

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Ezra Eddie Bakhsh
U.S. Patent No.: 9,696,868 Attorney Docket No.: 50095-0110IP1
Issue Date: July 4, 2017
Appl. Serial No.: 14/614,708
Filing Date: February 5, 2015
Title: SYSTEM AND METHOD FOR PROVIDING THREE-
DIMENSIONAL GRAPHICAL USER INTERFACE

DECLARATION OF DR. HENRY FUCHS

I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable under Section 1001 of Title 18 of the United States Code.

By: 
Henry Fuchs, Ph.D.

Date: 2022.12.13

Table of Contents

I.	INTRODUCTION	4
II.	QUALIFICATIONS	4
III.	LEGAL STANDARDS	10
	A. Person of Ordinary Skill in the Art.....	11
	B. Obviousness	11
	C. Claim Interpretation	13
IV.	PERSON OF ORDINARY SKILL IN THE ART	14
V.	MATERIALS CONSIDERED	15
VI.	OVERVIEW OF CONCLUSIONS FORMED	17
VII.	OVERVIEW OF THE '868 PATENT	18
VIII.	CLAIM CONSTRUCTION	23
IX.	OVERVIEW AND COMBINATIONS OF PRIOR ART REFERENCES ..	23
	A. Overview of Anthony	23
	B. Overview of Hanggie.....	28
	C. Combination of Anthony and Hanggie.....	36
	D. Combination of Hanggie and Anthony.....	42
	E. Overview of Matthews.....	46
	F. Combination of Matthews with HAC.....	48
	G. Overview of Robertson.....	49
	H. Combination of Robertson with HAC and Matthews	51
X.	MANNER IN WHICH THE PRIOR ART REFERENCES RENDER THE '868 CLAIMS UNPATENTABLE	53
	A. Claim 1	53
	B. Claim 2.....	78
	C. Claim 3.....	79
	D. Claim 4.....	80
	E. Claim 5.....	85
	F. Claim 6.....	87
	G. Claim 7.....	91
	H. Claim 8.....	93
	I. Claim 9.....	97
	J. Claim 10.....	98
	K. Claim 11.....	105
	L. Claim 12.....	106
	M. Claim 13.....	107

N. Claim 14.....	107
O. Claim 15.....	108
P. Claim 16.....	108
Q. Claim 17.....	108
R. Claim 18.....	109
S. Claim 19.....	109
T. Claim 20.....	112
XI. CONCLUSION.....	112

I. INTRODUCTION

1. I have been retained as a technical expert by counsel on behalf of Apple Inc. (“Apple”/“Petitioner”). I understand that Apple is requesting that the Patent Trial and Appeal Board institute an *inter partes* review (“IPR”) proceeding with respect to U.S. Patent No. 9,696,868 (“the ’868 Patent”) (APPLE1001).

2. I have been asked to provide my independent analysis of the ’868 Patent in light of certain prior art publications, and I have done so based on my personal knowledge and experience.

3. I am not, and never have been, an employee of Apple. I received no compensation for this Declaration beyond my normal hourly compensation based on my time actually spent analyzing the ’868 Patent, the prior art publications cited below, and various issues related thereto. I have no financial interest in the outcome of this proceeding, and will not receive any added compensation based on the outcome of any IPR or other proceeding involving the ’868 Patent.

II. QUALIFICATIONS

4. In formulating my opinions, I have relied on my knowledge, training, and experience in the relevant field. My education and experience are described more fully in the attached curriculum vitae (Appendix A). For ease of reference, I have highlighted certain information below.

5. I am the Federico Gil Distinguished Professor of Computer Science and an Adjunct Professor of Biomedical Engineering at the University of North Carolina at Chapel Hill. I head the UNC Graphics and Virtual Reality research group, supervising research scientists, engineers, PhD, MS, and undergraduate students. Students I have advised have gone on to senior faculty positions at leading universities such as MIT, Stanford, and Georgia Tech, and leading research labs such as Google, Intel, Meta (fka Facebook), and Microsoft, as well as to smaller companies and startups around the world.
6. I received a Bachelor of Arts degree in Information and Computer Science from the University of California at Santa Cruz in 1970, and a Ph.D. from the University of Utah in 1975.
7. I have over 50 years of experience working in the field of computer graphics. I have worked in the Imaging Lab of Caltech's NASA Jet Propulsion Laboratory, and have consulted for numerous organizations, including General Electric, the RAND Corporation, Mitsubishi Electric Research Laboratory, and Xerox Palo Alto Research Center. I have held visiting professorships at ETH Zurich and at TU Wien (the Vienna University of Technology).
8. My research in computer graphics has been supported by, among others, Cisco, DARPA, Google, Intel, Meta (fka Facebook), Microsoft, ONR, NIH, NSF, NVIDIA, U.S. Air Force, and Xerox. I have published over 250 papers, including

some in the top journals, such as ACM SIGGRAPH, SIGGRAPH Asia, ACM Transactions on Graphics, and IEEE Computer Vision and Pattern Recognition (CVPR).

9. I have served on the program and papers committees of some of the top conferences in the field, such as ACM SIGGRAPH, ACM SIGGRAPH Asia, and Eurographics. I was instrumental in starting the symposium series ACM Interactive 3D Graphics and Games, organizing the first meeting in 1986. I helped with the founding of the ACM Transactions on Graphics, the top journal in computer graphics, by serving as the guest editor of its inaugural issue in 1982.

10. A number of ideas from my publications have been widely adopted in commercial products. For example, my introduction of Binary Space Partitioning Trees (“BSP Trees”) in 1980 enabled real-time 3D games such as Doom and Quake to run on modest-sized PCs, and BSP Trees is now a standard rendering technique taught in major textbooks in computer graphics. The Pixel-Planes hardware graphics engines, which were developed in my UNC research group, pioneered several rendering techniques, for example, “tiled rendering”, a method now adopted world-wide in the Graphics Processing Units (GPUs) in computers of all sizes. The Pixel-Planes 5 project validated the tiled approach, a method of parallel rendering of an image in order of rectangular tiles, and introduced many of the techniques now standard for tiled renderers.

11. I have taught courses on computer graphics and related topics at UNC Chapel Hill, at University of Texas at Dallas, and at TU Wien. These courses often covered subjects such as stereoscopic displays and other 3D display technologies and applications. I am a named inventor on 20 patents and several pending patent applications, several of which involve stereoscopic display, autostereoscopic displays, and other 3D display technologies and applications. Examples of a few such patents are provided below.

12. US Patent No. 9,361,727 (issued June 7, 2016) to inventors H. Fuchs, L. McMillan, and A. Nashel, titled “Methods, systems, and computer readable media for generating autostereo three-dimensional views of a scene for a plurality of viewpoints using a pseudo-random hole barrier,” describes a system for generating stereoscopic display for multiple users without the need for any special eyewear.

13. US Patent No. 8,896,655 (issued November 25, 2014) to inventors J. Mauchly, M. Marathe, H. Fuchs, and J. Frahm, titled “System and method for providing depth adaptive video conferencing,” is about creating a combined image from panoramic image data of a conferencing room captured by a first camera and close-up image data of one or more conference participants captured through a second camera.

14. US Patent No. 5,870,136 (issued February 9, 1999) to inventors H. Fuchs, M. Livingston, T. Bishop, and G. Welch, titled “Dynamic generation of

imperceptible structured light for tracking and acquisition of three dimensional scene geometry and surface characteristics in interactive three dimensional computer graphics applications,” solves registration and occlusion problems in augmented reality systems.

15. U.S. Patent 4,607,255 (issued Aug. 19, 1986) to inventors H. Fuchs and S. Pizer, titled “Three dimensional display using a varifocal mirror,” teaches a method for creating a true 3-D display which presents stereoscopic views to multiple users simultaneously using a vibrating varifocal mirror, a point-plotting CRT, and a conventional 2D color video system.

16. I have been honored with multiple awards, including the ACM SIGGRAPH Steven A. Coons Award, considered the highest award in the field of computer graphics. I am a member of the National Academy of Engineering, one of about 20 computer graphics specialists who are members. I am also a fellow of the American Academy of Arts and Sciences, a fellow of the ACM and IEEE. I received an honorary doctorate from TU Wien, the Vienna University of Technology, in 2018, one of two conferred that year.

17. I believe that I am qualified to opine as a technical expert in this proceeding. The '868 Patent is about three-dimensional graphical user interfaces (“3D-GUIs”), and I have obtained ample knowledge and experience in this area over the years. Indeed, a portion of my work in the 1970s and 1980s focused on the computer

graphics hardware improvements necessary to transform consumer-level 3D-GUIs from a theoretical concept to an obtainable reality. Since that time, I've led extensive research and development efforts on 3D-GUIs, generally and with a particular focus on virtual reality and augmented reality applications. Like 3D environments portrayed on conventional 2D screens, such as the '868 Patent describes, augmented and virtual reality 3D-GUIs leverage depth cues (e.g., perspective, size, and occlusion) to create the illusion that virtual spaces and objects have real-world depth. Given this similarity, there is significant overlap between the various types of the 3D-GUIs, including from an underlying technology perspective and a design perspective.

