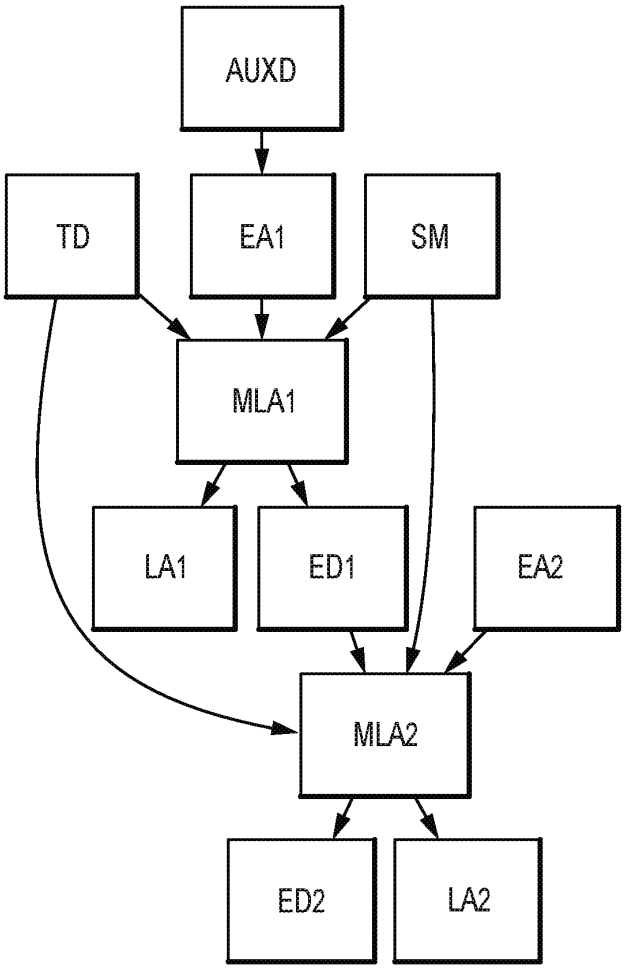


FIG.9

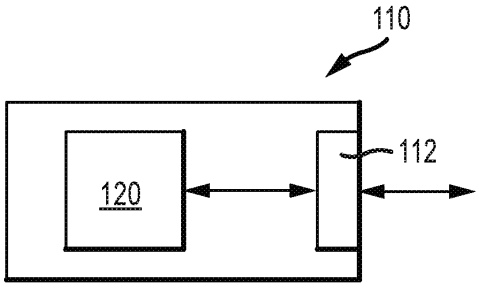

110
120
112

FIG.10

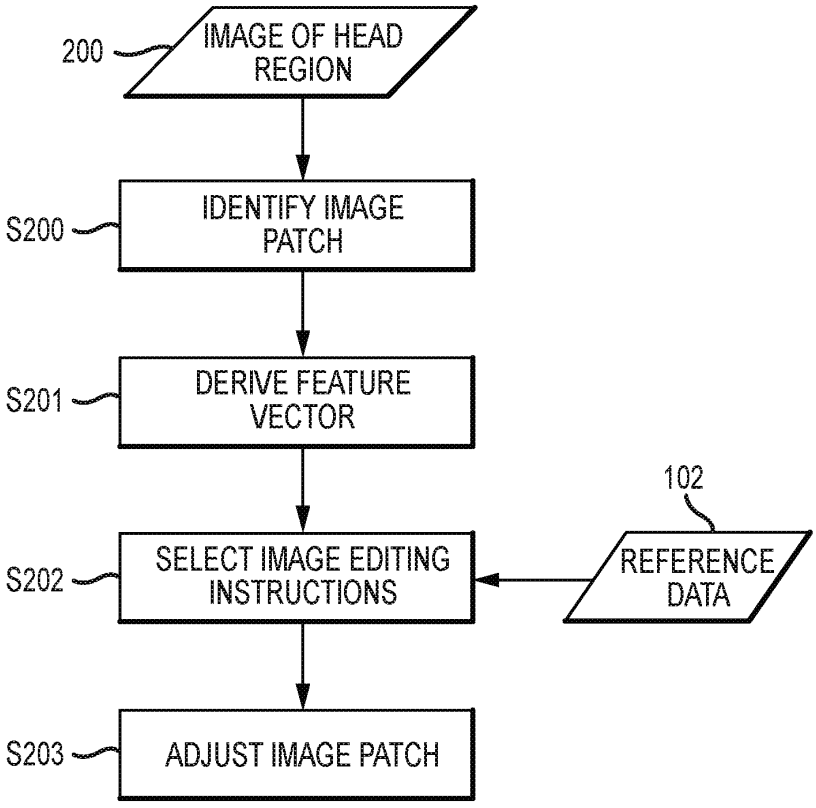

200
IMAGE OF HEAD REGION
S200
IDENTIFY IMAGE PATCH
S201
DERIVE FEATURE VECTOR
102
S202
SELECT IMAGE EDITING INSTRUCTIONS
REFERENCE DATA
S203
ADJUST IMAGE PATCH

FIG.11

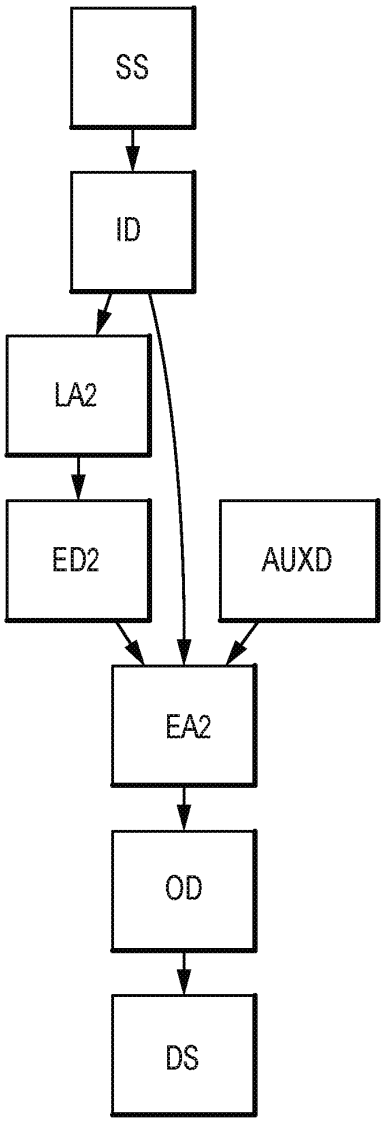


FIG.12

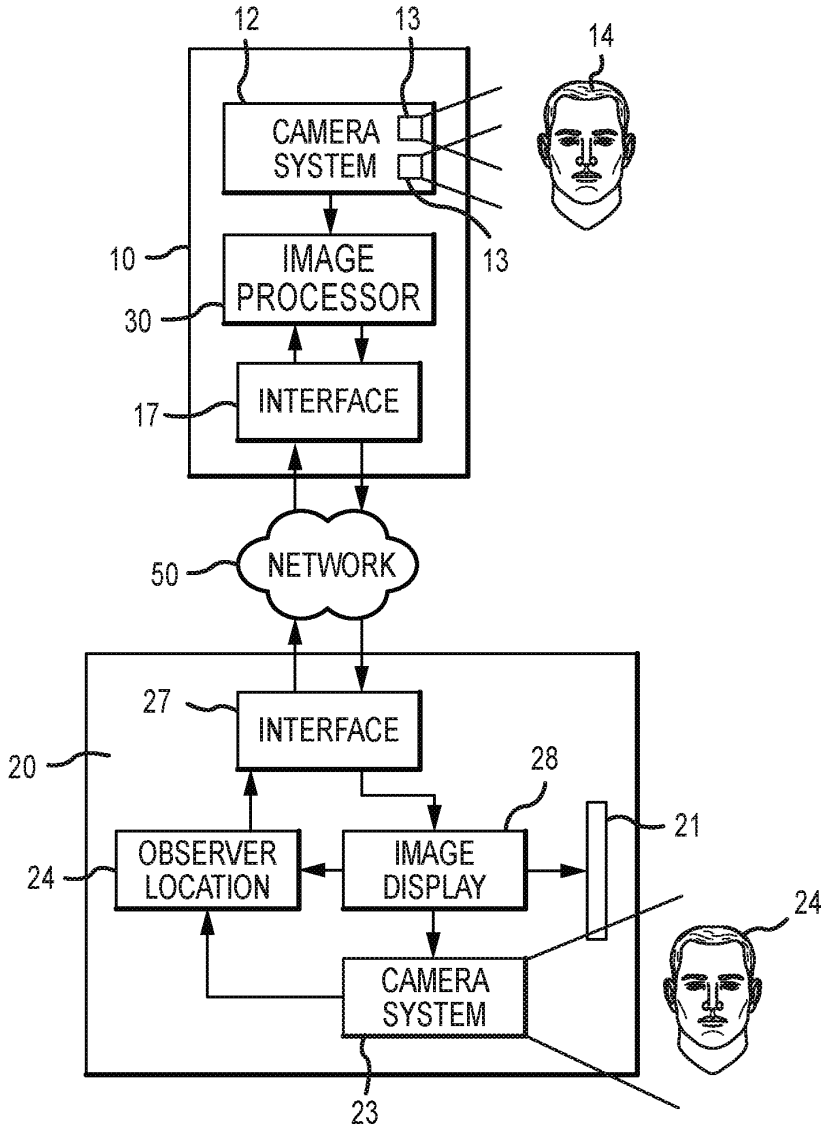

12
13
14
CAMERA SYSTEM
10
IMAGE PROCESSOR
13
30
17
INTERFACE
50
NETWORK
27
INTERFACE
20
28
21
24
OBSERVER LOCATION
IMAGE DISPLAY
24
CAMERA SYSTEM
23

FIG.13

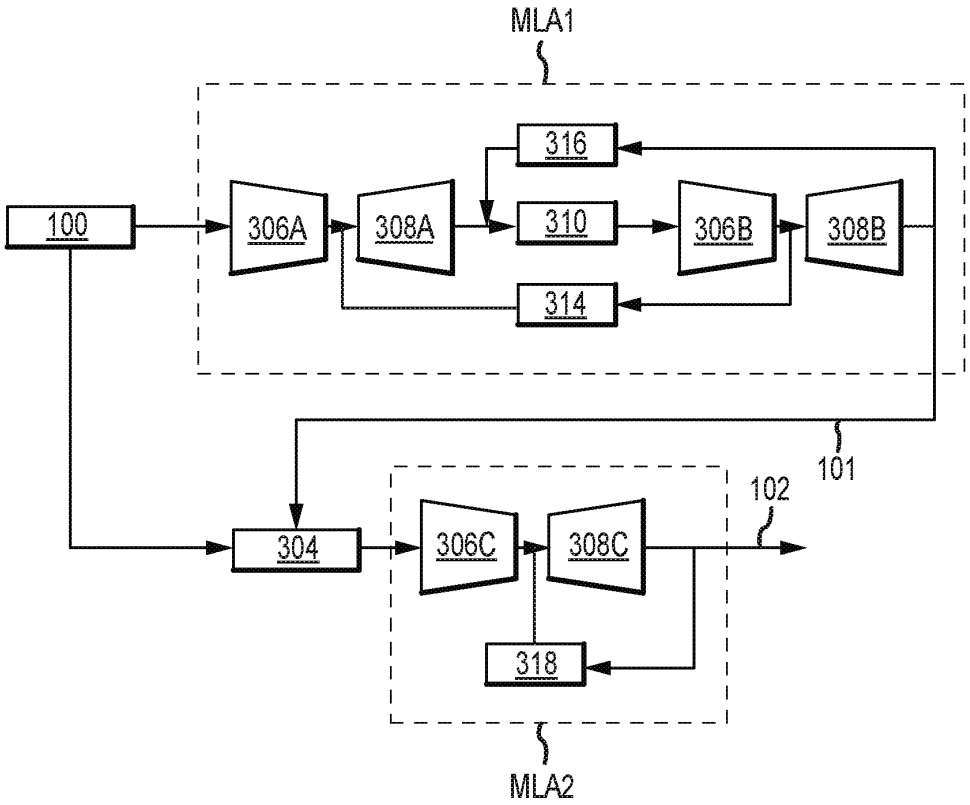

MLA1
316
100
306A
308A
310
306B
308B
314
101
102
304
306C
308C
318
MLA2

FIG.14

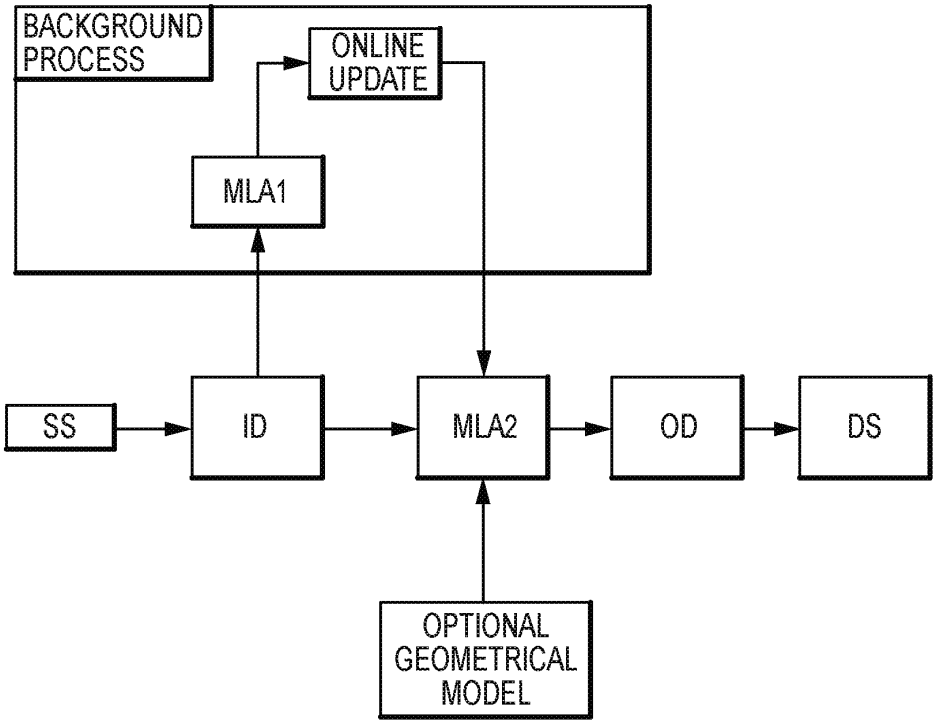

BACKGROUND PROCESS
ONLINE UPDATE
MLA1
SS
ID
MLA2
OD
DS
OPTIONAL GEOMETRICAL MODEL

FIG.15

Electronic Patent Application Fee Transmittal

Application Number:	16057566
Filing Date:	07-Aug-2018
Title of Invention:	Adjusting a digital representation of a head region
First Named Inventor/Applicant Name:	Eric Sommerlade
Filer:	Penny Lea Lowry/Stefan Bump
Attorney Docket Number:	409001

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension - 1 month with $0 paid	2251	1	100	100
Miscellaneous:				
		Total in USD ($)		**100**

Electronic Acknowledgement Receipt	
EFS ID:	34157242
Application Number:	16057566
International Application Number:	
Confirmation Number:	5211
Title of Invention:	Adjusting a digital representation of a head region
First Named Inventor/Applicant Name:	Eric Sommerlade
Customer Number:	145234
Filer:	Penny Lea Lowry/Stefan Bump
Filer Authorized By:	Penny Lea Lowry
Attorney Docket Number:	409001
Receipt Date:	30-OCT-2018
Filing Date:	07-AUG-2018
Time Stamp:	12:42:53
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$100
RAM confirmation Number	103018INTEFSW12445200
Deposit Account	506262
Authorized User	Stefan Bump
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Response to Pre-Exam Formalities Notice	409001_Response_NTFMP.pdf	90003 e4c12ecfce05ac319b9d64e8e2242f98abb70cc9	no	2
Warnings:					
Information:					
2	Drawings-only black and white line drawings	409001_Replacement_sheets.pdf	130765 a4d43741f462c7217cab67f4d8207f5c3905e7d6	no	12
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30025 db4f626f044e3b2836946cf255d856e009ee23e6	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	250793		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	RealD Spark, LLC		
Title:	Adjusting a digital representation of a head region		
Application No.:	16/057,566	Filed:	August 7, 2018
Examiner:	TBD	Group Art Unit:	2688
Atty. Docket No.:	409001	Conf. No.:	5211

Mail Stop Amendment
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

CERTIFICATE OF FILING ELECTRONICALLY VIA EFS
37 CFR 1.8

I HEREBY CERTIFY THAT I HAVE A REASONABLE BASIS FOR BELIEF THAT THIS CORRESPONDENCE IS BEING SUBMITTED TO THE UNITED STATES PATENT AND TRADEMARK OFFICE VIA EFS (ELECTRONICALLY) ON THE DATE INDICATED BELOW, AND IS ADDRESSED TO:

MAIL STOP AMENDMENT
COMMISSIONER FOR PATENTS
PO BOX 1450
ALEXANDRIA, VA 22313-1450

/Penny L Lowry/_____
Penny L. Lowry, Reg. No. 57186

DATE OF SUBMISSION: OCTOBER 26, 2018
ELECTRONIC FILING (EFS)

PRELIMINARY AMENDMENT

Prior to examination, please amend the above-identified application as indicated below.