18. I therefore believe that I have a detailed understanding of the state of the art during the relevant period, as well as a sound basis for opining how persons of skill in the art at that time would understand the technical issues in this case.

19. Additional details about my employment history, fields of expertise, and publications are included in my curriculum vitae (attached as Appendix A).

20. Counsel (Fish & Richardson) has informed me that I should consider these materials through the lens of one of ordinary skill in the art related to the '868 Patent at the time of the earliest possible priority date of the '868 Patent, and I have done so during my review of these materials. I have been informed by Counsel to use the filing date of the '868 Patent, February 5, 2015, as the "Priority Date" in

my analysis below. My analysis would not change even if Patent Owner asserted an earlier Priority Date such as September 13, 2005, the filing date of US Provisional Application Serial No. 60/717,019, from which the '868 Patent claims priority from.

21. In writing this declaration, I have considered the following: my own knowledge and experience, including my work experience in the fields of computer science and computer graphics and imaging; my experience in teaching related subjects; and my experience in working with others involved in those fields. In addition, I have analyzed various publications and materials, in addition to other materials I cite in my declaration.

22. My opinions, as explained below, are based on my education, experience, and expertise in the fields relating to the '868 Patent. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the art as of the earliest possible priority date. Any figures that appear within this document have been prepared with the assistance of Counsel and reflect my understanding of the '868 Patent and the prior art discussed below.

III. LEGAL STANDARDS

23. In conducting my analysis and providing my statements in this Declaration, I have applied the legal principles described to me by counsel for the Petitioner.

A. Person of Ordinary Skill in the Art

24. I understand that the factors considered in determining the ordinary level of skill in a field of art include: the level of education and experience of persons working in the field; the types of problems encountered in the field; the teachings of the prior art regarding solutions to such problems; and the sophistication of the technology at the time of the alleged invention. I understand that a person of ordinary skill in the art (“POSITA”) is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above and knowledge of all relevant prior art references, including the references I cite below.

B. Obviousness

25. I have been informed that a patent claim is invalid as “obvious” in light of one or more prior art references if it would have been obvious to a POSITA at the time of the alleged invention, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called “secondary considerations” of non-obviousness, which include: (i) “long-felt but unresolved need” for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) “copying” of the claimed invention by others.

26. While I do not know the exact date that the alleged invention of the '868 Patent was made, I do know that the '868 Patent's earliest claimed priority date is September 13, 2005. For purposes of my obviousness analysis, I have applied a date of September 13, 2005 as the date of the alleged invention ("Critical Date"), although in many cases the same analysis would hold true even if the date of the alleged invention were earlier or later.¹

27. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason that would have prompted a POSITA to modify or supplement the single prior art reference, or to combine two or more references, in a manner that provides the elements of the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference(s) themselves, the knowledge or "common sense" of a POSITA, or from the nature of the problem to be solved, and this reason may be explicit or implicit from the prior art as a whole. I have been informed that, under the law, the combination of familiar elements according to known methods is likely to be obvious when it does no more than

¹ Note, however, that I do not concede that the '868 Patent is entitled to its earliest claimed priority date.

yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

28. I understand that an obviousness determination also requires that a POSITA would have had a reasonable expectation of success. This concept has been explained to me as relating to the relative likelihood or predictability—from the perspective of a POSITA—of successfully modifying the prior art in a manner that would meet the claimed limitations of the patent being challenged (here the '868 Patent). I understand that the expectation of success need only be “reasonable” and, thus, does not require the absolute certainty gleaned from physically creating the proposed prior art modification.

C. Claim Interpretation

29. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted according to their “ordinary and customary meaning.” In determining the ordinary and customary meaning, I understand that the words of a claim are first given their plain meaning that those words would have had to a person of ordinary skill in the art at the time of the alleged invention. I also understand that the structure of the claims, the specification and file history may be used to better construe a claim. Moreover, I understand that even treatises and dictionaries may be used, albeit

under limited circumstances, to determine the meaning attributed by a person of ordinary skill in the art to a claim term.

30. I have been informed by counsel for Petitioner that the parties proposed constructions for certain claim terms in the '868 Patent in the co-pending litigation. I am not involved in the co-pending litigation and do not have direct knowledge of the events in that proceeding. Nor do I provide an opinion on claim construction in this proceeding.

IV. PERSON OF ORDINARY SKILL IN THE ART

31. Based on my knowledge and experience in the field and my review of the '868 Patent and its file history, I believe that a POSITA would have included a Bachelor's of Science degree in computer science or a comparable field and at least two years of professional experience working with 2D and 3D graphical user interfaces. Such experience could be obtained through research and study in a graduate program or through comparable exposure through industry employment, and additional years of experience could substitute for the advanced-level degree.

32. Accordingly, my analysis and conclusions expressed in this Declaration are based on the perspective of a POSITA having this level of knowledge and skill. My education, technical expertise and personal knowledge discussed in Section II shows that I meet the qualifications of a POSITA.

V. MATERIALS CONSIDERED

33. My analysis in this Declaration is based on my knowledge and experience.

Based on my above-described qualifications in Section II, the Patent Trial and Appeal Board should consider me to be an expert in the field. Also, based on my experiences, I understand and know of the capabilities of persons of ordinary skill in this field.

34. As part of my independent analysis for this Declaration, I have considered the following: the '868 Patent (APPLE1001) and its prosecution history (APPLE1002); the background knowledge/technologies that were commonly known to persons of ordinary skill; my own knowledge and experience gained from my work in the field; my experience in teaching and advising others in this field; and my experience working with others involved in this field. In addition, I have analyzed the following publications and materials:

APPLE1005	Apple Opening Claim Construction Brief, <i>SpaceTime3D, Inc. v Apple Inc.</i> , 6-22-cv-00149, (W.D. Tex.), Sept. 1, 2022
APPLE1006	US Patent Pub. No. 2005/0088447 (“Hanggie”)
APPLE1007	US Patent Pub. No. 2005/0091596 (“Anthony”)
APPLE1008	US Patent Pub. No. 2006/0107229 (“Matthews”)
APPLE1009	US Patent No. 6,414,677 (“Robertson”)

APPLE1010	Dictionary of Electrical & Computer Engineering, McGraw-Hill, 2004.
APPLE1011	US Patent Pub. No. 2012/0053926 (“Satpute”)
APPLE1012	US Patent No. 5,664,896 (“Blumberg”)
APPLE1013	US Patent No. 7,536,676 (“Baker”)

35. Note that my citations to non-patent literature throughout this Declaration reference the absolute page number added to the exhibit (as opposed to the original pagination of the document). For patent literature, I’ve used the column/line numbers or paragraph numbers. Note also that, unless I’ve indicated otherwise, all emphasis (bold/italics/underline) in any quoted text are ones I have added.

36. Although I cite and quote to selected portions of various references in this Declaration, the reader should understand that these citations are representative examples. A POSITA would have viewed each reference in its entirety and in combination with other references. Accordingly, I intend the references identified in this Declaration to be viewed as incorporated in their entireties.

VI. OVERVIEW OF CONCLUSIONS FORMED

37. This declaration explains my review of the '868 Patent, materials considered, and the conclusions that I have formed based on my knowledge and experience. Based on my review, I have concluded that:

- Claims 1-5, 9-14, and 18-20 are obvious over Anthony in combination with Hanggie;
- Claims 6-8 and 15-17 are obvious over Anthony in combination with Hanggie and Matthew;
- Claim 7 is obvious over Anthony in combination with Hanggie, Matthews, and Robertson;
- Claims 1-5, 9-14, and 18-20 are obvious over Hanggie in combination with Anthony;
- Claims 6-8 and 15-17 are obvious over Hanggie in combination with Anthony and Matthews; and
- Claim 7 is obvious over Hanggie in combination with Anthony, Matthews, and Robertson.

38. In support of these conclusions, I provide an overview of the references in Section IX and more detailed comments regarding the obviousness of claims 1-20 (“**the Challenged Claims**”) of the '868 Patent in Section X.

VII. OVERVIEW OF THE '868 PATENT

39. The '868 Patent is directed to a three-dimensional (3D) interactive computing interface “that allows the user to efficiently navigate though [sic] a virtual space wherein groups of windows can be easily organized, stored, and retrieved.” APPLE1001, 1:30-39, 2:41-50. The '868 Patent’s graphical user interface (GUI) “uses the two-dimensional (2D) display of a user's computer to display three-dimensional (3D) objects in a simulated real-time 3D immersive Cartesian space.” APPLE1001, 2:57-62. “Because the 3D GUI creates the illusion of infinite space in 3D, it can create a visual history of the user's computing session, whereby the user can visit past visual computing events (or a snapshot in time) by simply navigating to previously recorded states or viewpoints.” APPLE1001, 5:17-32.

40. In particular, the 3D GUI program “simulates a 3-D space within a 2-D window by redrawing objects in the space relative to one another as determined by their perceived distance from the viewer. Objects that are supposed to be further away are smaller whereas objects that are supposed to be closer are larger.” APPLE1001, 8:32-38. “The program runs within web browsers (e.g., Internet Explorer and Mozilla Firefox) or as a stand-alone application compatible with the local operating system.” APPLE1001, 8:14-18.

41. Examples of the '868 Patent's GUI are shown in the following figures. FIG. 9 (reproduced below) depicts "a bird's eye view of four 3D stacks 302, 304, 306, 308 drawn in a virtual space 300." APPLE1001, 18:4-27. 3D icons (342, 344, 346, 348) represent four different searches that resulted in the creation of stacks 302, 304, 306, 308. APPLE1001, 29:38-50. Navigator 320 allows a user to navigate through the items (e.g., pages) in each stack. APPLE1001, 29:51-30:7.

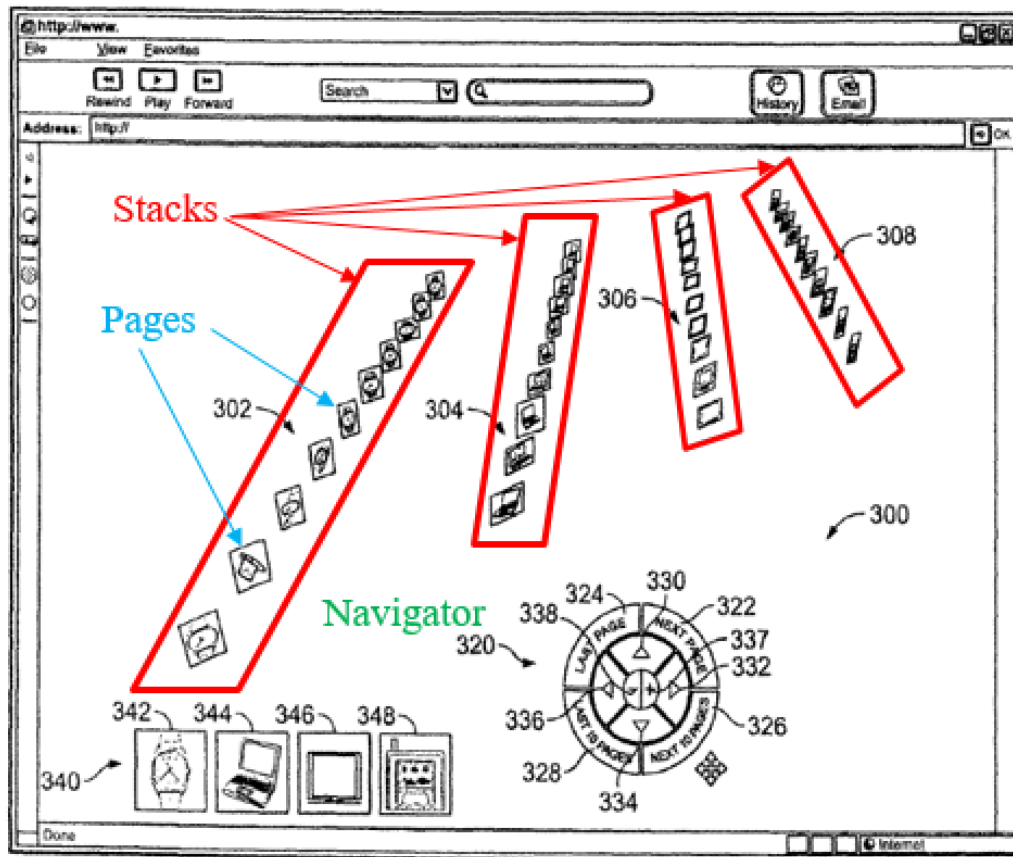


FIG. 9

APPLE1001 ('868 Patent), FIG. 9.²

² Annotations to the figures throughout this Petition are shown in color.

In another embodiment, shown in FIG. 15, content output into the 3D GUI application's virtual space results from a search initiated with the helper application 522 (e.g., Yahoo! Image Search). This helper application shows the search term van gogh, having been input into this helper application's text input field 530. The resulting first four image outputs (552, 554, 556, 558), generated by helper application 522 ..., created the 3D output of images and information from Yahoo! webservice, as shown in the 3D virtual space.

APPLE1001, 33:37-58.

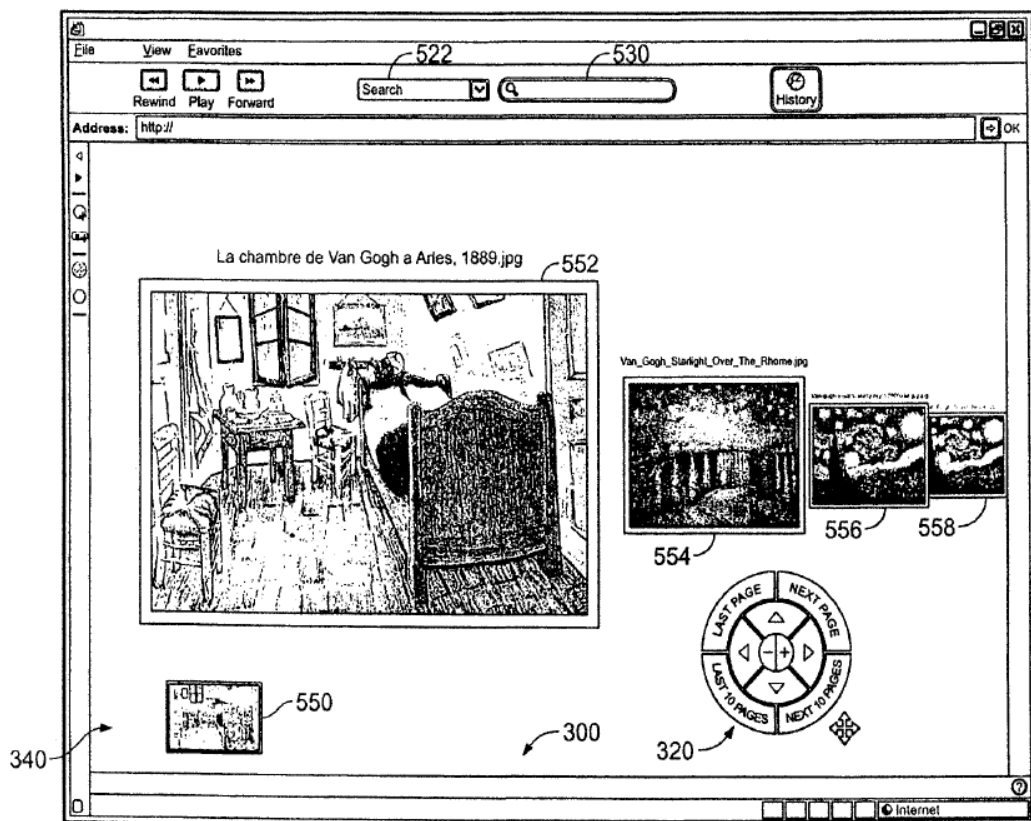
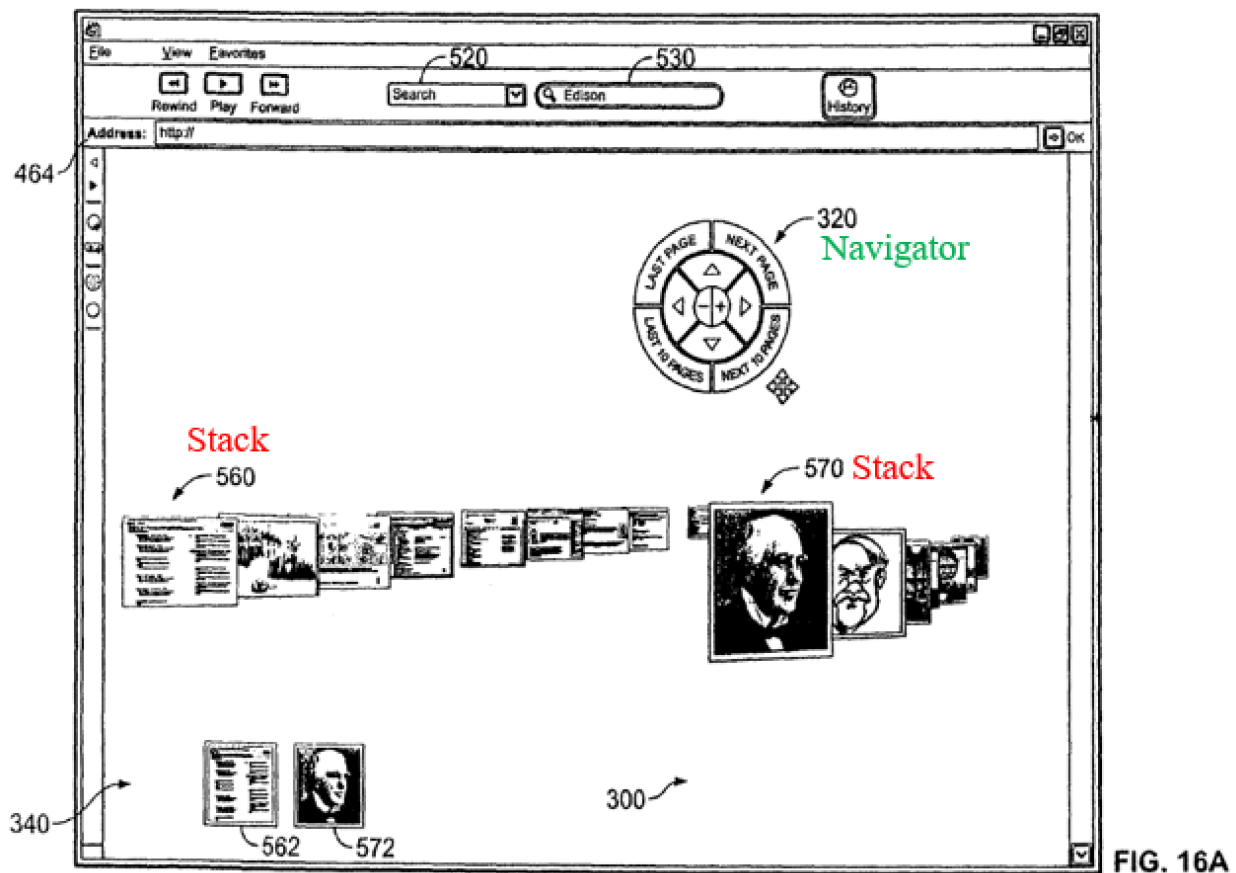


FIG. 15

APPLE1001 ('868 Patent), FIG. 15.