Amendments to the Claims begin on page 2 of this paper.

Remarks begin on page 11 of this paper.

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

Electronic Patent Application Fee Transmittal

Application Number:	16057566
Filing Date:	07-Aug-2018
Title of Invention:	Adjusting a digital representation of a head region
First Named Inventor/Applicant Name:	Eric Sommerlade
Filer:	Penny Lea Lowry/Stefan Bump
Attorney Docket Number:	409001

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY FILING FEE (ELECTRONIC FILING)	4011	1	75	75
UTILITY SEARCH FEE	2111	1	330	330
UTILITY EXAMINATION FEE	2311	1	380	380
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	2202	16	50	800
INDEPENDENT CLAIMS IN EXCESS OF 3	2201	3	230	690
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
LATE FILING FEE FOR OATH OR DECLARATION	2051	1	80	80
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**2355**

Electronic Acknowledgement Receipt	
EFS ID:	34130915
Application Number:	16057566
International Application Number:	
Confirmation Number:	5211
Title of Invention:	Adjusting a digital representation of a head region
First Named Inventor/Applicant Name:	Eric Sommerlade
Customer Number:	145234
Filer:	Penny Lea Lowry/Stefan Bump
Filer Authorized By:	Penny Lea Lowry
Attorney Docket Number:	409001
Receipt Date:	26-OCT-2018
Filing Date:	07-AUG-2018
Time Stamp:	15:37:46
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$2355
RAM confirmation Number	102918INTEFSW15400400
Deposit Account	506262
Authorized User	Stefan Bump
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		409001_Preliminary_Amendment.pdf	113016 f86a4579bce848bf3c748a4138ce6994e42b1bb1	yes	11

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Applicant Arguments/Remarks Made in an Amendment	11	11
	Claims	2	10
	Preliminary Amendment	1	1

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	40419 bb1e737172221add071f3ba79461cb7841a2cabe	no	2

Warnings:

Information:

Total Files Size (in bytes):	153435

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

REMARKS

Claims 1-36 were originally filed. Claims 4-6, 9-16, 18-19, 22, 30-31, and 36 are currently amended to remove multiple dependencies and to correct minor typographical errors. No new matter has been added.

The Examiner is requested to contact the undersigned Attorney of Record if such would expedite the prosecution of the present Application. No fees are believed due. If the Commissioner determines that any fees are due, the Examiner is requested to contact the undersigned Attorney of Record for any such fees, referencing Attorney Docket Number 409001.

Respectfully submitted,

/Penny L Lowry/

Date: October 26, 2018

Penny L. Lowry
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IPR2023-01046 - U.S. Patent No. 10,740,985

AMENDMENTS TO THE CLAIMS

1. (Original) A method of generating reference data for adjusting a digital representation of a head region, the method comprising:

receiving training data comprising:

a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and

a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region;

using a first machine learning algorithm to generate first reference data using the training data, the first reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region; and

using a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm, the second reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region.

2. (Original) The method of claim 1, wherein:

the first reference data comprise first editing instructions for a range of possible configurations of the target feature and first selection instructions for selecting editing instructions for a particular input patch from the first editing instructions based on the configuration of the target feature of the input patch; and

the second reference data comprise second editing instructions for a range of possible configurations of the target feature and second selection instructions for

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IPR2023-01046 - U.S. Patent No. 10,740,985

selecting editing instructions for a particular input patch from the second image editing instructions based on the configuration of the target feature of the input patch.

3. (Original) The method of claim 2, wherein the configuration of the target feature of each input patch is represented by a feature vector derived from plural local descriptors of the input patch, and the first and second selection instructions define how the feature vector is used to select editing instructions for the input patch.

4. (Currently amended) The method of claim 2 ~~or 3~~, wherein the editing instructions comprise a displacement vector field defining how the input patch is to be transformed.

5. (Currently amended) The method of claim 2 ~~or 3~~, wherein the editing instructions comprise a filter field, a brightness adjustment field, or a texture blending field.

6. (Currently amended) The method of claim 2 ~~any of claims 2-5~~, wherein:

a first editing algorithm is used by the first machine learning algorithm to define how the first editing instructions are to be applied to an input patch to derive an output patch; and

a second editing algorithm is used by the second machine learning algorithm to define how the second editing instructions are to be applied to an input patch to derive an output patch.

7. (Original) The method of claim 6, wherein:

the second editing instructions are principle component analysis components of a principle component analysis of the first editing instructions; and

the second image editing algorithm is configured to transform the second editing instructions into the first editing instructions by inverse principle component analysis transform.

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8. (Original) The method of claim 6, wherein:

the second editing instructions are wavelet components of the first editing instructions; and

the second editing algorithm is configured to transform the second editing instructions into the first editing instructions by inverse wavelet transform.

9. (Currently amended) The method of claim 2 ~~any of claims 2-8~~, wherein the first selection instructions for the first reference data are able to select between a larger number of alternative editing instructions than the second selection instructions for the second reference data.

10. (Currently amended) The method of claim 1 ~~any preceding claim~~, wherein the first machine learning algorithm is of a different machine learning algorithm type than the second machine learning algorithm.

11. (Currently amended) The method of claim 1 ~~any preceding claim~~, wherein the first machine learning algorithm comprises one or more of the following: a neural network; a support vector machine; and a generative adversarial network (GAN)~~, GAN~~.

12. (Currently amended) The method of claim 1 ~~any preceding claim~~, wherein the second machine learning algorithm comprises one or more of the following: a regression forest; regression ferns, cluster centres, a lookup table, and separable filter banks.

13. (Currently amended) The method of claim 1 ~~any of claims 1-10~~, wherein the first machine learning algorithm comprises a first neural network and the second machine learning algorithm comprises a second neural network, wherein the second neural network comprises fewer layers and/or smaller convolution fields than the first neural network.

14. (Currently amended) The method of claim 1 ~~any preceding claim~~, wherein the target feature comprises one or more of the following: an eye region comprising at least

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part of an eye, a nose region comprising at least part of a nose, a mouth region comprising at least part of a mouth, a chin region comprising at least part of a chin, a neck region comprising at least part of a neck, and a hair region comprising hair.

15. (Currently amended) The method of claim 1 ~~any of claims 1-13~~, wherein:

the target feature comprises an eye region comprising at least part of an eye and the adjustment of the digital representation of the head region comprises adjusting a gaze direction;

the target feature comprises a nose region comprising at least part of a nose and the adjustment of the digital representation of the head region comprises adjusting a shape and/or texture of the nose;

the target feature comprises a chin region comprising at least part of a chin and the adjustment of the digital representation of the head region comprises adjusting a shape and/or texture of the chin;

the target feature comprises a neck region comprising at least part of a neck and the adjustment of the digital representation of the head region comprises adjusting a shape and/or texture of the neck; and/or

the target feature comprises a hair region comprising hair and the adjustment of the digital representation of the head region comprises adjusting a color of the hair.

16. (Currently amended) The method of claim 1 ~~any preceding claim~~, wherein the second editing instructions in the second reference data are provided in a compressed representation.

17. (Original) The method of claim 16, wherein the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centers.

18. (Currently amended) A method of adjusting a digital representation of a head region, the method comprising

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receiving a digital representation of a head region; and

using reference data comprising editing instructions to adjust the digital representation of the head region, wherein the reference data comprises the second reference data generated by the method of claim 1 ~~any of claims 1-17~~.

19. (Currently amended) A method of adjusting a digital representation of a head region, the method comprising:

identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region;

deriving a feature vector from plural local descriptors of the target patch;

using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and

applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein:

the reference data comprises the second reference data generated by the method of claim 1 ~~any of claims 1-17~~.

20. (Original) A method of adjusting a digital representation of a head region, the method comprising:

identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region;

deriving a feature vector from plural local descriptors of the target patch;

using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and

applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein:

the editing instructions in the reference data are provided in a compressed representation.

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21. (Original) The method of claim 20, wherein the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centres.

22. (Currently amended) The method of claim 18 ~~any of claims 18-21~~, wherein a plurality of the digital representations of the head region are received and adjusted, each digital representation being captured from the head region at a different point in time, and the method further comprises updating the second machine learning algorithm using editing instructions generated by the first machine learning algorithm using one or more of the received and adjusted digital representations.

23. (Original) The method of claim 22, wherein the updating of the second machine learning algorithm is performed at or near input data frame rate.

24. (Original) The method of claim 23, wherein only a subset of the received and adjusted digital representations are used to update the second machine learning algorithm.

25. (Original) A method of training a machine learning algorithm to adjust a digital representation of a head region, comprising:

receiving training data comprising:

a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and

first reference data generated by a pre-trained first machine learning algorithm, the first reference data comprising a set of editing instructions in one-to-one correspondence with the input patches, each editing instruction being for adjusting the digital representation of the head region;

updating a pre-trained second machine learning algorithm trained to generate second reference data, where the input for the updating comprises the training data and

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the generated first reference data, the second reference data comprising editing instructions for adjusting the digital representation of the head region.

26. (Original) The method of claim 25, wherein the updating of the second machine learning algorithm is performed at or near input data frame rate.

27. (Original) A method of training a machine learning algorithm to adjust a digital representation of a head region, the method comprising:

receiving training data comprising a set of input digital representations of a head region;

training a first machine learning algorithm using the training data to perform an adjustment of a digital representation of a head region;

using the trained first machine learning algorithm to generate first reference data, the first reference data comprising an adjusted digital representation of the head region for each of at least a subset of the input digital representations, each adjusted digital representation being obtained by performed the adjustment that the first machine learning algorithm was trained to perform; and

training a second machine learning algorithm using at least a subset of the training data used to train the first machine learning algorithm and the first reference data to perform the same adjustment of a digital representation of a head region as the first machine learning algorithm.

28. (Original) The method of claim 27, wherein the adjustment of the digital representation comprises converting from a two-dimensional digital representation to a three-dimensional digital representation.

29. (Original) The method of claim 28, wherein the training of the first machine learning algorithm comprises iteratively using a rendering process to generate a two-dimensional digital representation from a three-dimensional digital representation generated by the first machine learning algorithm and comparing the generated digital representation with a corresponding digital representation in the training data.

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30. (Currently amended) The method of claim 25 ~~any of claims 25-29~~, further comprising receiving a further digital representation of the head region and using the updated or trained second machining learning algorithm to adjust the further digital representation.

31. (Currently amended) A computer program capable of execution by a processor and arranged on execution to cause the processor to perform a method according to claim 1 ~~any of the preceding claims~~.

32. (Original) A computer readable storage medium storing a computer program according to claim 31.

33. (Original) A device for generating reference data for adjusting a digital representation of a head region, the device comprising a data processing unit arranged to:

receive training data comprising:

a set of input patches, each input patch comprising information about a target feature of a digital representation of the head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and

a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target portion of the digital representation of the head region after adjustment of the digital representation of the head region;

use a first machine learning algorithm to generate first reference data using the training data; and

use a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data output by the first machine learning algorithm.

34. (Original) The device of claim 33, wherein:

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the first reference data comprises editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region;

the second reference data comprises editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region;

the second editing instructions in the second reference data are provided in a compressed representation.

35. (Original) A device for adjusting a digital representation of a head region, the device comprising a data processing unit arranged to process the digital representation of the head region by:

identifying a target patch in the digital representation of the head region, the target patch comprising information about a target feature of the digital representation of the head region;

deriving a feature vector from plural local descriptors of the target patch;

using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and

applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein:

the editing instructions in the reference data are provided in a compressed representation.

36. (Currently amended) The device of claim 35 ~~any of claims 33-35~~, further comprising a telecommunications interface arranged to transmit the adjusted digital representation over a telecommunications network to a destination device to allow display of the head region thereon.

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MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET

Substitute for Form PTO-1360
(For use with Form PTO/SB/06)

Application Number	Filing Date
16057566	

Applicant(s) Eric Sommerlade

* May be used for additional claims or amendments

CLAIMS	AS FILED		AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT	
	Indep	Depend	Indep	Depend	Indep	Depend
1	1					
2		1				
3		1				
4		2				
5		2				
6		(1)				
7		(1)				
8		(1)				
9		(1)				
10		(1)				
11		(1)				
12		(1)				
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Total Indep	6		0		0	
Total Depend	38	↵	0	↵	0	↵
Total Claims	44		0		0	

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/057,566	08/07/2018	Eric Sommerlade	409001

CONFIRMATION NO. 5211

145234
RealD Spark, LLC
100 North Crescent Drive
Suite 200
Beverly Hills, CA 90210

FORMALITIES LETTER

OC000000101836556

Date Mailed: 08/27/2018

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
- The application search fee must be submitted.
- The application examination fee must be submitted.

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
  - The drawings are not in compliance with 37 CFR 1.84 because figures 4# contain figure or view numbers that have incorrect orientation. Reference characters, sheet numbers, and view numbers must be oriented in the same direction as the view. See 37 CFR 1.84(p)(1).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

- Additional claim fees of $ **2300** as a small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.
  The surcharge is due for any one of:
  - late submission of the basic filing fee, search fee, or examination fee,
  - late submission of inventor's oath or declaration,
  - filing an application that does not contain at least one claim on filing, or
  - submission of an application filed by reference to a previously filed application.

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SUMMARY OF FEES DUE:

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. Small entity discount is in effect. If applicant is qualified for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- $ **75** basic filing fee.
- $ **80** surcharge.
- $ **330** search fee.
- $ **380** examination fee.
- $ **690** for **3** independent claims over 3.
- $ **1200** for **24** total claims over 20.
- $ **410** for multiple dependent claim surcharge.
- $(**0**) previous unapplied payment amount.
- $ **3165** TOTAL FEE BALANCE DUE.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  Eric Sommerlade
  Alexandros Neophytou

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web, including a copy of this Notice and selecting the document description "Applicant response to Pre-Exam Formalities Notice". https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

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/sgorems/

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/057,566

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	44 minus 20 =	* 24	x 50 =	1200	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	6 minus 3 =	* 3	x 230 =	690			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				410			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	3085		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/057,566	08/07/2018	2688	0.00	409001	36	6

CONFIRMATION NO. 5211

FILING RECEIPT

145234
RealD Spark, LLC
100 North Crescent Drive
Suite 200
Beverly Hills, CA 90210

OC000000101838555

Date Mailed: 08/27/2018

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Eric Sommerlade, Oxford, UNITED KINGDOM;
Alexandros Neophytou, Oxford, UNITED KINGDOM;

Applicant(s)

RealD Spark, LLC, Beverly Hills, CA;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 62/542,661 08/08/2017
and claims benefit of 62/543,587 08/10/2017

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 08/24/2018

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The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/057,566**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

Adjusting a digital representation of a head region

Preliminary Class

360

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

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LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Eric		Sommerlade	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Oxford	Country of Residence [i]	GB

Mailing Address of Inventor:

Address 1	100 N. Crescent Drive		
Address 2	Suite 200		
City	Beverly Hills	**State/Province**	CA
Postal Code	90210	**Country** [i]	US

Inventor 2

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Alexandros		Neophytou	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Oxford	Country of Residence [i]	GB

Mailing Address of Inventor:

Address 1	100 N. Crescent Drive		
Address 2	Suite 200		
City	Beverly Hills	**State/Province**	CA
Postal Code	90210	**Country** [i]	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ **An Address is being provided for the correspondence Information of this application.**			
Customer Number	145234		
Email Address	patpros@reald.com	Add Email	Remove Email

Application Information:

Title of the Invention	Adjusting a digital representation of a head region		
Attorney Docket Number	409001	**Small Entity Status Claimed**	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	12	**Suggested Figure for Publication (if any)**	3

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number			

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	
					Remove
Registration Number					
Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	
					Remove
Registration Number					

Additional Representative Information blocks may be generated within this form by selecting the **Add** button.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Claims benefit of provisional	62542661	2017-08-08

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Claims benefit of provisional	62543587	2017-08-10

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:	

If the Applicant is an Organization check here. ☒

Organization Name	RealD Spark, LLC

Mailing Address Information For Applicant:

Address 1	100 N. Crescent Drive		
Address 2	Suite 200		
City	Beverly Hills	**State/Province**	CA
Country[i]	US	Postal Code	90210
Phone Number	303-500-6151	Fax Number	
Email Address	patpros@reald.com		

Additional Applicant Data may be generated within this form by selecting the Add button.