42. “[E]ach new Yahoo! Image Search results in a new 3D stack created for that search result plotted in the 3D virtual space with its corresponding 3D icon drawn on the timeline. The search for information could be images, video or any other content available from a webservice.” APPLE1001, 33:58-34:4. For example, as shown in FIG. 16A, when a second search is conducted, a second stack 570 is created and a second icon 572 representing stack 570 is added to the timeline to the right of a previous icon in the timeline. APPLE1001, 13:4-28. In some cases, the timeline “includes an icon for each object presented within the virtual space, wherein the icons are organized in linear chronological order according to when the objects were presented within the virtual space.” APPLE1001, 3:11-24.



APPLE1001 ('868 Patent), FIG. 16A.

43. A user of the 3D GUI “can toggle or switch between 2D and 3D for any selectively captured computing output and information (webpages, applications, documents, desktops or anything that can be visualized on a computer) that was drawn within a 3D virtual space at will by” “clicking an icon or bottom (analogous to minimize in windows operating system).” APPLE1001, 22:7-30.

VIII. CLAIM CONSTRUCTION

44. I was informed by counsel that in pending district court proceedings, the construction of two terms has been agreed upon by the Patent Owner and the Petitioner.

- 3D space (claims 1, 10, 29): a virtual space defined by a three-dimensional coordinate system; and
- 2D space (claims 1, 10, 29): a finite graphical area defined by a two-dimensional coordinate system.

APPLE1005, 6.

45. It is my understanding that no other terms are at issue. I have applied the above-noted constructions for purposes of my analysis.

IX. OVERVIEW AND COMBINATIONS OF PRIOR ART REFERENCES

A. Overview of Anthony³

46. Anthony discloses “[a] three-dimensional (3D) view of a data collection based on an attribute.” APPLE1007, Abstract. As shown below in Anthony’s

³ General descriptions provided for this and other references and combinations thereof are incorporated into each subsection and mapping of the claims that includes citations to these references.

FIG. 4, the 3D view can take the form of a timeline, which when displayed, depicts a plurality of items in focal groups according to a logical order. APPLE1007, Abstract, ¶¶[0042], [0043], [0011]. The items can be “a visual representation of a file, folder, virtual folder, or any other data object that may be stored in an operating system and/or file system, for example, icons, thumbnails, and the like.” APPLE1007, ¶[0042]. The order of the items “may be based on time, thus arranging the items chronologically, e.g., by using a date of creation or date of edit attribute as the ordering attribute.” APPLE1007, ¶[0042].

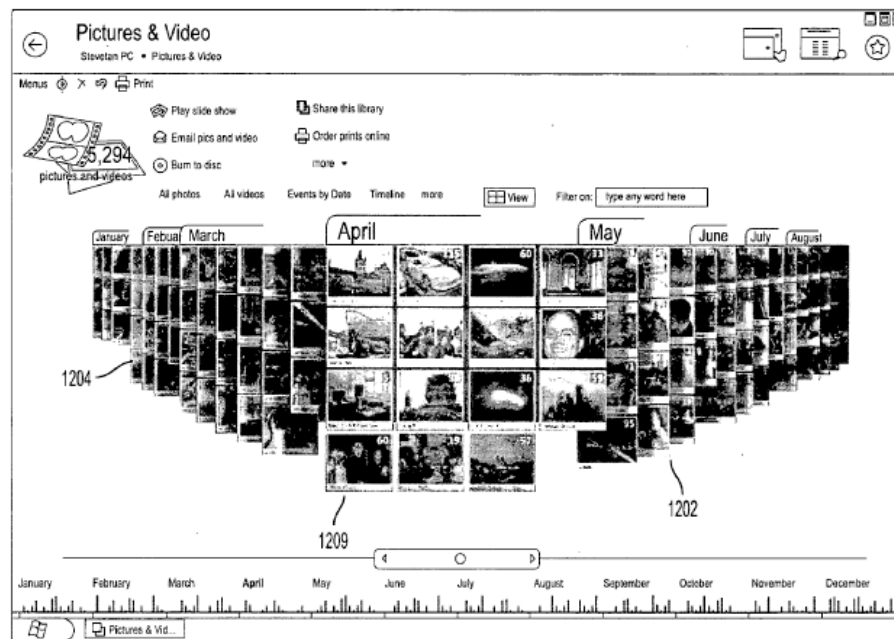


FIG. 4

APPLE1007 (Anthony), FIG. 4.

47. Anthony’s method is implemented in a computing device that includes computer 110 connected to a monitor 191. APPLE1007, FIG. 1, ¶¶[0034]-[0039]. Monitor 191 has a screen with a fixed resolution, and is used to display the

timeline. APPLE1007, Abstract, ¶[0050]. Examples of resolutions include a 96 dpi screen resolution. APPLE1007, ¶[0050]. As shown below in FIG. 1, Anthony's computer system includes "application programs 135[/145], other program modules 136[/146], and program data 137[/147]." APPLE1007, ¶¶[0036], [0038]. In the context of viewing images, Anthony's computer system can display images using various application programs, such as Digital Image Pro, preinstalled or installed thereafter on the operating system. APPLE1007, ¶[0003]. Anthony also gives an example of excel spreadsheets, indicating that Anthony's computer system can also execute the Microsoft Excel application. APPLE1007, ¶[0049] ("For example, if the ordering attribute were file type, the focal group header 602a might contain a label that simply says, 'Excel Spreadsheets' or some other file type as is known in the art").

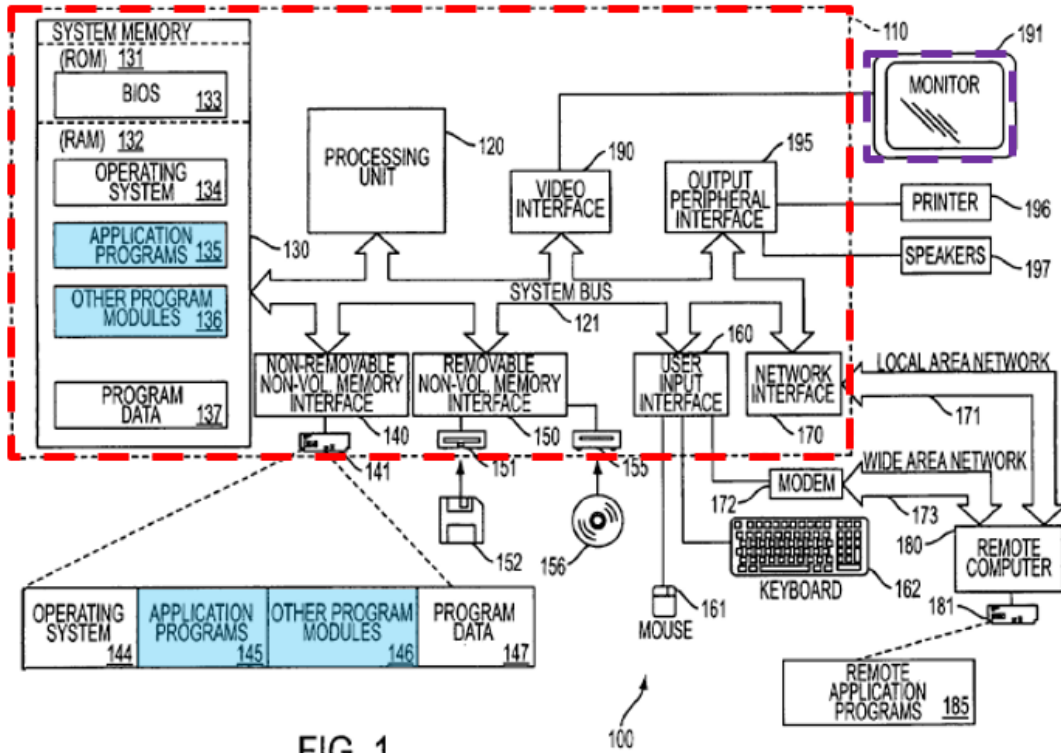


FIG. 1

APPLE1007 (Anthony), FIG. 1.