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Microsoft Corporation v. RealD Spark, LLC
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

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

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	409001
	Application Number	
Title of Invention	Adjusting a digital representation of a head region	

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Penny L. Lowry/			Date (YYYY-MM-DD)	
First Name	Penny L.	Last Name	Lowry	Registration Number	57186

Additional Signature may be generated within this form by selecting the Add button.

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Microsoft Corporation v. RealD Spark, LLC
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Adjusting a Digital representation of a Head Region

TECHNICAL FIELD

[01] This application relates to adjusting a digital representation, such as an image or a three-dimensional geometrical representation, of a head region, particularly a facial and/or neck region. The application relates particularly to adjusting target features of the digital representation of the head region, for example to correct a perceived gaze direction of eyes, or to modify the texture and/or shape of features such as the nose, mouth, chin or neck.

BACKGROUND

[02] In many systems, images of a head, which may comprise single images at different times, or stereoscopic pairs of images or other multi-view images, may be captured in one device and displayed on a different device for viewing by an observer. One non-limitative example is a system for performing teleconferencing between two telecommunications devices. In that case, each device may capture images of the observer of that device and transmit them to the other device over a telecommunications network for display and viewing by the observer of the other device. Digital representations other than images and/or complementary to images may also be captured, for example using depth measurements (e.g. using a time-of-flight camera).

[03] When an image or other digital representation of a head is captured and displayed, the gaze of the head may not be directed at the observer. This may be caused for example by the gaze of the head not being directed at the sensing system (e.g. camera system) used to capture the digital representation (e.g. image), for example because a user whose head is imaged is observing a display in the same device as a camera system and the camera system is offset above (or below) that display. In that case, the gaze in the displayed images will be perceived to be downwards (or upwards). The human visual system has evolved high sensitivity to gaze during social interaction, using cues gained from the relative position of the iris and white sclera of other observers. Errors in the perceived gaze are disconcerting. For example in a system for performing teleconferencing, errors in the perceived gaze can create unnatural interactions between the users.

[04] The present disclosure is concerned with processing techniques (e.g. image processing

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techniques) for adjusting digital representations (e.g. images) of a head region to correct the perceived gaze and/or to improve other aspects of a computer-generated display of the head region. The present disclosure is particularly concerned with implementing such processing techniques with minimal demands on computer hardware and/or power such that they provide results at or near input data frame rate or user feedback requirements.

BRIEF SUMMARY

[05] According to a first aspect of the present disclosure, there is provided a method of generating reference data for adjusting a digital representation of a head region, the method comprising: receiving training data comprising: a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region; using a first machine learning algorithm to generate first reference data using the training data, the first reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region; and using a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm, the second reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region.

[06] The described use of two machine learning algorithms allows an improved balance to be achieved between accuracy of the adjustment process and speed of execution. The first machine learning algorithm can be configured to provide highly detailed first reference data, which provides high accuracy. Use of this first reference data directly in a processing technique (e.g. image processing technique) to adjust a digital representation (e.g. image or three-dimensional geometrical representation) of a head region would be relatively expensive in terms of computational resources because of the high level of detail. By arranging instead for the first reference data to be provided to a second machine learning algorithm, which provides, based on

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the first reference data and the original training data, the reference data (the second reference data) that is to be used for the adjustment of the digital representation of the head region, it is possible to benefit to an extent from the high accuracy of the first machine learning algorithm whilst also providing reference data that is less detailed and thus easier to process efficiently when performing the adjustment of the digital representation of the head region. The quality of the reference data provided by the second machine learning algorithm is found to be significantly improved when the second machine learning algorithm is provided with both the first reference data and the training data in comparison to when the second machine learning algorithm is provided only with the training data.

[07] In an embodiment, efficiency is further improved by providing editing instructions (e.g. image editing instructions) in the second reference data in a compressed representation. The use of a compressed representation reduces data storage and bandwidth requirements during use of the editing instructions to perform adjustment of a digital representation of a head region.

[08] According to a second aspect of the present disclosure, there is provided a device configured to perform a similar method to the first aspect of the invention.

[09] According to a third aspect of the present disclosure, there is provided a method of adjusting a digital representation of a head region, the method comprising: identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region; deriving a feature vector from plural local descriptors of the target patch; using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein the editing instructions in the reference data are provided in a compressed representation.

[10] According to a fourth aspect of the present disclosure, there is provided a device configured to perform a similar method of the third aspect of the invention.

[11] The use of a compressed representation reduces data storage and bandwidth requirements.

[12] According to a fifth aspect of the present disclosure, there is provided a method of training a machine learning algorithm to adjust a digital representation of a head region,

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comprising: receiving training data comprising: a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and first reference data generated by a pre-trained first machine learning algorithm, the first reference data comprising a set of editing instructions in one-to-one correspondence with the input patches, each editing instruction being for adjusting the digital representation of the head region; updating a pre-trained second machine learning algorithm trained to generate second reference data, where the input for the updating comprises the training data and the generated first reference data, the second reference data comprising editing instructions for adjusting the digital representation of the head region.

[13] According to a sixth aspect of the present disclosure, there is provided a method of training a machine learning algorithm to adjust a digital representation of a head region, the method comprising: receiving training data comprising a set of input digital representations of a head region; training a first machine learning algorithm using the training data to perform an adjustment of a digital representation of a head region; using the trained first machine learning algorithm to generate first reference data, the first reference data comprising an adjusted digital representation of the head region for each of at least a subset of the input digital representations, each adjusted digital representation being obtained by performed the adjustment that the first machine learning algorithm was trained to perform; and training a second machine learning algorithm using at least a subset of the training data used to train the first machine learning algorithm and the first reference data to perform the same adjustment of a digital representation of a head region as the first machine learning algorithm.

BRIEF DESCRIPTION OF THE DRAWINGS

[14] Non-limitative embodiments are illustrated by way of example in the accompanying figures, in which like reference numbers indicate similar parts, and in which:

[15] **FIGURE 1** is a schematic perspective view of a device that captures a stereoscopic pair of images;

[16] **FIGURE 2** is a schematic perspective view of a device that displays the stereoscopic pair of images;

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[17] **FIGURE 3** is a flow chart of a method of adjusting a stereoscopic pair of images;

[18] **FIGURE 4** is a diagram illustrating the processing of the stereoscopic pair of images in the method of FIGURE 3;

[19] **FIGURE 5** is a flow chart of a step of extracting an image patch;

[20] **FIGURE 6** and **FIGURE 7** are flow charts of two alternatives for a step of adjusting an image;

[21] **FIGURE 8** is flow chart of a method of generating reference data;

[22] **FIGURE 9** schematically depicts data flow in an example method of generating reference data;

[23] **FIGURE 10** depicts a device for generating reference data;

[24] **FIGURE 11** is a flow chart of a method of adjusting an image of a head region;

[25] **FIGURE 12** schematically depicts data flow in an example of a method of adjusting an image of a head region;

[26] **FIGURE 13** is a diagram of a telecommunications system in which the method may be implemented;

[27] **FIGURE 14** schematically depicts data flow in an example method of generating reference data for converting a two-dimensional digital representation of a head region to a three-dimensional digital representation of a head region; and

[28] **FIGURE 15** schematically depicts data flow in an example of a method of adjusting a digital representation of a head region in which a second machine learning algorithm is updated online.

DETAILED DESCRIPTION

[29] **FIGURE 1** and **FIGURE 2** illustrate how incorrect gaze is perceived when a stereoscopic pair of images of a head is captured by the device 10 shown in FIGURE 1 which will be referred to as the source device 10, and displayed on a different device 20 shown in FIGURE 2 which will be referred to as the destination device 20. Capturing of a stereoscopic pair of images is shown as an example. A similar effect can occur when a monocular image is captured and when more than two views of the head are captured. A similar effect can also occur when alternative or additional sensing techniques are used to build a digital representation

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of the head (e.g. where a depth sensor such as a time-of-flight camera is used to obtain three-dimensional geometrical information about positions on the surface of the head).

[30] In the embodiment shown, the capture device 10 includes a display 11 and a camera system 12. In this particular example, the camera system comprises two cameras 13 in order to capture the stereoscopic pair of images of the head of a source observer 14. In a monocular implementation a single camera may be provided instead of the two cameras 13. In other implementations a depth sensor is alternatively or additionally provided. The source observer 14 views the display 11, along line 15. The cameras 13 (optionally including one or more depth sensors) of the camera system 12 are offset from the display 11, in this case being above the display 11. Thus, the cameras 13 effectively look down on the source observer 14 along line 16.

[31] The display device 20 includes a display 21, which in this example can be a stereoscopic display of any known type, for example an autostereoscopic display of any known type. The display 21 displays the stereoscopic pair of images as captured by the capture device 10. A destination observer 24 views the display 21. If the destination observer 24 is located in a normal viewing position perpendicular to the center of the display 21, as shown by the hard outline of the destination observer 24, then the gaze of the source observer 14 is perceived by the destination observer 24 to be downwards, rather than looking at the destination observer 24, because the cameras 13 of the source device 10 look down on the source observer 14.

[32] Although the cameras 13 are above the display 11 in this example, the cameras 13 could in general could be in any location adjacent the display 11, and the gaze of the source observer 14 perceived by the destination observer 24 would be correspondingly incorrect.

[33] If the destination observer 24 is located in an offset viewing position, as shown by the dotted outline of the destination observer 24 so that the destination observer 24 views the display 21 along line 26, then the offset of the destination observer 24 creates an additional error in the gaze of the source observer 14 perceived by the destination observer 24. A similar additional error in the perceived gaze of the source observer 14 occurs if the destination observer 24 is located in the normal viewing position along line 25, but the displayed image (or stereoscopic pair of images in this example) is displayed on the display 25 in a position offset from the center of the display 25.

[34] A stereoscopic pair of images is an example of multi-view images where there are two

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images. Although FIGURE 1 illustrates an example where the camera system 12 includes two cameras 13 that capture a stereoscopic pair of images, alternatively the camera system may include more than two cameras 13 that capture more than two multi-view images, in which case similar issues of incorrect perceived gaze exist on display. The camera system may alternatively include only one camera and/or one or more depth sensors.

[35] **FIGURE 3** illustrates a method of adjusting multi-view images to correct such errors in the perceived gaze. The method of FIGURE 3 is a specific example of a method of adjusting digital representations of a head region in a case where the digital representations comprise images of the head region and where the images comprise one or more multi-view images of the head region. For simplicity, this method will be described with respect to the adjustment of multi-view images comprising a stereoscopic pair of images. The method may be generalized to multi-view images comprising more than two images, simply by performing similar processing on a larger number of images. The method may also be generalized to the case where single view (monocular) images of the head region are used and to the case where information from other sensing modalities, such as depth measurements, is included within the digital representations of the head region.

[36] The method may be performed in an image processor 30 (or other processor). The image processor 30 may be implemented by a processor executing a suitable computer program or by dedicated hardware or by some combination of software and hardware. Where a computer program is used, the computer program may comprise instructions in any suitable language and may be stored on a computer readable storage medium, which may be of any type, for example: a recording medium which is insertable into a drive of the computing system and which may store information magnetically, optically or opto-magnetically; a fixed recording medium of the computer system such as a hard drive; or a computer memory.

[37] The image processor 30 (or other processor) may be provided in the source device 10, the destination device 10 or in any other device, for example a server on a telecommunications network, which may be suitable in the case that the source device 10 and the destination device 10 communicate over such a telecommunications network.

[38] In this example, a stereoscopic pair of images 31 are captured by the camera system 12. Although the camera systems 12 is illustrated in FIGURE 1 as including two cameras 13, this is

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not limitative and more generally the camera system 13 may have the following properties.

[39] The camera system comprises a set of one or more cameras 13, with at least two cameras 13 in the case where multi-view images are processed. Where two cameras are provided, the cameras are typically spaced apart by a distance less than the average human intrapupilar distance. In the alternative that the method is applied to more than two multi-view images, then there are more than two cameras 13, that is one camera 13 per image. In some embodiments, a depth sensor is provided for obtaining three-dimensional geometrical information about a surface of the head region, optionally in addition to one or more other cameras (e.g. optical cameras). The depth sensor may comprise a time-of-flight camera.

[40] Where plural cameras 13 are provided, the cameras 13 may be spatially related to each other and the display 11. The spatial relationship between the cameras 13 themselves and between the cameras 13 and the display 11 is known in advance. Known methods for finding the spatial relationship may be applied, for example a calibration method using a reference image, or specification *a priori*.

[41] The camera or cameras 13 face in the same direction as the display 11. Thus, when the source observer 14 is viewing the display 11, then the camera or cameras 13 face the source observer 14 and the captured information, such as depth information, image or images (e.g. stereoscopic pair of images) are digital representations (e.g. images and/or three-dimensional geometrical representations) of the head of the source observer 14. Different cameras in the camera system can have different fields of view.

[42] The camera system 12 may include cameras 13 having different sensing modalities, including but not limited to visible light, infrared, and time-of-flight (depth).

[43] In some embodiments, the main output of the camera system 13 is images 31 which are typically video images output at a video rate. The output of the camera system 13 may also include data representing the spatial relationship between the cameras 13 and the display 11, the nature of the sensing modalities and internal parameters of the cameras 13 (for example focal length, optical axis) which may be used for angular localization, as well as three-dimensional geometrical information, for example from depth measurements.

[44] An example of the method performed on a digital representation of a head region comprising a stereoscopic pair of images 31, for the case of adjustment of eye regions, is as

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follows. To illustrate this example method, reference is also made to **FIGURE 4** which shows an example of the stereoscopic pair of images 31 at various stages of the method.

[45] In step S1, the stereoscopic pair of images 31 are analyzed to detect the location of the head and in particular the eyes of the source observer 14 within the stereoscopic pair of images 31. This is performed by detecting presence of a head, tracking the head, and localizing the eyes of the head. Step S1 may be performed using a variety of techniques that are known in the art.

[46] One possible technique for detecting the presence of the head is to use Haar feature cascades, for example as disclosed in Viola and Jones, "Rapid Object Detection using a Boosted Cascade of Simple Features", CVPR 2001, pp 1-9, which is herein incorporated by reference in its entirety.

[47] One possible technique for tracking the head is to use the approach of Active Appearance Models to provide the position of the head of the subject, as well as the location of the eyes, for example as disclosed in Cootes et al., "Active shape models - their training and application", Computer Vision and Image Understanding, 61(1):38-59, Jan. 1995 and in Cootes et al. "Active appearance models", IEEE Trans. Pattern Analysis and Machine Intelligence, 23(6):681-685, 2001, both of which are herein incorporated by reference in their entireties.

[48] In step S1, typically, a set of individual points ("landmarks") are set to regions of the face, typically the eyes, for example corners of the eye, upper and lower lid locations, etc., thereby localizing the eyes.

[49] In step S2, patches representing portions of a digital representation of the head region, which in this example may be referred to image patches, containing the left and right eyes of the head, respectively, are identified in each image 31 of the stereoscopic pair. FIGURE 4 shows the identified image patches 32 of the right eye in each image 31 (the image patches for the left eye being omitted in FIGURE 4 for clarity).

[50] Step S2 may be performed as shown in **FIGURE 5**, as follows.

[51] In step S2-1, image patches 32 containing the left and right eyes of the head are identified in each image 31 of the stereoscopic pair. This is done by identifying an image patch 39 in each image 31 located around the identified points ("landmarks") corresponding to features of an eye, as shown for example in FIGURE 4.

[52] In step S2-2, the image patches 32 identified in step S2-1 are transformed into a

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normalized coordinate system, being the same normalized coordinate system as used in the machine learning process which is described further below. The transformation is chosen to align the points ("landmarks") of the eye within the image patch that were identified in step S1, with predetermined locations in the normalized coordinate system. The transformation may include translation, rotation and scaling, to appropriate extents to achieve that alignment. The output of step S2-2 is identified image patches 33 of the right eye in each image in the normalized coordinate system as shown for example in FIGURE 4.

[53] The following steps may be performed separately (a) in respect of the image patches containing the left eyes of the head in each image 31 of the stereoscopic pair, and (b) in respect of the image patches containing the right eyes of the head in each image 31 of the stereoscopic pair (in this example). For brevity, the following description will refer merely to image patches and eyes without specifying the left or right eye, but noting the same steps are performed for both left and right eyes.

[54] In step S3, a feature vector 34 is derived from plural local descriptors (representing information about a local region in a patch), which in this example may be referred to as local image descriptors, of an image patch 33 in at least one image 31 of the stereoscopic pair (in this example). Depending on the approach and as described further below, this may be an image patch in a single image 31 of the stereoscopic pair or may be both images 31 of the stereoscopic pair. Thus, the local image descriptors are local image descriptors derived in the normalized coordinate system.