48. Anthony's dynamic timeline can be viewed in a 3D environment, as shown above in FIG. 4. APPLE1007, ¶[0043]. A user viewing the timeline can "freely navigate documents, files, or other data objects in a chronological manner, and" can "change the point of focus to an arbitrary location on a timeline."

APPLE1007, ¶[0044]. For example, as shown below in FIG. 5:

[a] timeline 500 has a start date 502 and an end date 504. The timeline 500 may include various time intervals (e.g., days, months, years, etc., not called out in FIG. 5). According to an aspect of the invention, the point of view of the GUI may be based on a conceptual camera 506

pointed at the time interval containing the files or objects on which the user wishes to focus. This time range is called the focal point 508 or focal point interval. The focal point 508 may represent a point in time or an interval of time on the timeline 500. Items that are within the time range covered by the focal point are collectively called the focal group 509. Items in the focal group 509 are typically presented to the user in greater detail than is shown for items in other time intervals on the timeline 500. Items in other time intervals on timeline 500 are grouped together in non-focal groups 510.

APPLE1007, ¶[0044].

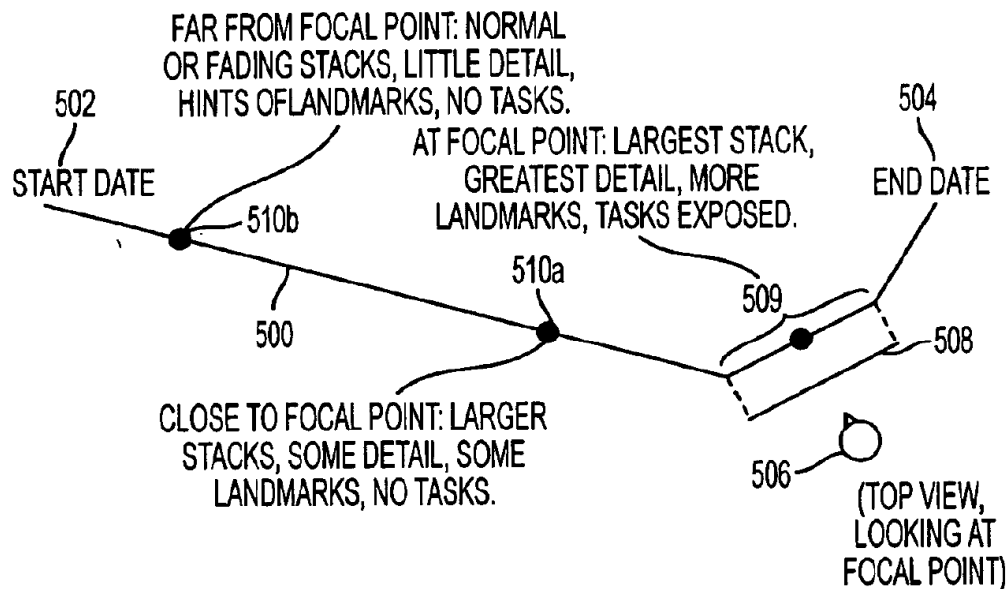


FIG. 5

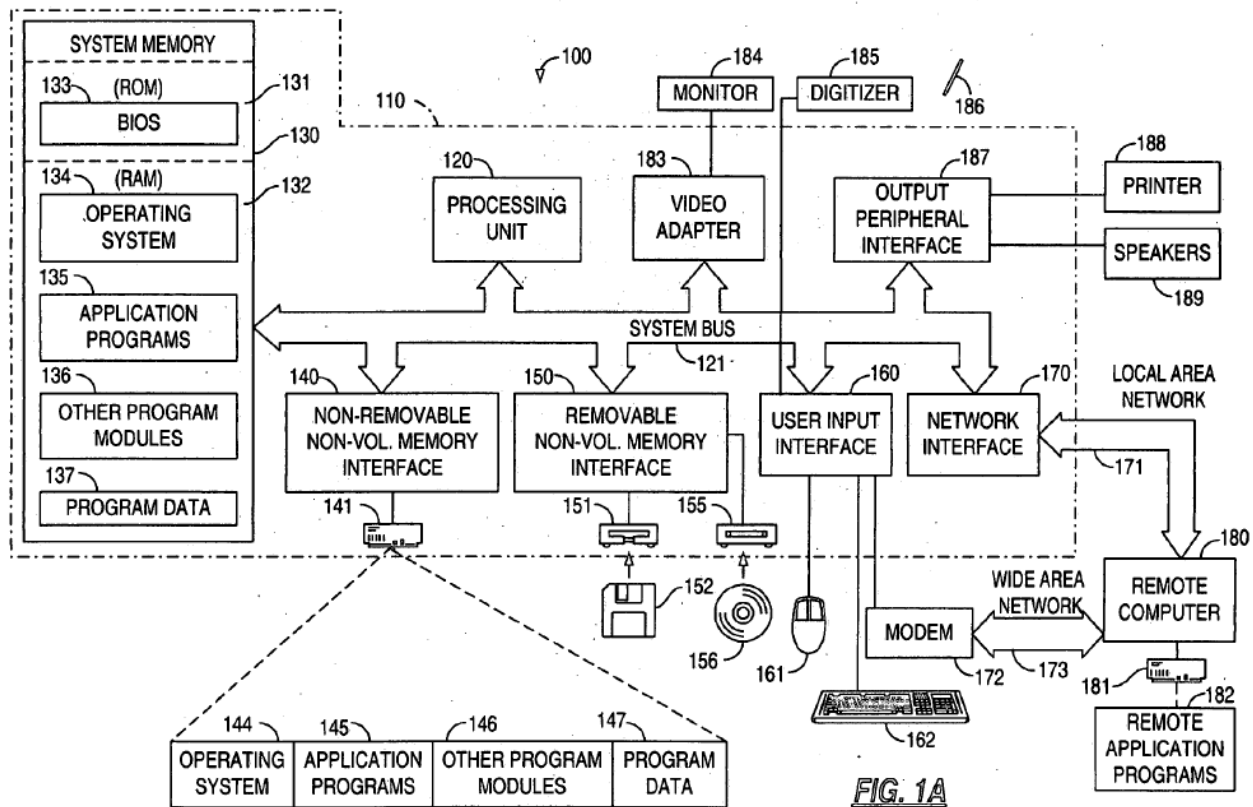
APPLE1007 (Anthony), FIG. 5.

49. A user can interact with the dynamic timeline (shown in a 3D environment) by navigating to different points of the timeline or selecting a particular icon to open the application associated with the icon. APPLE1007, ¶¶[0043]-[0044], [0047], [0066], [0084]-[0085].

B. Overview of Hanggie

50. Hanggie discloses “[a] method and system for rendering a desktop on a computer using a composited desktop model operating system” “with intrinsic support for composition-agnostic legacy applications.” APPLE1006, Abstract, ¶[0001]. A software layer, referred to as the Desktop Window Manager (DWM) is “responsible for managing user interface objects such as icons, menus, cursors, windows and desktops, arbitrating events from input devices such as the mouse and keyboard; and providing user interface services to software applications.” APPLE1006, ¶[0005]. Earlier implementations of DWM were unable to or had difficulty rendering more advanced features such as “transparency, shadows, 3D graphics and advanced lighting effects. APPLE1006, ¶[0007]. Hanggie discloses a compositing DWM (CDWM) that “provide[s] a rich, full featured operating system ... to provide a desktop that uses advanced textures, lighting, and 3D transformations, yet supports legacy applications.” APPLE1006, ¶¶[0012], [0015], [0026].

51. Hanggie's CWDM can be implemented using computer software and systems, as shown in Hanggie's FIGS. 1A and 1B. For instance, Hanggie's FIG. 1A (reproduced below) illustrates an example computer system environment 100 including computer 110 that further includes a processing unit 120, a system memory 130, and a system bus 121. APPLE1006, ¶¶[0028]-[0031]. The system memory 130 includes read only memory (ROM) 131 and random access memory (RAM) 132 that stores operating system 134, application programs 135, other program modules 136, and program data 137. APPLE1006, ¶¶[0033]-[0034]. A hard disk drive can store the same or different data than the RAM 132. APPLE1006, ¶[0035].



APPLE-1006 (Hanggie), FIG. 1A.

52. “The CDWM composes the desktop by drawing the desktop from the bottom up, beginning with the desktop background and proceeding through overlapping windows in reverse Z order. While composing the desktop, the CDWM may draw each window based in part on the content on top of which the window is being drawn, and based in part on other environmental factors (e.g., light source, reflective properties, etc.).” APPLE1006, ¶[0039]. “The CDWM may reside as part of the operating system 134, 144,” and may use a compositing engine based on Direct3D® and DirectX® technology by Microsoft Corporation or OpenGL graphics engine. APPLE1006, ¶[0040]. The compositing engine “enables 3D

graphics and animation, transparency, shadows, lighting effects, bump mapping, environment mapping, and other rich visual features on the desktop.”

APPLE1006, ¶[0040].