[55] The feature vectors 34 are representations of the image patches 33 that are suitable for use in looking up reference data 35 to be used for adjusting the image patches. The reference data 35 may comprise reference displacement vector fields that represent transformations of the image patch, or other representations of transformations of the image patch, including compressed representations as described below, and are associated with possible values of the feature vector.

[56] The reference data 35 is obtained and analyzed in advance using a machine learning technique. The machine learning technique may derive the form of the feature vectors 34 and associate transformations such as the reference displacement vector fields with the possible values of the feature vector. A specific example of a machine learning technique applied in the

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case where it is desired to correct gaze using digital representations of a head region comprising images of the head region, will now be described before reverting to the method of FIGURE 3.

[57] The training input to the machine learning technique is two sets of images (or image patches), which may be stereoscopic pairs of images or monoscopic images, as discussed further below. Each set may comprise images of the head of the same group of individuals but captured from cameras in different locations relative to the gaze so that the perceived gaze differs as between them (in the case where gaze is to be corrected).

[58] The first set are input images, being images of each individual with an incorrect gaze where the error is known *a priori*. In particular, the images in the first set may be captured by at least one cameras in a known camera location where the gaze of the individual which is in a different known direction. For example in the case of the source device of FIGURE 1, the camera location may be the location of a camera 13 and while the gaze of the imaged individual is towards the center of the display 11.

[59] The second set are output images, being images of each individual with correct gaze for a predetermined observer location relative to a display location in which the image is to be displayed. In the simplest case, the observer location is a normal viewing position perpendicular to the center of the display location, for example as shown by the hard outline of the destination observer 24 in the case of the destination device 20 of FIGURE 2.

[60] For each image in the two sets, the image is analyzed to detect the location of the head and in particular the eyes using the same technique as used in step S1 described above, and then image patches containing the left and right eyes of the head, respectively, are identified using the same technique as used in step S2 described above. The following steps may then be performed separately (a) in respect of the image patches containing the left eyes of the head in each image, and (b) in respect of the image patches containing the right eyes of the head in each image. For brevity, the following description will refer merely to image patches and eyes without specifying the left or right eye, but noting the same steps are performed for both left and right eyes in this embodiment.

[61] Each image patch is transformed into the same normalized coordinate system as used in step S2 described above. As described above, the transformation is chosen to align points ("landmarks") of the eye with predetermined locations in the normalized coordinate system. The

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transformation may include, for example, translation, rotation and/or scaling, to appropriate extents to achieve that alignment.

[62] Thus, the image patches input and output images of each individual are aligned in the normalized coordinate system.

[63] From an input and output image of each individual, there is derived a displacement vector field that represents the transformation of the image patch in the input image required to obtain the image patch of the output image, for example as follows. Defining positions in the image patches by (x,y), the displacement vector field **F** is given by

$$\mathbf{F}=\{u(x, y), v(x, y)\}$$

where u and v define the horizontal and vertical components of the vector at each position (x,y).

[64] The displacement vector field **F** is chosen so that the image patch of the output image O(x,y) is derived from the image patch of the input image I(x,y) as

$$O(x, y) = I(x+u(x, y), y+v(x,y))$$

[65] For image data from more than one camera, the system delivers a displacement vector field for the input image from each camera.

[66] The displacement vector field **F** for an input and output image of an individual may be derived using a process in which a trial feature vector $\mathbf{F}'=\{u',v'\}$ is modified to minimize error, optionally in an iterative process, for example in accordance with:

$$\sum\left|O(x,y) - I\left(x + u'(x,y), y + v'(x,y)\right)\right| = min!$$

[67] By way of non-limitative example, the displacement vector field **F** may be derived as disclosed in Kononenko et al., "Learning To Look Up: Realtime Monocular Gaze Correction Using Machine Learning", Computer Vision and Pattern Recognition, 2015, pp. 4667-4675, which is herein incorporated by reference in its entirety, wherein the displacement vector field **F** is referred to as a "flow field".

[68] Another example for editing instructions, which may be referred to as image editing instructions in cases where the digital representation of the head region consists of images, which can be used additionally or as an alternative to the displacement vector field in any of the arrangements disclosed herein, is given by filter field L = {k(P, x, y) }, which defines a filter kernel for a given location (x, y). This filter field L is chosen so that the image patch of the output image O(x, y) is derived from the image patch of the input image I(x, y) as O(x, y) =

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k(P(I, x, y)), x, y)), where P(I, x, y) is a local region around the point (x,y) in the image I, and k(P, x, y) operates on the patch P with coefficients depending on the position (x, y). For example, it could be the output of a convolution of the patch with a Gaussian filter with width depending on the position x in the image, or a brightness increase of a local pixel depending on the vertical position y.

[69] Another example for editing instructions (e.g. image editing instructions) which can be used additionally or as an alternative to the displacement vector field in any of the arrangements disclosed herein, is given by a set of typical image components that make up the edited image area, e.g. texture showing beard stubbles. These are then blended with a factor depending on the image coordinates and local image content (i.e. a texture blending field). Other transformation fields can be used, such as a brightness adjustment field.

[70] A machine learning technique is used to obtain a map from the displacement vector field **F** (or other editing instructions such as image editing instructions) of each individual to respective feature vectors derived from plural local (e.g. image) descriptors of a target patch of an input image.

[71] The local descriptors (e.g. local image descriptors) capture relevant information of a local part of a patch (e.g. image patch) of an input digital representation of the head region (e.g. an input image) and the set of local descriptors usually form a continuous vectorial output.

[72] The local descriptors input into the machine learning process are of types expected to provide discrimination between different individuals, although the specific image descriptors are selected and optimized by the machine learning process itself. In general, the local descriptors may be of any suitable type, some non-limitative examples which may be applied in any combination being as follows.

[73] The local descriptors may include values of individual pixels or a linear combination thereof. Such a linear combination may be, for example, a difference between the pixels at two points, a kernel derived within a mask at an arbitrary location, or a difference between two kernels at different locations.

[74] The local descriptors may include distances of a pixel location from the position of an eye point ("landmark").

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[75] The local descriptors may include SIFT features (Scale-invariant feature transform features), for example as disclosed in Lowe, "Distinctive Image Features from Scale-Invariant Keypoints", International Journal of Computer Vision 60 (2), pp 91–110, which is herein incorporated by reference in its entirety.

[76] The local descriptors may include HOG features (Histogram of Oriented Gradients features) , for example as disclosed in Dalal et al. "Histograms of Oriented Gradients for Human Detection", Computer Vision and Pattern Recognition, 2005, pp. 886-893, which is herein incorporated by reference in its entirety.

[77] The local descriptors may include "low level representations" from pre-classification stages in deep learning neural networks, for example as disclosed in Yang and Ramanan, "Multi-scale recognition with DAG-CNNs", ICCV 2015, which is herein incorporated by reference in its entirety. In a classifying deep learning neural network with multiple layers applied to an input digital representation (e.g. image), for example, such low level features could be taken from a layer before the final classification layer of the network.

[78] The derivation of the feature vector from plural local descriptors depends on the type of machine learning applied.

[79] In a first type of machine learning technique, the feature vector may comprise features that are values derived from the local descriptors (e.g. local image descriptors) in a discrete space, being binary values or values discretized into more than two possible values. In this case, the machine learning technique associates a reference displacement vector field **F** derived from the training input with each possible value of the feature vector in the discrete space, so the reference data 35 may provide similar functionality to a look-up table, with the machine learning generating a machine learning parameter set that can be used to generate corresponding editing instructions. This allows a reference displacement vector field **F** to be simply selected from the reference data 35 on the basis of the feature vector 34 derived in step S3, as described below.

[80] In the case that the feature vector comprises features that are binary values derived from the local descriptors, the feature vector has a binary representation. Such binary values may be derived in various ways from the values of descriptors, for example by comparing the value of a descriptor with a threshold, comparing the value of two descriptors, or by comparing the distance of a pixel location from the position of an eye point ("landmark").

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[81] Alternatively, the feature vector may comprise features that are discretized values of the local descriptors. In this case, more than two discrete values of each feature are possible.

[82] Any suitable machine learning technique may be applied, for example using a decision tree, a decision forest, a decision fern or an ensemble or combination thereof, or a neural network.

[83] By way of example, a suitable machine learning technique using a feature vector comprising features that are binary values derived by comparing a set of individual pixels or a linear combination thereof against a threshold, is disclosed in Ozuysal et al. "Fast Keypoint Recognition in Ten Lines of Code", Computer Vision and Pattern Recognition, 2007, pp. 1-8, which is herein incorporated by reference in its entirety.

[84] By way of further example, a suitable machine learning technique using a distance of a pixel location with the position of an eye landmark is disclosed in Kononenko et al., "Learning To Look Up: Realtime Monocular Gaze Correction Using Machine Learning", Computer Vision and Pattern Recognition, 2015, pp. 4667-4675, which is herein incorporated by reference in its entirety.

[85] By way of further example, a suitable machine learning technique using a random decision forest is disclosed in Ho, "Random Decision Forests", Proceedings of the 3rd International Conference on Document Analysis and Recognition, Montreal, QC, 14–16 August 1995, pp. 278-282, which is herein incorporated by reference in its entirety.

[86] In a second type of machine learning technique, the feature vector may comprise features that are discrete values of the local descriptors (e.g. local image descriptors) in a continuous space. In this case, the machine learning technique associates a reference displacement vector field **F** (in this example, but other editing instructions could be used) derived from the training input with possible discrete values of the feature vector in the continuous space. This allows a displacement vector field **F** to be derived from the reference data 35 by interpolation from the reference displacement vector fields based on the relationship between the feature vector 34 derived in step S3 and the values of the feature vector associated with the reference displacement vector fields.

[87] Any suitable machine learning technique may be applied, for example using support vector regression.

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[88] By way of example, a suitable machine learning technique using support vector regression is disclosed in Drucker et al. "Support Vector Regression Machines", Advances in Neural Information Processing Systems 9, NIPS 1996, 155–161, which is herein incorporated by reference in its entirety. The output of the technique is a continuously varying set of interpolation directions that form part of the reference data 35 and are used in the interpolation.

[89] The machine learning technique, regardless of its type, inherently also derives the form of the feature vectors 34 that is used to derive the reference displacement vector fields **F** (or other image editing instructions). This is the form of the feature vectors 34 that is derived in step S3.

[90] The description now reverts to the method of FIGURE 3.

[91] In step S4, at least one displacement vector field 37 representing a transformation of an image patch is derived by using the feature vector 34 derived in step S3 to look up the reference data 35. Due to the derivation of the displacement vector field 37 from the reference data 35, the transformation represented thereby corrects the gaze that will be perceived when the stereoscopic pair of images 31 are displayed.

[92] In the case that the feature vector 34 comprises features that are values in a discrete space and the reference displacement vector fields of the reference data 35 comprise a reference displacement vector field associated with each possible value of the feature vector in the discrete space, then the displacement vector field for the image patch is derived by selecting the reference displacement field associated with the actual value of the derived feature vector 34.

[93] In the case that the feature vector 34 comprises features that are discrete values of the local descriptors in a continuous space, then then the displacement vector field for the image patch is derived by interpolating a displacement vector field from the reference displacement vector fields based on the relationship between the actual value of the derived feature vector 34 and the values of the feature vectors associated with the reference displacement vector fields. In the case that the machine learning technique was support vector regression, this may be done using the interpolation directions that form part of the reference data 35.

[94] In step S5, each image 31 of the stereoscopic pair is adjusted by transforming the image patches containing the left and right eyes of the head in accordance with the derived displacement vector fields 37. This produces an adjusted stereoscopic pair of images 38 as

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shown in FIGURE 4, in which the gaze has been corrected. In particular, the adjustment may be performed using two alternative methods, as follows.

[95] A first method for performing step S5 is shown in **FIGURE 6** and performed as follows.

[96] In step S5-1, the image patch is transformed in the normalised coordinate system in accordance with the corresponding displacement vector field 37 in respect of the same image, thereby correcting the gaze. As described above, for a displacement vector field **F** the transformation of the image patch of the input image I(x,y) provides the output image O(x,y) in accordance with

$$O(x, y) = I(x+u(x, y), y+v(x,y))$$

[97] In step S5-2, the transformed image patch output from step S5-1 is transformed out of the normalised coordinate system, back into the original coordinate system of the corresponding image 31. This is done using the inverse transformation from that applied in step S2-2.

[98] In step S5-3, the transformed image patch output from step S5-2 is superimposed on the corresponding image 31. This may be done with a full replacement within an eye region corresponding to the eye itself, and a smoothed transition between the transformed image patch and the original image 31 over a boundary region around the eye region. The width of the boundary region may be of fixed size or a percentage of the size of the image patch in the original image 31.

[99] A second method for performing step S5 is shown in **FIGURE 7** and performed as follows.

[100] In this second, alternative method, the transformation back into the coordinate system of the corresponding image 31 occurs before the transformation of the image patch in accordance with the transformed displacement vector field **F**.

[101] In step S5-4, the displacement vector field **F** is transformed out of the normalised coordinate system, back into the original coordinate system of the corresponding image 31. This is done using the inverse transformation from that applied in step S2-2.

[102] In step S5-5, the image patch 32 in the coordinate system of the image 31 is transformed in accordance with the displacement vector field **F** that has been transformed into the same coordinate system in step S5-4. As described above, for a displacement vector field **F** the

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transformation of the image patch of the input image I(x,y) provides the output image O(x,y) in accordance with

$$O(x, y) = I(x+u(x, y), y+v(x,y))$$

but this is now performed in the coordinate system of the original image 31.

[103] Step S5-6 is the same as S5-3. Thus, in step S5-6, the transformed image patch output from step S5-5 is superimposed on the corresponding image 31. This may be done with a full replacement within an eye region corresponding to the eye itself, and a smoothed transition between the transformed image patch and the original image 31 over a boundary region around the eye region. The width of the boundary region may be of fixed size or a percentage of the size of the image patch in the original image 31.

[104] **FIGURE 8** depicts a method of generating reference data (including reference data 37 of the type described in the specific examples discussed above) for adjusting a digital representation of a head region. In some embodiments, the digital representation of the head region comprises or consists of an image of the head region. In some embodiments, the digital representation of the head region comprises or consists of a three-dimensional digital representation (representing, for example, three-dimensional geometrical information). The three-dimensional digital representation may be obtained from depth measurements, using for example a time-of-flight camera. In an embodiment, the digital representation of the head region is usable to provide a computer generated display of the head region. In an embodiment, the adjustment of the digital representation comprises converting a two-dimensional digital representation of the head region to a three-dimensional digital representation of the head region.

[105] In a case where the digital representation of the head region (prior to adjustment, after adjustment, or both) comprises a three-dimensional digital representation, this may be provided in any of various known ways. For example, the three-dimensional digital representation may comprise a point cloud, a particle system, or a mesh representation. The mesh representation may comprise one or more of: a polygonal surface, a multi-resolution surface, a subdivision surface. The digital representation may comprise a three-dimensional digital representation and texture information associated with the three-dimensional digital representation, e.g. via a texture map. The digital representation may comprise a three-dimensional geometrical representation and color information (e.g. obtained from an optical camera) aligned with the three-dimensional

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geometrical representation. Other volumetric representations such as particle system or implicit definitions such as signed distance functions may also be used.

[106] The method comprises a step S100 of receiving training data 100. The training data 100 may be provided for example via a communications interface 112 (e.g. connecting to an external data connection or storage device) connected to a data processing unit 120 that is to perform the method (as depicted schematically in FIGURE 10). The training data 100 comprises a set of input patches. A patch consists of a target portion of a digital representation of a head region. In a case where the digital representation comprises an image, the patch may be referred to as an image patch. Each input patch (e.g. input image patch) comprises a target feature of the digital representation (e.g. image) of the head region prior to adjustment of the digital representation (e.g. adjustment of the image to be displayed) of the head region. The target feature is the same for each input patch. The target feature may comprise one or more of the following: an eye region comprising at least part of an eye (as in the specific examples discussed above with reference to FIGURE 4 for example), a nose region comprising at least part of a nose, a mouth region comprising at least part of a mouth, a chin region comprising at least part of a chin, and a neck region comprising at least part of a neck. In an embodiment each input image patch comprises a portion of the image of the head region corresponding to the target feature, such as the above-mentioned eye region, nose region, mouth region, chin region, or neck region.

[107] In an embodiment, the target feature comprises an eye region comprising at least part of an eye and the adjustment of the digital representation (e.g. image) of the head region comprises adjusting a gaze direction.

[108] In an embodiment, the target feature comprises a nose region comprising at least part of a nose and the adjustment of the digital representation (e.g. image) of the head region comprises adjusting a shape and/or texture of the nose (e.g. to make nose look smaller and/or slimmer by a fixed proportion, similar to the effect of a "tele lens").

[109] In an embodiment, the target feature comprises a chin region comprising at least part of a chin and the adjustment of the digital representation (e.g. image) of the head region comprises adjusting a shape and/or texture of the chin (e.g. to reduce or remove double chin appearance).

[110] In an embodiment, the target feature comprises a neck region comprising at least part of a neck and the adjustment of the digital representation (e.g. image) of the head region comprises

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adjusting a shape and/or texture of the neck (e.g. to reduce or remove wrinkles).

[111] In an embodiment, the target feature comprises a hair region comprising hair and the adjustment of the digital representation (e.g. image) of the head region comprises adjusting a color of the hair (e.g. by a fixed hue).

[112] In the case where the target feature comprises an eye region, the input patches may be obtained using the methodology described above with reference to steps S2-1 and S2-2, except that stereoscopic pairs of images are not necessarily required. Thus, the input patches may be obtained by using identified points ("landmarks") corresponding to features of an eye to locate the relevant region of the digital representation (e.g. image) of the head region (e.g. surrounding the eye) and/or transformation of the input patch into a normalized coordinate system, including alignment of the landmarks with predetermined locations in the normalized coordinate system using translation, rotation and/or scaling.

[113] In some embodiments, the training data 100 further comprises a set of output patches. As described above, each patch consists of a target portion of a digital representation of a head region. In a case where the digital representation comprises an image, the patch may be referred to as an image patch. The output patches (e.g. output images patches) are in one-to-one correspondence with the input patches. Each output patch comprises the target feature of the digital representation (e.g. image) of the head region after adjustment of the digital representation (e.g. adjustment of the image to be displayed) of the head region. Thus, in the case where an image of the head region is to be adjusted to correct a gaze direction, each output patch comprises an eye region that has been adjusted so that the gaze appears to be in the desired direction (e.g. directly towards a destination observer 24).

[114] The method further comprises a step S101 comprising using a first machine learning algorithm to generate first reference data 101 using the training data 100. The first reference data 101 comprises editing instructions (e.g. image editing instructions) for adjusting the digital representation (e.g. image) of the head region for a range of possible digital representations (e.g. digital representations representing different states of the head, such as different positions and/or orientations, optionally represented as different images) of the head region.

[115] The method further comprises a step S102 comprising using a second machine learning algorithm to generate second reference data 102. The second machine learning algorithm uses

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the same training data 100 as the first machine learning algorithm in step S101. The second machine learning algorithm further uses the first reference data 101 output by the first machine learning algorithm in step S101. The second reference data 102 comprises editing instructions (e.g. image editing instructions) for adjusting the digital representation (e.g. image) of the head region for a range of possible digital representations (e.g. different positions and/or orientations, optionally represented as different images) of the head region.

[116] In an embodiment, the first reference data 101 comprises first editing instructions (e.g. first image editing instructions) for a range of possible configurations of the target feature (e.g. different gaze directions and/or eye morphologies in the case where the target feature comprises an eye region) and first selection instructions for selecting editing instructions (from the first editing instructions) for a particular input patch (e.g. input image patch) based on the configuration of the target feature of the input patch (e.g. the particular gaze direction and/or particular eye morphology of that input patch).

[117] In an embodiment, the second reference data comprises second editing instructions (e.g. second image editing instructions) for a range of possible configurations of the target feature and second selection instructions for selecting editing instructions (from the second editing instructions) for a particular input patch (e.g. input image patch) based on the configuration of the target feature of the input patch.

[118] The configuration of the target feature of each input patch may be represented by a feature vector derived from plural local descriptors (e.g. local image descriptors) of the input patch, as described above with reference to step S3 of FIGURE 3 for the particular case where stereoscopic pairs of images containing eye regions are processed (but the method is applicable more generally than this particular case). As described above, the feature vector may take various forms but is generally adapted to be suitable for looking up editing instructions for performing adjustment of the digital representation (e.g. image) of the head region. In the present embodiment, the first and second selection instructions define how the feature vector is used to select editing instructions for the input patch. In an embodiment, the editing instructions comprise a displacement vector field defining how the input patch is to be transformed to perform the adjustment. The displacement vector field may take any of the forms discussed above. The editing instructions are not limited to displacement vector fields, however. Other

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editing operations may additionally or alternatively be associated with the features vectors to perform other desired adjustments of the digital representation (e.g. image) of the head region, including for example adjustments to pixel colors or intensities, or changes to underlying geometries (e.g. via a filter field, brightness adjustment field, or texture blending field).

[119] In an embodiment, a first editing algorithm (e.g. first image editing algorithm) is used by the first machine learning algorithm to define how the first editing instructions are to be applied to an input patch to derive an output patch. A second editing algorithm (e.g. second image editing algorithm) is used by the second machine learning algorithm to define how the second editing instructions are to be applied to an input patch to derive an output patch. The first and second editing algorithms may comprise any of the methods described above for implemented step S5 of FIGURE 3, described with reference to FIGURES 6 and 7.

[120] In an embodiment, the second editing instructions in the second reference data are provided in a compressed representation. The compressed representation may comprise a principle component analysis representation or a wavelet representation for example. In this case, the first and second editing algorithms may be adapted to define how to operate efficiently in this context.

[121] In an embodiment, the second editing instructions are principle component analysis components of a principle component analysis of the first editing instructions. The second editing algorithm in this case transforms the second editing instructions into the first editing instructions by inverse principle component analysis transform.

[122] In an alternative approach, the second editing instructions are wavelet components of the first editing instructions. The second editing algorithm in this case transforms the second editing instructions into the first editing instructions by inverse wavelet transform.

[123] In an embodiment, the first selection instructions for the first reference data are able to select between a larger number of alternative editing instructions (e.g. image editing instructions) than the second selection instructions for the second reference data. The first machine learning algorithm may thus be described as having more input parameters than the second machine learning algorithm. The first machine learning algorithm may provide higher accuracy than the second machine learning algorithm but will typically operate considerably slower. Additionally, the first selection instructions may be significantly more complex (e.g. involving linear algebra

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or other relatively computer intensive operations) than the second selection instructions (where the selection instructions may resemble a computationally straightforward look-up table, a combination of a look-up table and a tree structure, or similar).

[124] In one particular embodiment, the first machine learning algorithm comprises a neural network (known to provide relatively high accuracy, but at the expense of relatively high computational demands). In such an embodiment, and others, the second machine learning algorithm may comprises a regression forest (known to provide higher computational efficiency, but at the expense of reduced accuracy). The inventors have found that the combination of the two different machine learning algorithms provides reference data that can be used in an adjustment method with high efficiency while still achieving high adjustment accuracy. The first machine learning algorithm may alternatively comprise a support vector machine or a generative adversarial network (GAN). The second machine learning algorithm may alternatively comprise regression ferns, cluster centres, a lookup table, or separable filter banks. In one embodiment, the first machine learning algorithm comprises a first neural network and the second machine learning algorithm comprises a second neural network, wherein the second neural network comprises fewer layers and/or smaller convolution fields than the first neural network.

[125] **FIGURE 9** schematically depicts data flow in a detailed example of the method of generating reference data of FIGURE 8. The first and second machine learning algorithms are respectively labelled MLA1 and MLA2. The first machine learning algorithm MLA1 receives the training data (labelled TD) and, optionally, the first editing algorithm EA1, and a similarity metric SM. The similarity metric SM provides a numerical value to measure similarity between an adjusted image and a desired image and can be used to control the first machine learning algorithm MLA1 and the second machine learning algorithm MLA2 to vary the extent to which differences are penalized according to the nature of the differences. For example, the similarity metric SM may be configured to penalize reductions in portions of images that it is desired to maintain (e.g. sclera in the case where eye regions are being adjusted) or deviations of adjusted features from a known form (e.g. deviations in the shape of an iris from an elliptical form) or from a form that is observed in training data. Alternatively or additionally, the training data may comprise an average absolute or square difference between the adjusted image and a target, or average absolute or square difference between low level representations of the adjusted image

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and target, such as low level features from a deep learning network (as discussed above). In the example shown, the first editing algorithm EA1 receives auxiliary data AuxD, which defines a basis set used for providing a compressed representation of image editing instructions. The first machine learning algorithm MLA1 outputs first selection instructions LA1 and first editing instructions ED1. The second machine learning algorithm MLA2 receives the same training data TD and, optionally, the second editing algorithm EA2, and the similarity metric SM. The second machine learning algorithm MLA2 additionally receives the first editing instructions ED1. The second machine learning algorithm outputs second selection instructions LA2 and second editing instructions ED2.

[126] The second machine learning algorithm MLA2 thus gets the editing instructions to match or to approximate, and does not have to infer these from the matched input images as MLA1.

[127] **FIGURE 10** depicts a device 110 for generating the reference data. The device 110 comprises a data processing unit 120 configured to perform the method of generating the reference data according to any of the disclosed embodiments. The data processing unit 110 may be implemented by a processor executing a suitable computer program or by dedicated hardware or by some combination of software and hardware. Data input/output may be provided via a communications interface 112. Where a computer program is used, the computer program may comprise instructions in any suitable language and may be stored on a computer readable storage medium, which may be of any type, for example: a recording medium which is insertable into a drive of the computing system and which may store information magnetically, optically or opto-magnetically; a fixed recording medium of the computer system such as a hard drive; or a computer memory.

[128] **FIGURE 11** depicts a method of adjusting a digital representation of a head region. In the example shown, the digital representation comprises an image of a head region, but the method can be adapted to use any of the digital representations discussed above (e.g. to additionally or alternatively process three-dimensional digital representations). The method may use reference data generated using any of the methods of generating reference data disclosed herein or may use reference data generated using other methods.

[129] The method comprises a step S200 in which a target patch (in this case an image patch) is identified in an image 200 of a head region that is to be adjusted. The target patch comprises a

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target feature of the head region. The target feature may take any of the forms discussed above. The step S200 may optionally comprise detecting a head and/or eye location as described above with reference to step S1 of FIGURE 3. The step S200 may optionally further comprise identifying image patches using the methodology described above with reference to steps S2-1 and S2-2 of FIGURE 5, except that the image patches do not necessarily need to be identified as stereoscopic pairs (although they may be if desired).

[130] In step S201, a feature vector is derived from plural local descriptors (e.g. local image descriptors) of the target (e.g. image) patch. The feature vector may be derived using the methodology described above with reference to step S3 of FIGURE 3. The feature vector may take any of the forms discussed above.

[131] In step S202, the feature vector is used to select editing instructions (e.g. image editing instructions) from reference data 102. The reference data 102 comprising editing instructions for a range of possible values of the feature vector (representing for example different gaze directions and/or eye morphologies in the case where the target feature comprises an eye region).

[132] In step S203, the selected editing instructions are applied to the target patch to adjust the image of the head region (e.g. to correct a gaze direction).

[133] In an embodiment, the editing instructions (e.g. image editing instructions) are provided in a compressed representation, comprising for example one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centers. The use of a compressed representation reduces data storage and bandwidth requirements during use of the image editing instructions to perform adjustment of the digital representation (e.g. image) of the head region. Alternatively or additionally, the reference data containing the editing instructions may be generated using any of the embodiments disclosed herein. The reference data may comprise the second reference data discussed above for example.

[134] Reference to editing instructions herein is understood to encompass any data which can be used to define how a digital representation (e.g. image) of a head region should be adjusted to achieve a desired aim (e.g. gaze correction or conversion from a two-dimensional digital representation to a three-dimensional digital representation or both). The editing instructions may comprise data that can used directly to modify a digital representation (e.g. image), such as

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a vector field, or intermediate data such as a machine learning parameter set that can be used to generate data that can be used directly to modify the digital representation (e.g. image).

[135] **FIGURE 12** schematically depicts data flow in a detailed example of a method of adjusting a digital representation of a head region in the case where the digital representation comprises an image, using reference data generated according to the detailed example of FIGURE 9. Input data ID is provided from a sensor system SS (e.g. comprising one or more cameras). The input data ID is input to the second selection instructions LA2 to select editing instructions appropriate to the input data ID from the second editing instructions ED2. The selected editing instructions, which in this example are provided in a compressed representation (e.g. principle component analysis components or wavelet components) from the compressed second editing instructions ED2, are then used by the second editing algorithm EA2, in combination with the auxiliary data AuxD providing the basis set for the compressed representation, to provide output data OD. The output data OD comprises an adjusted image of the head region and is displayed via a display DS.

[136] As described above, the method of adjusting a digital representation of a head region (e.g. an image of a head region) may be implemented in an image processor 30 provided in various different devices. By way of non-limitative example, there will now be described a particular implementation in a telecommunications system which is shown in **FIGURE 13** and arranged as follows.

[137] In this implementation, the source device 10 and the destination device 10 communicate over such a telecommunications network 50. For communication over the telecommunications network 50, the source device 10 includes a telecommunications interface 17 and the destination device 20 includes a telecommunications interface 27.

[138] In this implementation, the image processor 30 is provided in the source device 10 and is provided with an image of a head region directly from a camera system 12 (in this example, a stereoscopic pair of images). The telecommunications interface 17 is arranged to transmit the adjusted images 38 over the telecommunications network 50 to the destination device 20 for display thereon.

[139] The destination device 20 includes an image display module 28 that controls the display 26. The adjusted images 38 are received in the destination device 20 by the telecommunications

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interface 27 and supplied to the image display module 28 which causes them to be displayed on the display 26.

[140] The following elements of the destination device 20 are optionally included in the case that the method corrects gaze for a destination observer 24 in an observer location other than a normal viewing position perpendicular to the center of the display location. In this case, the destination device 20 includes a camera system 23 and an observer location module 29. The camera system 23 captures an image of the destination observer 24. The observer location module 29 derives the location data 40. The observer location module 29 includes a head tracking module that uses the output of the camera system 23 to detect the location of the destination observer 24. Where the relative observer location also takes into account the location of the image displayed on the display 21, the observer location module 29 obtains the location of the image displayed on the display 21 from the image display module 28. The telecommunications interface 17 is arranged to transmit the location data 40 over the telecommunications network 50 to the source device 10 for use thereby.

[141] Although the above description refers to a method applied to images supplied from a source device 10 to a destination device 20, the method may equally be applied to images supplied in the opposite direction from the destination device 20 to the source device 10, in which case the destination device 20 effectively becomes the "source device" and the source device 10 effectively becomes the "destination device". Where images are supplied bi-directionally, the labels "source" and "destination" may be applied to both devices, depending on the direction of communication being considered.

[142] **FIGURE 14** depicts a further embodiment of a method of generating reference data for adjusting a digital representation of a head region using a framework of the type depicted in FIGURE 8. In this embodiment, the training data 100 received in step S100 (FIGURE 8) comprises a set of input digital representations of a head region (e.g. input patches each consisting of a target portion of a two-dimensional digital representation of the head region, such as a captured image).

[143] In step S101, a first machine learning algorithm MLA1 is trained using the training data 100, the training causing the first machine learning algorithm MLA1 to become capable of performing an adjustment of a digital representation of a head region. In an embodiment, the

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adjustment of the digital representation comprises converting from a two-dimensional digital representation to a three-dimensional digital representation (e.g. converting from a 2D image of a portion of a head region to a 3D mesh of a portion of the head region). The trained first machine learning algorithm MLA1 is then used to generate first reference data 101. The first reference data 101 comprises an adjusted digital representation of the head region for each of at least a subset of the input digital representations in the training data 100. Each adjusted digital representation is obtained by performing the adjustment that the first machine learning algorithm MLA1 was trained to perform.

[144] In step S102, a second machine learning algorithm MLA2 is trained using at least a subset of the training data 100 used to train the first machine learning algorithm MLA2 and the first reference data 101. The training causes the second machine learning algorithm MLA2 to become capable of performing the same adjustment of a digital representation of a head region as the first machine learning algorithm MLA1.