53. Referring to Hanggie’s FIG. 1B, the CWDM 190 “may include an Application Programming Interface 190a through which a composition-ware Application software 191 obtains CDWM window and content creation and management services” and is connected to a Legacy Windowing Graphics Subsystem 192. APPLE1006, FIG. 1B, ¶[0041]. “The Legacy Graphical User Interface Subsystem 192 may include a Legacy Window Manager 192a and Legacy Graphics Device Interface 192b.” APPLE1006, ¶[0042]. “The Legacy Graphics Device Interface 192b provides 2D graphics services to both legacy applications as well as the Legacy Window Manager.” APPLE1006, ¶[0042].

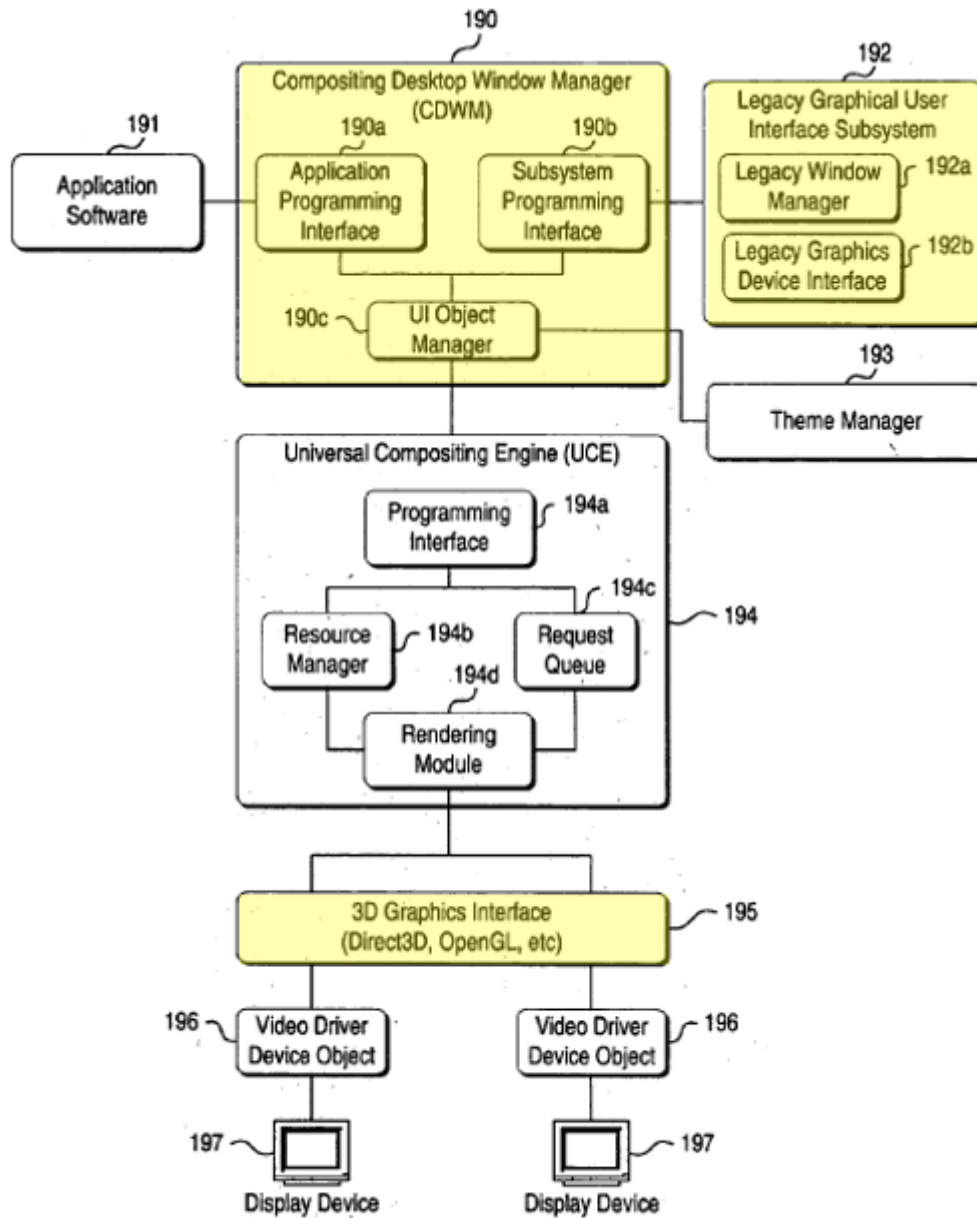


FIG. 1B

APPLE1006 (Hanggie), FIG. 1B.

54. As shown in FIG. 1B, a Unified Compositing Engine (UCE) 194 is connected to the CDWM 190 and a 3D Graphics Interface 195, and provides graphic services to the CDWM 190. APPLE1006, ¶¶[0043]-[0044]. The 3D

Graphics Interface 195 can include software services “such as Direct3D®, OpenGL®, or the like” and provide an abstract interface to display devices 197 in a multiple-display system via multiple device drivers 196. Thus, Hanggie’s system can support 2D displays of legacy applications as well as 3D displays.

55. With respect to the rendering of windows in 3D, Hanggie explains that “the UCE processes incoming composition and resource updates from the CDWM,” and uses “the immediate-mode rendering services provided by a **3D graphics engine** (such as Microsoft Direct3D®), which in turn transfers the desktop to a primary display surface.”⁴ APPLE1006, ¶¶[0056], [0065]. An example of such a window is shown below in Hanggie’s FIG. 3. Hanggie explains that “[t]he frame or base content 303 of the window 301 may host child content including **buttons 305 (e.g., used to restore, maximize, minimize, close the window, etc.)**, an indicative icon 307, scrollbars 309, menu bar 311, and window caption text 313. A primary content object area 315 may be derived from the redirection buffer obtained from the Legacy Window and Graphical User Interface subsystem, or be created and attached to the standard base content and rendered by a composition-aware owning application.” APPLE1006, ¶[0058].

⁴ Throughout this declaration, unless otherwise indicated, the bolding in quotations has been added by me, for emphasis.

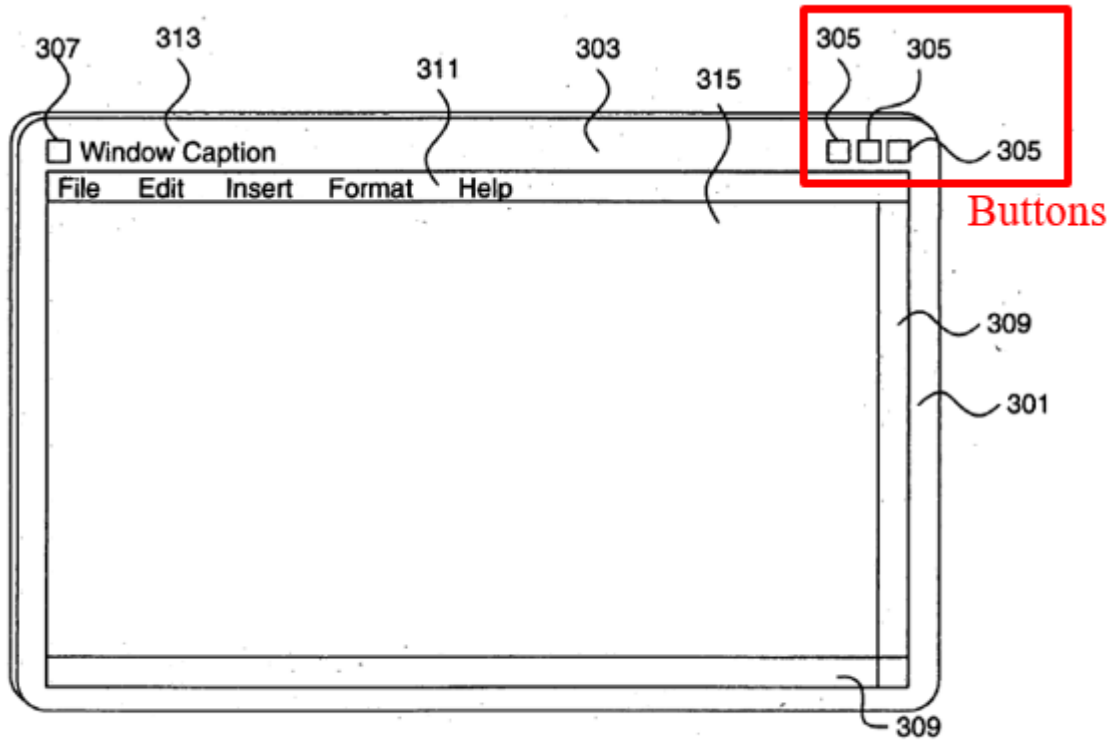


FIG. 3

APPLE1006 (Hanggie), FIG. 3.

56. Another example of a window is shown below in FIG. 5, which depicts a “My Documents” folder/window within which icons for additional folders/applications (e.g., My Music, My Pictures) are located. APPLE1006, FIG. 5, ¶[0083].