[145] In the particular embodiment of FIGURE 14, the first machine learning algorithm MLA1 comprises a first encoder 306A and a first predictor 308A. The training data 100 is input to the first encoder 306A. In this embodiment, the first encoder 306A comprises a feature extractor algorithm. The feature extractor algorithm derives informative and non-redundant values from the training data 100 (i.e. extracts meaningful features from the training data 100). Examples of feature extractor algorithms include Convolutional Neural Networks, Principal Component Analysis, SIFT (Scale Invariant Feature Transform). An output from the first encoder 306A is input to a first predictor 308A. The first predictor 308A generates an adjusted version of each input digital representation in the training data 100 based on the output of the first encoder 306A (e.g. features extracted by the first encoder 306A). In this embodiment, each input digital representation comprises a two-dimensional digital representation (e.g. a two-dimensional image) and the adjusted version of each input digital representation comprises a three-dimensional digital representation (e.g. a mesh). Each three-dimensional digital representation is input to a renderer 310. The renderer 310 synthesizes one or more two-dimensional digital representations corresponding to each input three-dimensional digital representation (e.g. one or more photorealistic images of the head region defined by the three-dimensional digital representation). The output from the renderer 310 is then input to a second encoder 306B. The

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second encoder 306B may be identical to the first encoder 306A. An output from the second encoder 306B is input to a second predictor 308B. The second predictor 308B may be identical to the first predictor 308A. A first regularizer 314 is provided that compares the output from the first encoder 306A with the output from the second encoder 306B and imposes one or more predetermined first constraints. A second regularizer 316 is provided that compares the output from the first predictor 308A with the output from the second predictor 308B and imposes one or more predetermined second constraints. The first regularizer 314 and the second regularizer 316 may use a set of semantically meaningful constraints (examples of the first constraints and second constraints) or additional information to help reach a desirable solution and to prevent overfitting. The constraints may help to ensure that generated three-dimensional digital representations are natural looking for example, by requiring high levels of natural levels of smoothness. Using this architecture, the first machine learning algorithm MLA1 iteratively updates properties of the first predictor 308A and the second predictor 308B (e.g. by adjusting parameters such as weights defining the operation of the predictor) to maximize matching between the outputs from the first and second encoders (as measured by the first regularizer 314) subject to the first constraints and to maximize matching between the outputs from the first and second predictors (as measured by the second regularizer 316) subject to the second constraints. In other embodiments, the first encoder 306A and second encoder 306B may also be iteratively updated. The training of the first machine learning algorithm MLA1 thus comprises iteratively using a rendering process to generate a two-dimensional digital representation from a three-dimensional digital representation generated by the first machine learning algorithm MLA1 and comparing the generated digital representation with a corresponding digital representation in the training data. Once matching has been achieved or a predetermined number of iterations have been performed, the first machine learning algorithm MLA1 is considered trained and the resulting output from the second predictor 308B can be used to provide the first reference data 101 (which in this embodiment comprises three-dimensional digital representations corresponding to the input two-dimensional representations in the training data 100).

[146] As an extension, new two-dimensional and/or three-dimensional digital representations can be generated by applying editing instructions either to two-dimensional digital representations (which are converted to three-dimensional digital representations by the trained

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first machine learning algorithm MLA1) or to three-dimensional digital representations output by the trained first machine learning algorithm MLA1). In this case, the first reference data 101 may include the two-dimensional digital representations and/or three-dimensional representations after modification by the editing instructions.

[147] A set of thus generated three-dimensional digital representations output as first reference data 101 and corresponding two-dimensional digital representations (e.g. directly from the training data 100 as shown in FIGURE 14) are used to train the second machine learning algorithm MLA2 (input at block 304). In this embodiment, the second machine learning algorithm MLA2 also comprises an encoder 306C and a predictor 308C, which may be configured as described above for the first machine learning algorithm MLA1. The predictor 308C (and, optionally, the encoder 308C) may be iteratively updated (trained) using a regularizer 318 based on the input training data 100 and first reference data 101. Thus, the second machine learning algorithm MLA2 learns to convert between a two-dimensional digital representation and a three-dimensional digital representation based on the mapping between two-dimensional digital representations and three-dimensional digital representations derived using the renderer 310 in the first machine learning algorithm MLA1. Provided the mapping derived by the first machine learning algorithm MLA1 is reliable, the second machine learning algorithm MLA2 will be able to provide accurate conversion between two-dimensional digital representations and three-dimensional digital representations using a simpler trained machine learning model (which can be stored and operated using fewer computing resources than the first machine learning algorithm MLA1).

[148] **FIGURE 15** depicts data flow in an example implementation of an embodiment in which a pre-trained second machine learning algorithm MLA2 is updated (i.e. trained further) in at or near input data frame rate (i.e. online). In embodiments of this type, a plurality of the digital representations (e.g. images) of the head region may be received as input data ID (e.g. from a sensor system SS as described above) and adjusted (e.g. as described above with reference to FIGURES 11, 12 and 14) to provide output data OD that is subsequently displayed via display DS (as described above with reference to FIGURE 12). The input data ID may comprise a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target

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feature is the same for each input patch. The adjustment may be performed using a pre-trained version of the second machine learning algorithm MLA2, optionally in combination with a geometrical model. The input data ID may comprise digital representations captured at different points in times, such as different frames in a sequence of images obtained by the sensor system SS in a video capture mode. In an embodiment, the method comprises updating the pre-trained second machine learning algorithm MLA2 using first reference data (e.g. editing instructions) generated by the first machine learning algorithm MLA1 using one or more of the received digital representations (from the input data ID). The first reference data may comprise a set of editing instructions in one-to-one correspondence with the input patches, each editing instruction being for adjusting the digital representation of the head region. In the example depicted in FIGURE 15, the first reference data for the updating is generated in a background process and the second machine learning algorithm MLA2 is updated at or near input data frame rate (i.e. online).

[149] The updating thus uses a pre-trained version of the first machine learning algorithm MLA1 (which, as described above, is configured to provide more highly detailed reference data at the expense of higher computational demands, relative to the second machine learning algorithm MLA2) to generate first reference data that is used to update the second machine learning algorithm MLA2. Where the first machine learning algorithm MLA1 is slower than the second machine learning algorithm MLA2 (which will normally be the case where the first machine learning algorithm MLA1 is configured to provide more highly detailed reference data than the second machine learning algorithm MLA2), only a subset of the input data ID (comprising the received and adjusted digital representations) are used to update the second machine learning algorithm MLA2, thereby allowing the updating process to keep up with the adjusting of the input data ID by the second machine learning algorithm MLA2 to provide the output data OD. Any of various known techniques may be used to perform the updating of the second machine learning algorithm MLA2. For example, the online updating may be performed as described in Amir Saffari, Christian Leistner, Jakob Santner, Martin Godec, and Horst Bischof, "On-line Random Forests," in 3rd IEEE ICCV Workshop on On-line Computer Vision, 2009, which is herein incorporated by reference in its entirety, or as described in Online Deep Learning: Learning Deep Neural Networks on the Fly, Doyen Sahoo, Quang Pham, Jing Lu,

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Steven C.H., Hoi School of Information Systems, Singapore Management University (https://arxiv.org/pdf/1711.03705.pdf), which is herein incorporated by reference in its entirety. The second machine learning algorithm MLA2 can therefore be gradually improved during use, as more input data ID are encountered and processed by the system.

[150] Additional embodiments of the disclosure are described in the following numbered clauses.

1. A method of generating reference data for adjusting an image of a head region, the method comprising:

receiving training data comprising:

a set of input image patches, each input image patch comprising a target feature of an image of a head region prior to adjustment of the image of the head region, wherein the target feature is the same for each input image patch; and

a set of output image patches in one-to-one correspondence with the input image patches, each output image patch comprising the target feature of the image of the head region after adjustment of the image of the head region;

using a first machine learning algorithm to generate first reference data using the training data, the first reference data comprising image editing instructions for adjusting the image of the head region for a range of possible images of the head region; and

using a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm, the second reference data comprising image editing instructions for adjusting the image of the head region for a range of possible images of the head region.

2. The method of clause 1, wherein:

the first reference data comprise first image editing instructions for a range of possible configurations of the target feature and first selection instructions for selecting image editing instructions for a particular input image patch from the first image editing instructions based on the configuration of the target feature of the input image patch; and

the second reference data comprise second image editing instructions for a range of possible configurations of the target feature and second selection instructions for selecting image

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editing instructions for a particular input image patch from the second image editing instructions based on the configuration of the target feature of the input image patch.

3. The method of clause 2, wherein the configuration of the target feature of each input image patch is represented by a feature vector derived from plural local image descriptors of the input image patch, and the first and second selection instructions define how the feature vector is used to select image editing instructions for the input image patch.

4. The method of clause 2 or 3, wherein the image editing instructions comprise a displacement vector field defining how the input image patch is to be transformed.

5. The method of clause 2 or 3, wherein the image editing instructions comprise a filter field, a brightness adjustment field, or a texture blending field.

6. The method of any of clauses 2-5, wherein:

a first image editing algorithm is used by the first machine learning algorithm to define how the first image editing instructions are to be applied to an input image patch to derive an output image patch; and

a second image editing algorithm is used by the second machine learning algorithm to define how the second image editing instructions are to be applied to an input image patch to derive an output image patch.

7. The method of clause 6, wherein:

the second image editing instructions are principle component analysis components of a principle component analysis of the first image editing instructions; and

the second image editing algorithm is configured to transform the second image editing instructions into the first image editing instructions by inverse principle component analysis transform.

8. The method of clause 6, wherein:

the second image editing instructions are wavelet components of the first image editing instructions; and

the second image editing algorithm is configured to transform the second image editing instructions into the first image editing instructions by inverse wavelet transform.

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9. The method of any of clauses 2-8, wherein the first selection instructions for the first reference data are able to select between a larger number of alternative image editing instructions than the second selection instructions for the second reference data.

10. The method of any preceding clause, wherein the first machine learning algorithm is of a different machine learning algorithm type than the second machine learning algorithm.

11. The method of any preceding clause, wherein the first machine learning algorithm comprises one or more of the following: a neural network; a support vector machine; a generative adversarial network, GAN.

12. The method of any preceding clause, wherein the second machine learning algorithm comprises one or more of the following: a regression forest; regression ferns, cluster centres, a lookup table, separable filter banks.

13. The method of any of clauses 1-10, wherein the first machine learning algorithm comprises a first neural network and the second machine learning algorithm comprises a second neural network, wherein the second neural network comprises fewer layers and/or smaller convolution fields than the first neural network.

14. The method of any preceding clause, wherein the target feature comprises one or more of the following: an eye region comprising at least part of an eye, a nose region comprising at least part of a nose, a mouth region comprising at least part of a mouth, a chin region comprising at least part of a chin, a neck region comprising at least part of a neck, and a hair region comprising hair.

15. The method of any of clauses 1-13, wherein:

the target feature comprises an eye region comprising at least part of an eye and the adjustment of the image of the head region comprises adjusting a gaze direction;

the target feature comprises a nose region comprising at least part of a nose and the adjustment of the image of the head region comprises adjusting a shape and/or texture of the nose;

the target feature comprises a chin region comprising at least part of a chin and the adjustment of the image of the head region comprises adjusting a shape and/or texture of the chin;

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the target feature comprises a neck region comprising at least part of a neck and the adjustment of the image of the head region comprises adjusting a shape and/or texture of the neck; and/or

the target feature comprises a hair region comprising hair and the adjustment of the image of the head region comprises adjusting a color of the hair.

16. The method of any preceding clause, wherein the second image editing instructions in the second reference data are provided in a compressed representation.

17. The method of clause 16, wherein the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centres.

18. A method of adjusting an image of a head region, the method comprising:

identifying an image patch in the image of the head region, the image patch comprising a target feature of the image of the head region;

deriving a feature vector from plural local image descriptors of the image patch;

using the feature vector to select image editing instructions from reference data, the reference data comprising image editing instructions for a range of possible values of the feature vector; and

applying the selected image editing instructions to the image patch to adjust the image of the head region, wherein:

the reference data comprises the second reference data generated by the method of any of clauses 1-17.

19. A method of adjusting an image of a head region, the method comprising:

identifying an image patch in the image of the head region, the image patch comprising a target feature of the image of the head region;

deriving a feature vector from plural local image descriptors of the image patch;

using the feature vector to select image editing instructions from reference data, the reference data comprising image editing instructions for a range of possible values of the feature vector; and

applying the selected image editing instructions to the image patch to adjust the image of the head region, wherein:

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the image editing instructions in the reference data are provided in a compressed representation.

20. The method of clause 19, wherein the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centres.

21. A computer program capable of execution by a processor and arranged on execution to cause the processor to perform a method according to any of the preceding clauses.

22. A computer readable storage medium storing a computer program according to clause 21.

23. A device for generating reference data for adjusting an image of a head region, the device comprising a data processing unit arranged to:

receive training data comprising:

a set of input image patches, each input image patch comprising information about a target feature of an image of the head region prior to adjustment of the image of the head region, wherein the target feature is the same for each input image patch; and

a set of output image patches in one-to-one correspondence with the input image patches, each output image patch comprising the target portion of the image of the head region after adjustment of the image of the head region;

use a first machine learning algorithm to generate first reference data using the training data; and

use a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data output by the first machine learning algorithm.

24. A device for adjusting an image of a head region, the device comprising an image processor arranged to process the image of the head region by:

identifying an image patch in the image of the head region, the image patch comprising information about a target feature of the image of the head region;

deriving a feature vector from plural local image descriptors of the image patch;

using the feature vector to select image editing instructions from reference data, the reference data comprising image editing instructions for a range of possible values of the feature vector; and

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applying the selected image editing instructions to the image patch to adjust the image of the head region, wherein:

the image editing instructions in the reference data are provided in a compressed representation.

25. The device of clause 24, further comprising a telecommunications interface arranged to transmit the adjusted image over a telecommunications network to a destination device for display thereon.

[151] 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.

[152] 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 embodiment(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 "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:

1. A method of generating reference data for adjusting a digital representation of a head region, the method comprising:

receiving training data comprising:

a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and

a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target feature of the digital representation of the head region after adjustment of the digital representation of the head region;

using a first machine learning algorithm to generate first reference data using the training data, the first reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region; and

using a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data generated by the first machine learning algorithm, the second reference data comprising editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region.

2. The method of claim 1, wherein:

the first reference data comprise first editing instructions for a range of possible configurations of the target feature and first selection instructions for selecting editing instructions for a particular input patch from the first editing instructions based on the configuration of the target feature of the input patch; and

the second reference data comprise second editing instructions for a range of possible configurations of the target feature and second selection instructions for selecting editing instructions for a particular input patch from the second image editing instructions based on the configuration of the target feature of the input patch.

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3. The method of claim 2, wherein the configuration of the target feature of each input patch is represented by a feature vector derived from plural local descriptors of the input patch, and the first and second selection instructions define how the feature vector is used to select editing instructions for the input patch.

4. The method of claim 2 or 3, wherein the editing instructions comprise a displacement vector field defining how the input patch is to be transformed.

5. The method of claim 2 or 3, wherein the editing instructions comprise a filter field, a brightness adjustment field, or a texture blending field.

6. The method of any of claims 2-5, wherein:

a first editing algorithm is used by the first machine learning algorithm to define how the first editing instructions are to be applied to an input patch to derive an output patch; and

a second editing algorithm is used by the second machine learning algorithm to define how the second editing instructions are to be applied to an input patch to derive an output patch.

7. The method of claim 6, wherein:

the second editing instructions are principle component analysis components of a principle component analysis of the first editing instructions; and

the second image editing algorithm is configured to transform the second editing instructions into the first editing instructions by inverse principle component analysis transform.

8. The method of claim 6, wherein:

the second editing instructions are wavelet components of the first editing instructions; and

the second editing algorithm is configured to transform the second editing instructions into the first editing instructions by inverse wavelet transform.

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9. The method of any of claims 2-8, wherein the first selection instructions for the first reference data are able to select between a larger number of alternative editing instructions than the second selection instructions for the second reference data.

10. The method of any preceding claim, wherein the first machine learning algorithm is of a different machine learning algorithm type than the second machine learning algorithm.

11. The method of any preceding claim, wherein the first machine learning algorithm comprises one or more of the following: a neural network; a support vector machine; a generative adversarial network, GAN.

12. The method of any preceding claim, wherein the second machine learning algorithm comprises one or more of the following: a regression forest; regression ferns, cluster centres, a lookup table, separable filter banks.

13. The method of any of claims 1-10, wherein the first machine learning algorithm comprises a first neural network and the second machine learning algorithm comprises a second neural network, wherein the second neural network comprises fewer layers and/or smaller convolution fields than the first neural network.

14. The method of any preceding claim, wherein the target feature comprises one or more of the following: an eye region comprising at least part of an eye, a nose region comprising at least part of a nose, a mouth region comprising at least part of a mouth, a chin region comprising at least part of a chin, a neck region comprising at least part of a neck, and a hair region comprising hair.

15. The method of any of claims 1-13, wherein:

the target feature comprises an eye region comprising at least part of an eye and the adjustment of the digital representation of the head region comprises adjusting a gaze direction;

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the target feature comprises a nose region comprising at least part of a nose and the adjustment of the digital representation of the head region comprises adjusting a shape and/or texture of the nose;

the target feature comprises a chin region comprising at least part of a chin and the adjustment of the digital representation of the head region comprises adjusting a shape and/or texture of the chin;

the target feature comprises a neck region comprising at least part of a neck and the adjustment of the digital representation of the head region comprises adjusting a shape and/or texture of the neck; and/or

the target feature comprises a hair region comprising hair and the adjustment of the digital representation of the head region comprises adjusting a color of the hair.

16. The method of any preceding claim, wherein the second editing instructions in the second reference data are provided in a compressed representation.

17. The method of claim 16, wherein the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centers.

18. A method of adjusting a digital representation of a head region, the method comprising

receiving a digital representation of a head region; and

using reference data comprising editing instructions to adjust the digital representation of the head region, wherein the reference data comprises the second reference data generated by the method of any of claims 1-17.