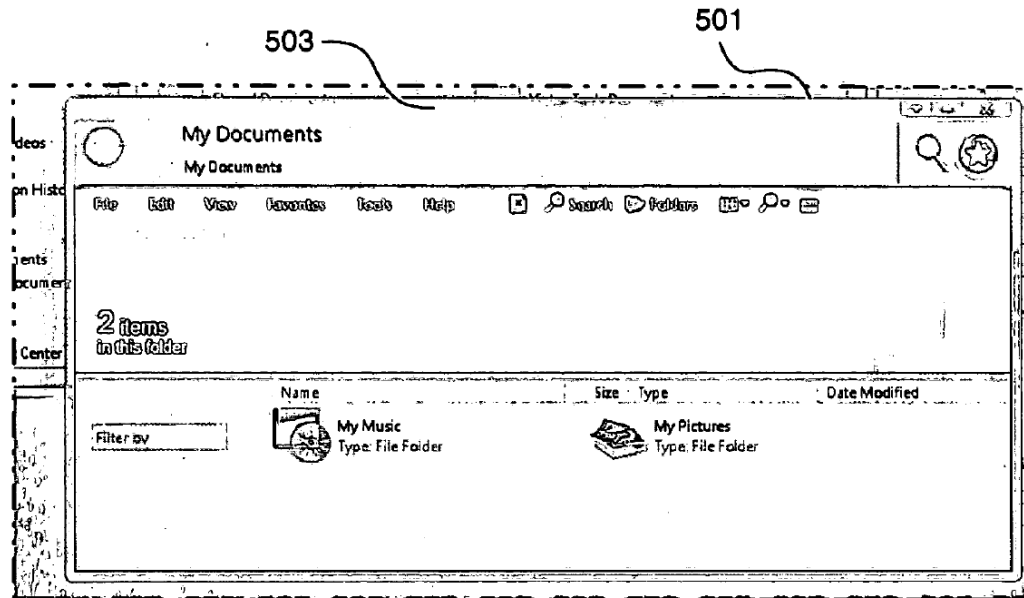


FIG. 5

APPLE1006 (Hanggie), FIG. 5.

57. The window may be provided by or correspond to an application.

APPLE1006, ¶[0058]. “[T]he CDWM may allow an application to alter the default anatomy of a window by allowing applications to define multiple custom content objects.” APPLE1006, ¶[0059]. Hanggie teaches that each CDWM window can be defined by attributes related to an application, such that 3D user interaction with the window can be reported to the application. APPLE1006, ¶[0060] (“The CDWM maps mouse hit-test points relative to application-defined, content-local, 3D coordinates, and delivers mouse event notifications to the application”).

58. Hanggie explains that a user may choose to operate in a 2D mode (legacy drawing mode) or a 3D mode (CDWM) based on a number of factors such as

system capabilities or power conservation conditions. APPLE1006, ¶[0092]. For example, a user may want to the computer to operate in the legacy drawing mode when the computer has “low video memory” or “no 3D acceleration hardware.” APPLE1006, ¶[0092]. Hanggie explains that “the selection may be made automatically or manually. For example, the selection may be made via manual user control, in accordance with the drawing mode defined by an activated visual style (theme) selected by the user.” APPLE1006, ¶[0092].

C. Combination of Anthony and Hanggie

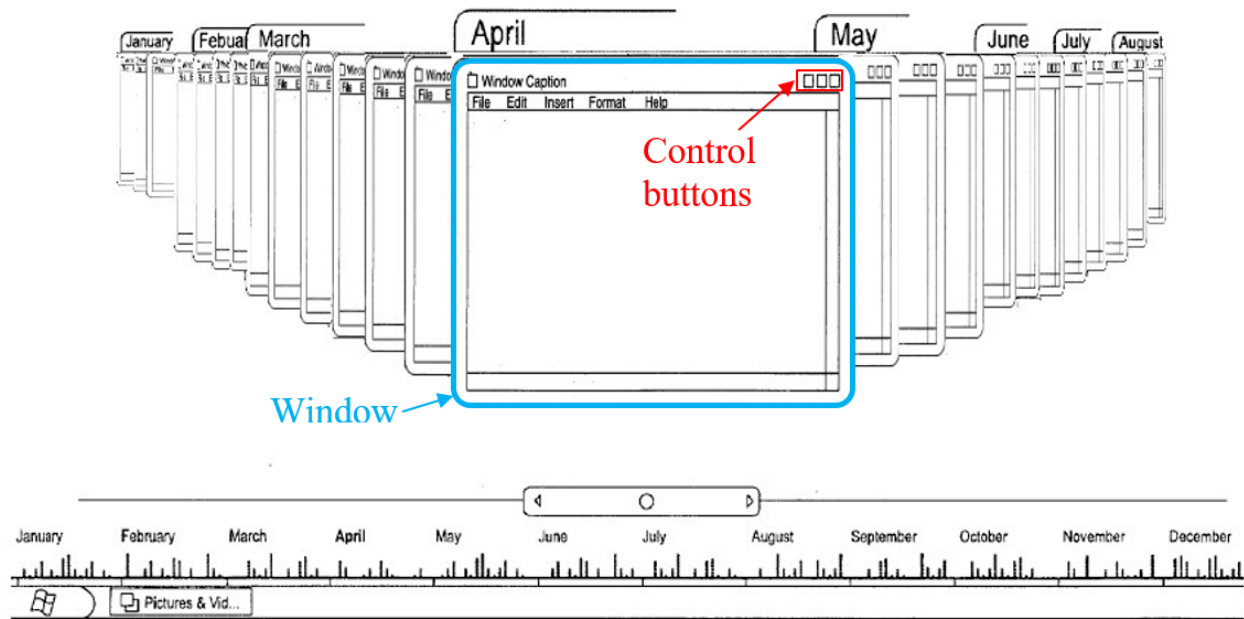
59. It would have been obvious for a POSITA to combine the teachings of Anthony and Hanggie to (1) to implement one or more windows corresponding to one or more applications as displayed focal group windows in Anthony’s timeline, (2) implement a control selection through which a user can switch between 2D and 3D viewing of application windows, and (3) implement control buttons 305 on the windows that would allow a user to restore, maximize, minimize, or close the windows. As explained by Hanggie, a control selection allows a user to select the operating mode that may be more suitable for the existing operating conditions of the device. For example, a user may want to operate in the 2D mode when battery power is low, or operate in 3D mode when the battery of the device is full. APPLE1006, ¶[0092].

60. A POSITA would also have combined Hanggie's control buttons 305 in Anthony's focal group windows so that a user can close, minimize, maximize, or restore a window when desired. This would have provided a user more control over the displayed contents and would have allowed the user to interact with a particular window only when desired. Moreover, implementing a window as one of the focal group windows in Anthony's timeline is consistent with the teachings of Anthony, which organizes such windows in a timeline and also states that the items in a timeline can be "a visual representation of a file, folder, virtual folder, or any other data object that may be stored in an operating system and/or file system." APPLE1007, ¶[0042].

61. A POSITA would have understood and found it obvious that a maximized window would occupy all, or almost all, parts of a display. As such, a POSITA would have understood that viewing a maximized window in a traditional 2D format would, in some cases, allow certain users to interact with an application in a 2D environment similar to their past experiences in 2D. A POSITA would have also found it obvious to implement the maximize control button such that manual user selection of that button would result in Anthony's user interface switching from a 3D timeline view enabling user interaction with the plurality of applications represented within windows displayed within that timeline, to a 2D view of the maximized window. APPLE1006, ¶[0092].

62. Additional advantages would have further motivated the POSITA to implement the maximize control button in this manner. For example, because a maximized 2D window would obscure Anthony's 3D timeline, it would not be necessary to expend computing resources on rendering the 3D timeline while a window is in a maximized state. For example, Hanggie teaches that it can be beneficial to switch from a 3D mode to a 2D mode to reduce graphics processing and thereby conserve battery power, and a POSITA would have recognized that those same advantages could be obtained by switching from a 3D to a 2D state upon user selection of a maximize control button. APPLE1006, ¶[0092].

63. Below, I provide an example of the combination of Anthony and Hanggie's teachings. In the combination figure shown below, the focal group windows in Anthony's FIG. 4 are replaced by the window shown in Hanggie's FIG. 3. The windows are organized in a timeline consistent with Anthony's teachings, and each window has a window caption and control buttons, consistent with Hanggie's teachings. APPLE1007, Abstract, ¶¶[0042], [0043], [0011]; APPLE1006, ¶[0058], FIG. 3. The window captions would indicate the name of the application for which each window is associated with. For example, a window caption may be "Excel Spreadsheets" when the window includes one or more excel spreadsheets. APPLE1007, ¶[0049].