19. A method of adjusting a digital representation of a head region, the method comprising:

identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region;

deriving a feature vector from plural local descriptors of the target patch;

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using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and

applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein:

the reference data comprises the second reference data generated by the method of any of claims 1-17.

20. A method of adjusting a digital representation of a head region, the method comprising:

identifying a target patch in the digital representation of the head region, the target patch comprising a target feature of the digital representation of the head region;

deriving a feature vector from plural local descriptors of the target patch;

using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and

applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein:

the editing instructions in the reference data are provided in a compressed representation.

21. The method of claim 20, wherein the compressed representation comprises one or more of the following: a principle component analysis representation; a wavelet representation; Fourier and/or discrete cosine transform components; cluster centres.

22. The method of any of claims 18-21, wherein a plurality of the digital representations of the head region are received and adjusted, each digital representation being captured from the head region at a different point in time, and the method further comprises updating the second machine learning algorithm using editing instructions generated by the first machine learning algorithm using one or more of the received and adjusted digital representations.

23. The method of claim 22, wherein the updating of the second machine learning algorithm is performed at or near input data frame rate.

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24. The method of claim 23, wherein only a subset of the received and adjusted digital representations are used to update the second machine learning algorithm.

25. A method of training a machine learning algorithm to adjust a digital representation of a head region, comprising:

receiving training data comprising:

a set of input patches, each input patch comprising a target feature of a digital representation of a head region prior to adjustment of the digital representation of the head region, wherein the target feature is the same for each input patch; and

first reference data generated by a pre-trained first machine learning algorithm, the first reference data comprising a set of editing instructions in one-to-one correspondence with the input patches, each editing instruction being for adjusting the digital representation of the head region;

updating a pre-trained second machine learning algorithm trained to generate second reference data, where the input for the updating comprises the training data and the generated first reference data, the second reference data comprising editing instructions for adjusting the digital representation of the head region.

26. The method of claim 25, wherein the updating of the second machine learning algorithm is performed at or near input data frame rate.

27. A method of training a machine learning algorithm to adjust a digital representation of a head region, the method comprising:

receiving training data comprising a set of input digital representations of a head region;

training a first machine learning algorithm using the training data to perform an adjustment of a digital representation of a head region;

using the trained first machine learning algorithm to generate first reference data, the first reference data comprising an adjusted digital representation of the head region for each of at least a subset of the input digital representations, each adjusted digital representation being

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obtained by performed the adjustment that the first machine learning algorithm was trained to perform; and

training a second machine learning algorithm using at least a subset of the training data used to train the first machine learning algorithm and the first reference data to perform the same adjustment of a digital representation of a head region as the first machine learning algorithm.

28. The method of claim 27, wherein the adjustment of the digital representation comprises converting from a two-dimensional digital representation to a three-dimensional digital representation.

29. The method of claim 28, wherein the training of the first machine learning algorithm comprises iteratively using a rendering process to generate a two-dimensional digital representation from a three-dimensional digital representation generated by the first machine learning algorithm and comparing the generated digital representation with a corresponding digital representation in the training data.

30. The method of any of claims 25-29, further comprising receiving a further digital representation of the head region and using the updated or trained second machining learning algorithm to adjust the further digital representation.

31. A computer program capable of execution by a processor and arranged on execution to cause the processor to perform a method according to any of the preceding claims.

32. A computer readable storage medium storing a computer program according to claim 31.

33. A device for generating reference data for adjusting a digital representation of a head region, the device comprising a data processing unit arranged to:

receive training data comprising:

a set of input patches, each input patch comprising information about a target feature of a digital representation of the head region prior to adjustment of the digital

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representation of the head region, wherein the target feature is the same for each input patch; and

a set of output patches in one-to-one correspondence with the input patches, each output patch comprising the target portion of the digital representation of the head region after adjustment of the digital representation of the head region;

use a first machine learning algorithm to generate first reference data using the training data; and

use a second machine learning algorithm to generate second reference data using the same training data as the first machine learning algorithm and the first reference data output by the first machine learning algorithm.

34. The device of claim 33, wherein:

the first reference data comprises editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region;

the second reference data comprises editing instructions for adjusting the digital representation of the head region for a range of possible digital representations of the head region;

the second editing instructions in the second reference data are provided in a compressed representation.

35. A device for adjusting a digital representation of a head region, the device comprising a data processing unit arranged to process the digital representation of the head region by:

identifying a target patch in the digital representation of the head region, the target patch comprising information about a target feature of the digital representation of the head region;

deriving a feature vector from plural local descriptors of the target patch;

using the feature vector to select editing instructions from reference data, the reference data comprising editing instructions for a range of possible values of the feature vector; and

applying the selected editing instructions to the target patch to adjust the digital representation of the head region, wherein:

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the editing instructions in the reference data are provided in a compressed representation.

36. The device of any of claims 33-35, further comprising a telecommunications interface arranged to transmit the adjusted digital representation over a telecommunications network to a destination device to allow display of the head region thereon.

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Abstract

Methods and devices for generating reference data for adjusting a digital representation of a head region, and methods and devices for adjusting the digital representation of a head region are disclosed. In some arrangements, training data are received. A first machine learning algorithm generates first reference data using the training data. A second machine learning algorithm generates second reference data using the same training data and the first reference data generated by the first machine learning algorithm.

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Fig.1

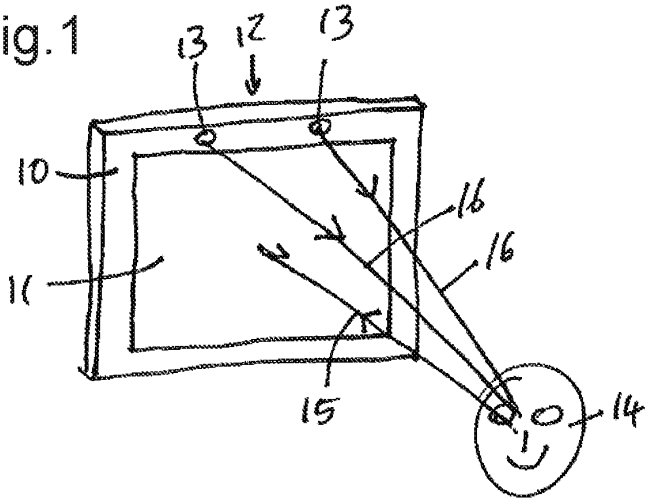
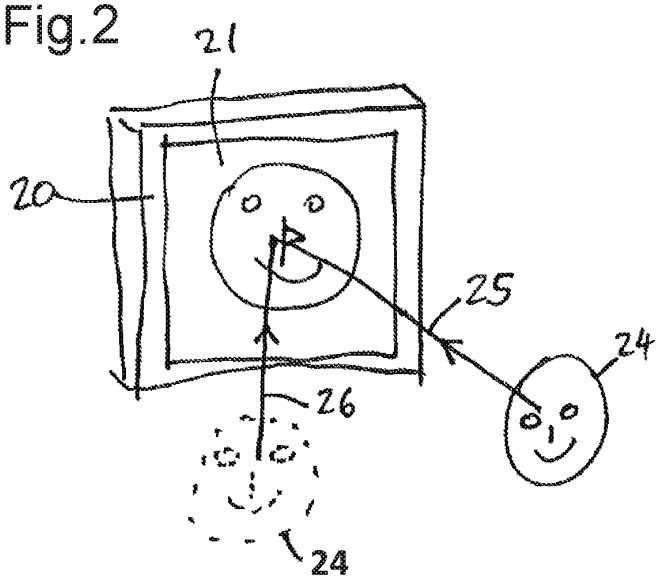


Fig.2



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Fig.3

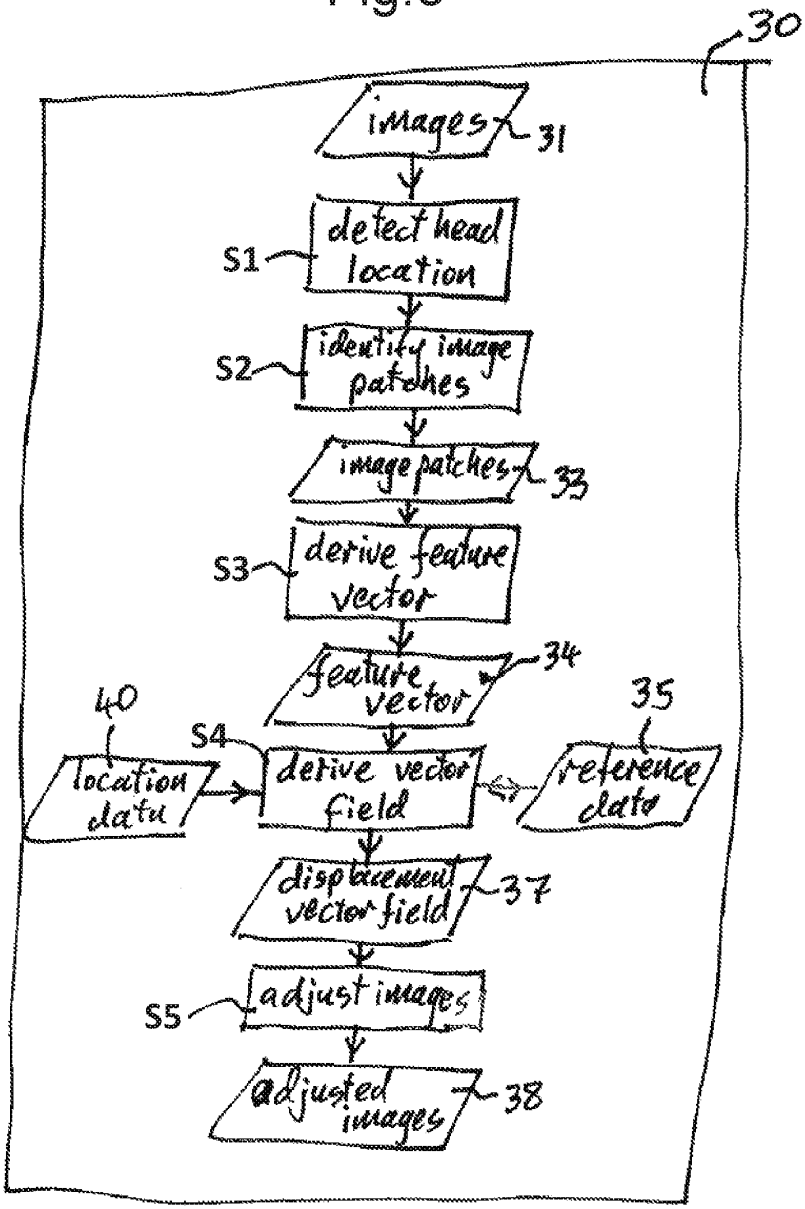
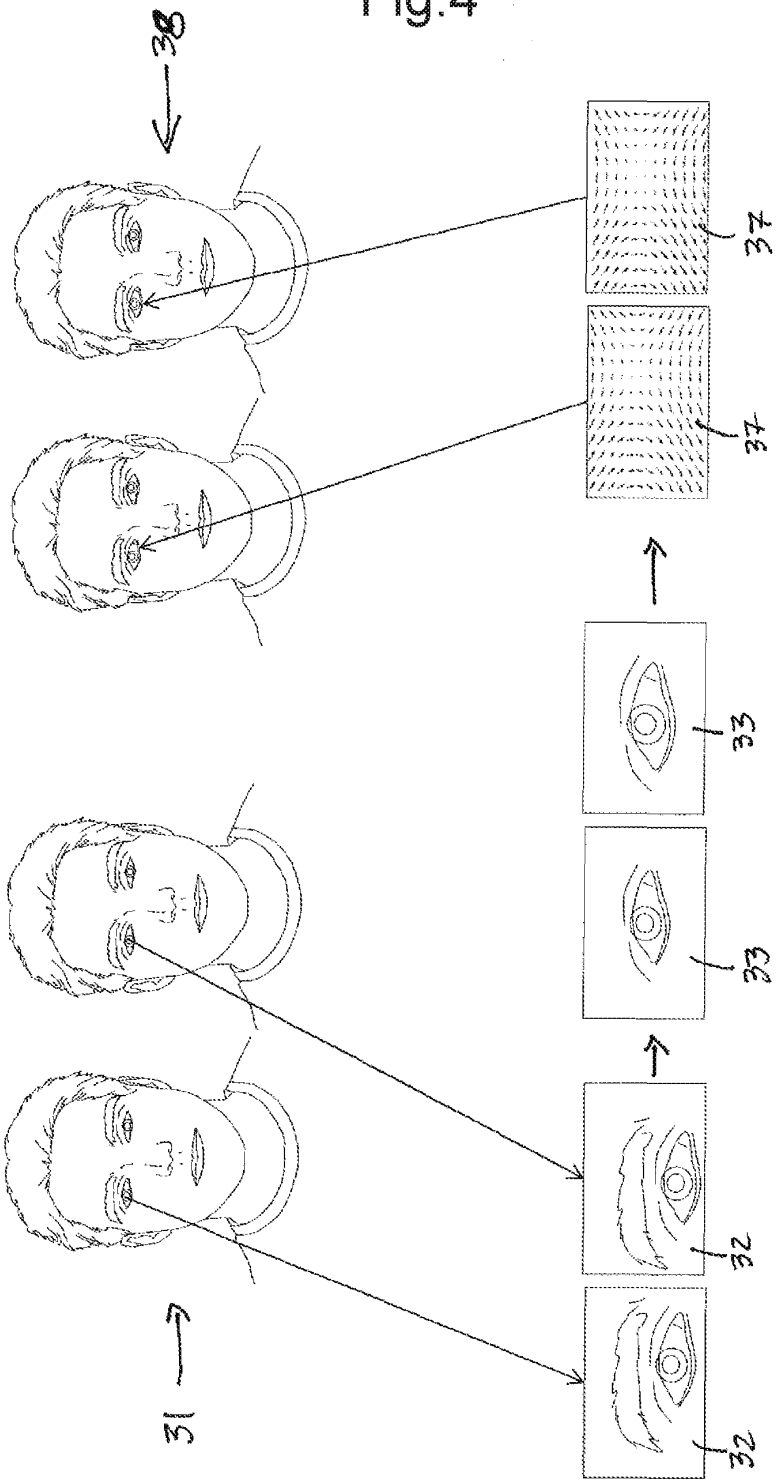

30
images
31
detect head location
S1
identify image patches
S2
image patches
33
derive feature vector
S3
feature vector
34
40
35
S4
location data
derive vector field
reference data
displacement vector field
37
adjust images
S5
adjusted images
38

Fig.4



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Fig.5

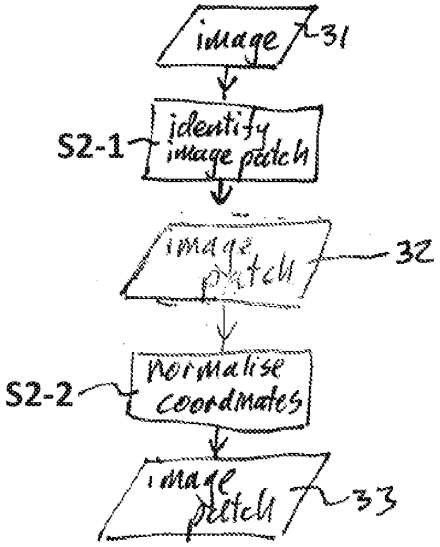
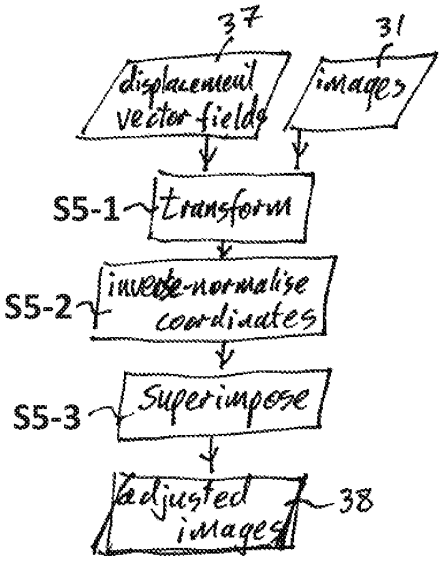
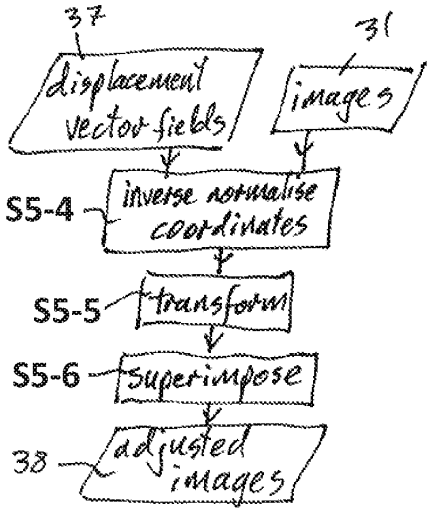


Fig.6



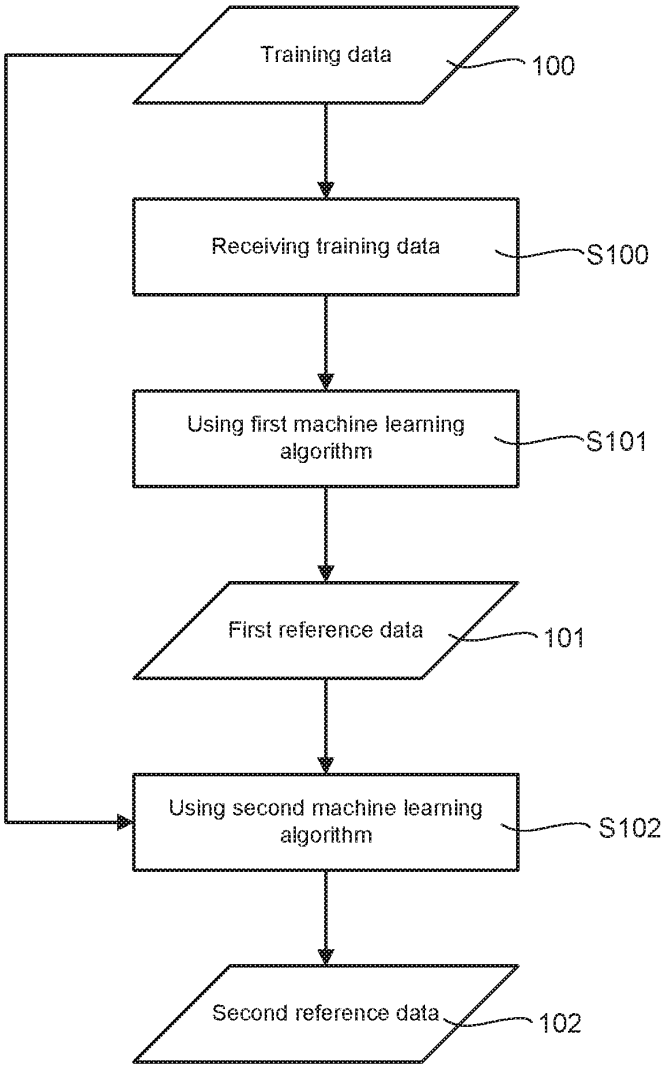
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Fig.7



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Fig.8



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Fig.9

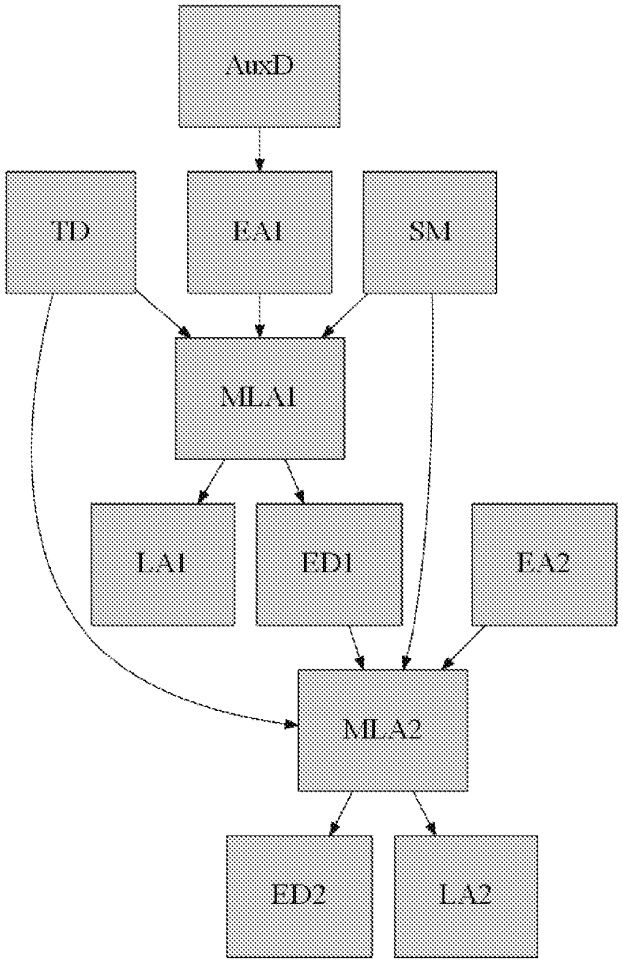


Fig.10

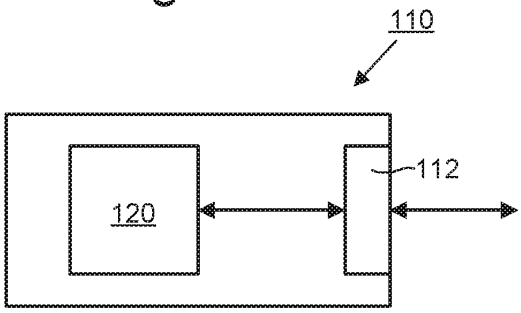

110
120
112

Fig.11

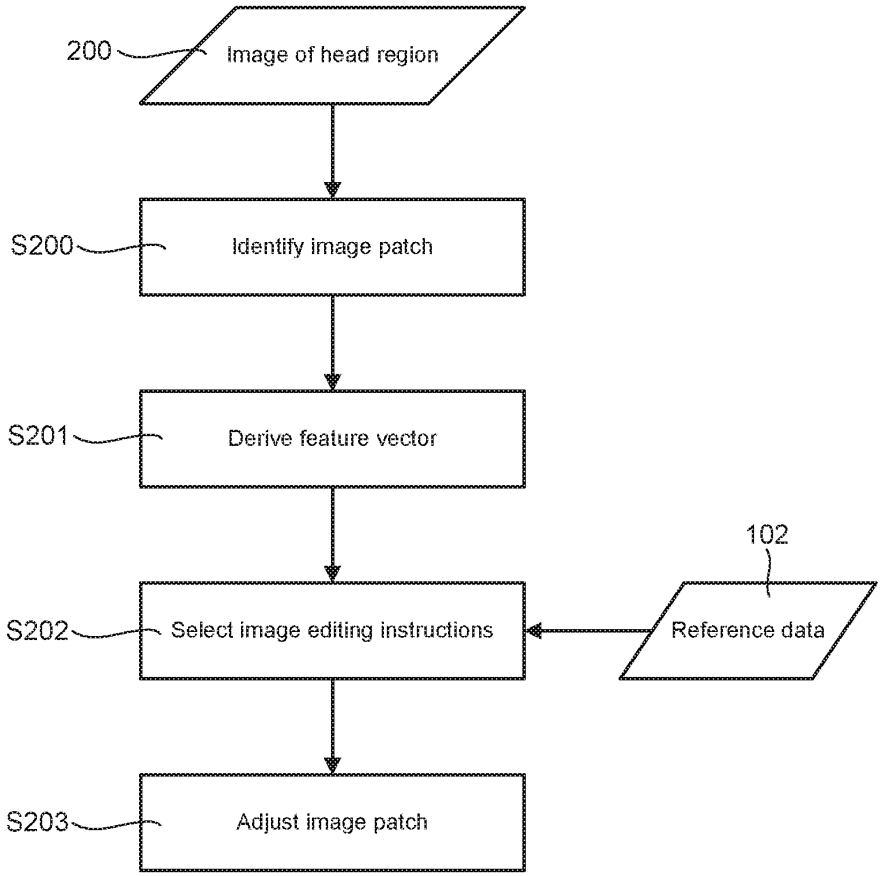

200
Image of head region
S200
Identify image patch
S201
Derive feature vector
102
S202
Select image editing instructions
Reference data
S203
Adjust image patch

Fig.12

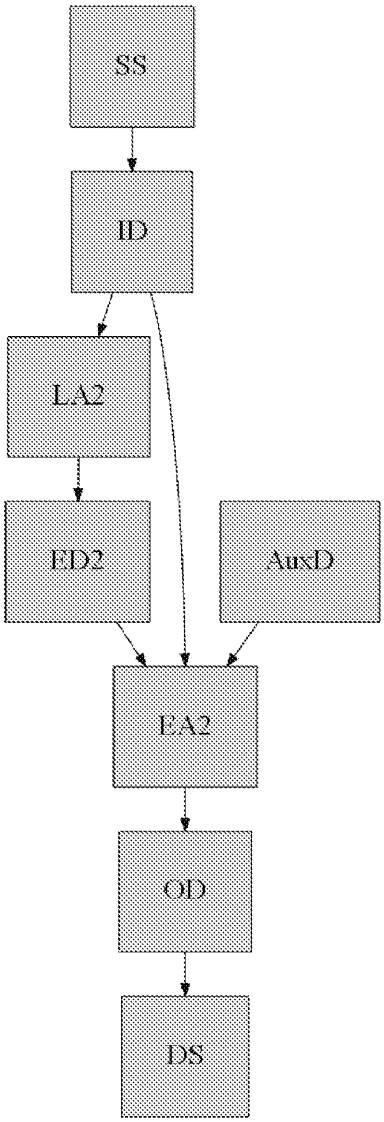


Fig.13

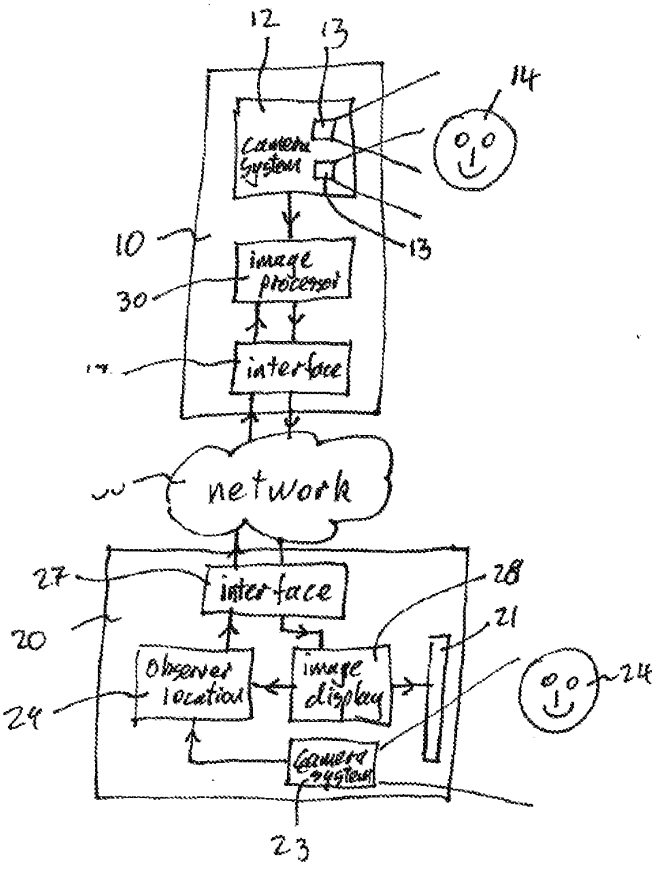

12
13
14
camera system
13
10
image processor
30
interface
network
27
interface
28
21
20
observer location
image display
24
29
camera system
23

Fig.14

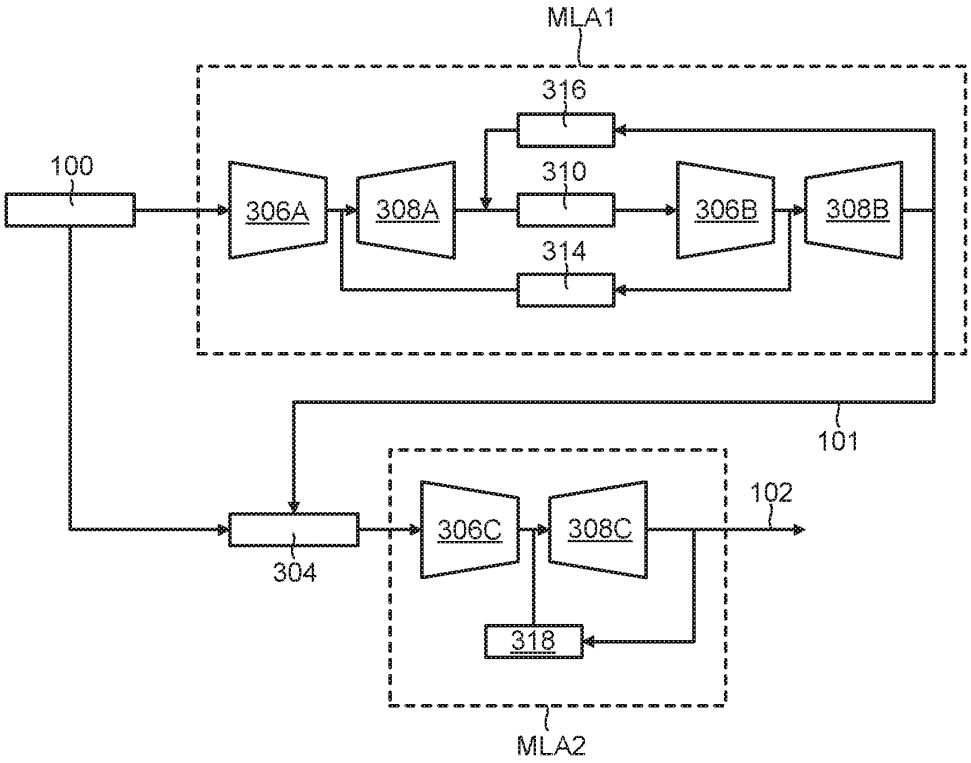
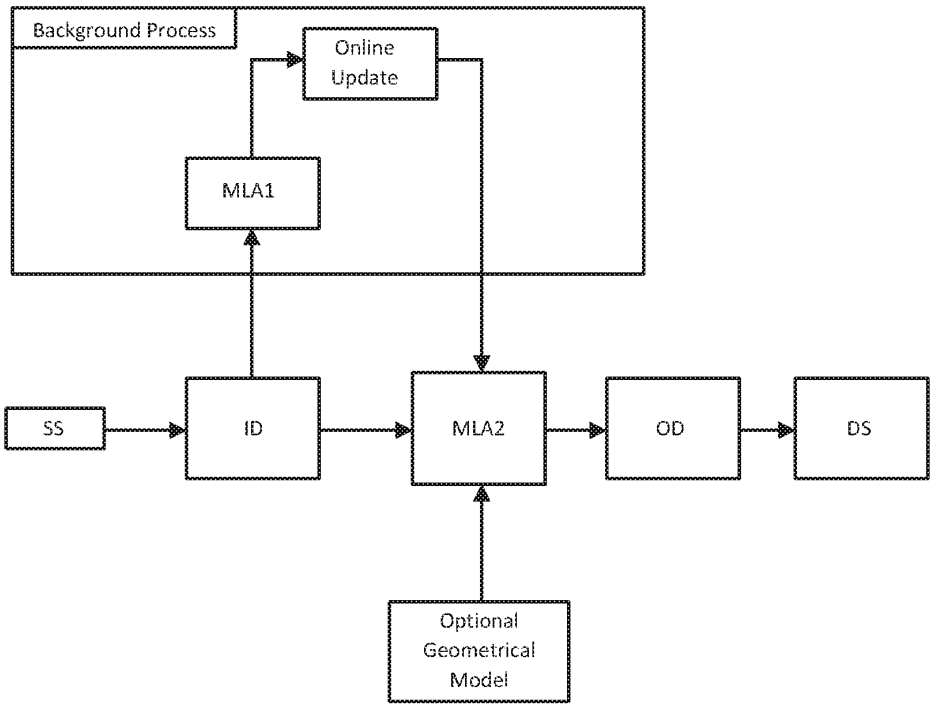

MLA1
316
100
306A
308A
310
306B
308B
314
101
102
306C
308C
304
318
MLA2

Fig.15



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IPR2023-01046 - U.S. Patent No. 10,740,985

Electronic Acknowledgement Receipt

EFS ID:	33396896
Application Number:	16057566
International Application Number:	
Confirmation Number:	5211
Title of Invention:	Adjusting a digital representation of a head region
First Named Inventor/Applicant Name:	Eric Sommerlade
Customer Number:	145234
Filer:	Penny Lea Lowry/Stefan Bump
Filer Authorized By:	Penny Lea Lowry
Attorney Docket Number:	409001
Receipt Date:	07-AUG-2018
Filing Date:	
Time Stamp:	18:15:10
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	WebADS.pdf	129597 ae267f885efe17016b2658f6fc3dbfe425d966a7	no	8

Warnings:

Information:					
2		409001_NPV_Application.pdf	528301 f390d84a61e0d14a93990351300a7a8f95ddeb5d	yes	59

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Specification	1	37
	Claims	38	46
	Abstract	47	47
	Drawings-only black and white line drawings	48	59

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