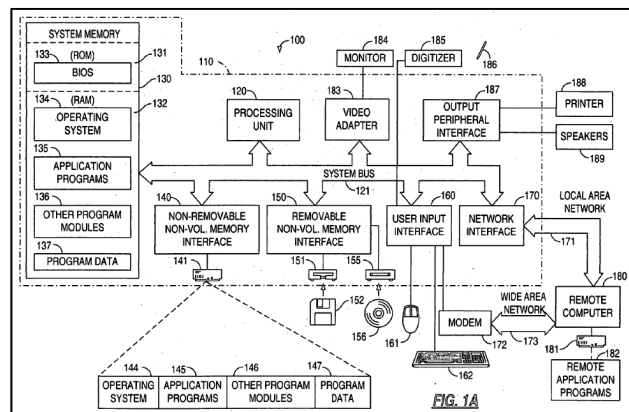
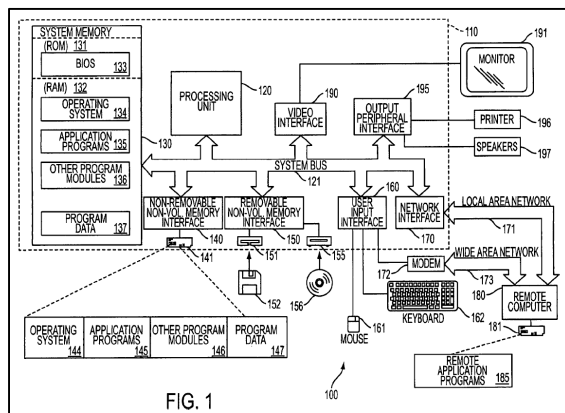


Self-generated figure basedd on the combination of Anthony's FIG. 4

(APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

64. Combining the teachings of Anthony and Hanggie in the above-noted matter would have merely involved combining prior art elements according to known methods to yield predictable results. Here, the known methods disclosed by Hanggie would have been combined with Anthony's teachings to yield the predictable result of Anthony's system being able to switch between 2D and 3D viewing of application windows and to implement control buttons in the windows to provide a user more control, as explained above. In addition, the combination of Hanggie and Anthony would yield the predictable results of Anthony's system providing standard captions and control buttons for application windows represented within its 3D timeline, and being able to switch between 3D and 2D

interface modes. The combination would have been foreseeable and predictable as Anthony and Hanggie are directed to similar systems and use the same or similar software for rendering 3D graphics. For instance, as shown below, Anthony's computer system depicted in FIG. 1 is similar to Hanggie's computer system in FIG.1A (compare Hanggie and Anthony's system memory 130, hard disk drive 141, processing unit 120, monitor 191/184). Anthony and Hanggie both disclose using 3D Graphics software such as Direct3D®, OpenGL® to enable 3D viewing of images (*see* Anthony's ¶[0043] and Hanggie's ¶[0047]).



APPLE1007, FIG. 1 (left); APPLE1006, FIG. 1A (right).

65. As shown in Anthony's FIG. 1 and Hanggie's FIG. 1A, Anthony and Hanggie's systems have similar architectures (compare Hanggie's FIG. 1A to Anthony's FIG. 1). In fact, several components such as the system memory 130, computer 110, and processing unit 120 even share the exact same reference number. And because the functions and operations of the system components in both Anthony and Hanggie are largely similarly (if not identical), a POSITA would

have understood that descriptions associated with components shared commonly in both systems would have been obvious to implement in both systems (if not explicitly stated in one of the references) and consequently in the Anthony and Hanggie combination. For example, a POSITA would have understood that features of components such as input and output devices (e.g., keyboard, monitor, printer) if described in Anthony would also have been features of Hanggie's input and output devices, *vice versa*, and also part of the Anthony and Hanggie combination system.

66. Anthony and Hanggie also share one common inventor and have a common assignee. APPLE1006, cover; APPLE1007, cover. And Anthony and Hanggie are both directed to a graphical user interface and system for 3D viewing of data. APPLE1006, title, abstract; APPLE1007, title, abstract. In view of the common inventors, assignee, methods and software used to render 3D graphics, and similar computer systems/architecture, modifying Anthony to incorporate Hanggie's teachings would have been foreseeable and predictable for a POSITA.

(19) **United States**
(12) **Patent Application Publication**
Hanggie et al.

(54) **COMPOSITING DESKTOP WINDOW
MANAGER**

(76) Inventors: **Scott Hanggie**, Redmond, WA (US);
Victor Tan, Kirkland, WA (US);
Gerardo Bermudez, Redmond, WA
(US); **Gregory D. Swedberg**, Bellevue,
WA (US); **Mark Richard Ligameri**,
Snohomish, WA (US); **Greg Scott**
Melander, Redmond, WA (US)

Correspondence Address:
BANNER & WITCOFF LTD.,
ATTORNEYS FOR MICROSOFT
1001 G STREET , N.W.
ELEVENTH STREET
WASHINGTON, DC 20001-4597 (US)

(21) Appl. No.: **10/691,450**

(22) Filed: **Oct. 23, 2003**

(19) **United States**
(12) **Patent Application Publication**
Anthony et al.

(54) **GRAPHICAL USER INTERFACE FOR
3-DIMENSIONAL VIEW OF A DATA
COLLECTION BASED ON AN ATTRIBUTE
OF THE DATA**

(75) Inventors: **Colin Ray Anthony**, Kirkland, WA
(US); **Stephane St-Michel**,
Woodinville, WA (US); **Zeke Book**
Odins-Lucas, Seattle, WA (US);
Jordan Luther King Schwartz,
Seattle, WA (US); **Richard Malcolm**
Banks, Egham (GB); **Marcus Simon**
Howell Harvey, Seattle, WA (US);
Charles Cummins, Seattle, WA (US);
Charles W. Stabb, Seattle, WA (US);
Mark Richard Ligameri, Snohomish,
WA (US)

Correspondence Address:
BANNER & WITCOFF LTD.,
ATTORNEYS FOR MICROSOFT
1001 G STREET , N.W.
ELEVENTH STREET
WASHINGTON, DC 20001-4597 (US)

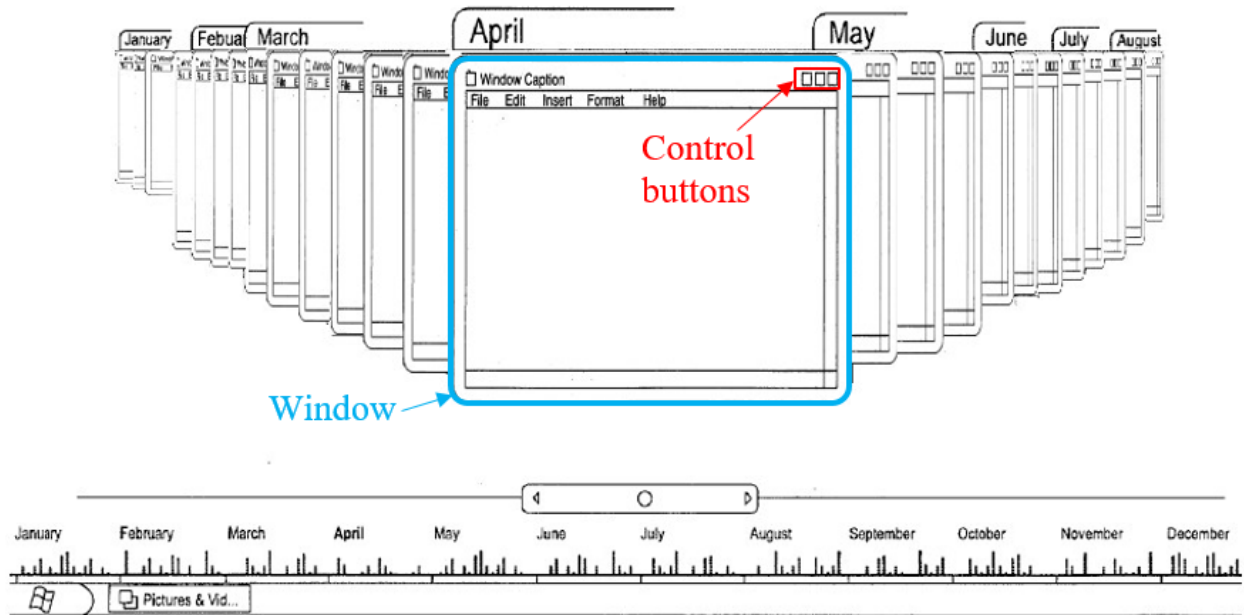
APPLE1006, cover (left); APPLE1007, cover (right).

D. Combination of Hanggie and Anthony

67. It would also have been obvious to combine Hanggie and Anthony such that the teachings of Anthony are implemented in Hanggie's system. In particular, while Hanggie teaches that it's "CDWM may draw each window based in part on the content on top of which the window is being drawn" and that the windows may be arranged in a stacked order, Hanggie does not explicitly describe how the stacked order of windows can be arranged in a user-friendly manner to facilitate user interaction. APPLE1006, ¶¶[0039], [0003]. Anthony provides such

details and discloses that a chronological order of the windows and that items such as files and folders “may be based on time, thus arranging the items chronologically, e.g., by using a date of creation or date of edit attribute as the ordering attribute.” APPLE1007, ¶[0042].

68. Combining the teachings of Anthony and Hanggie in the above-noted matter would have merely involved combining prior art elements according to known methods to yield predictable results. Here, the known methods disclosed by Hanggie would have been combined with Anthony’s teachings to yield the predictable result of Hanggie’s windows being arranged in a timeline to provide a logical and orderly manner in which a user can interact with multiple windows in Hanggie’s system. A POSITA would have recognized that ordering and representing Hanggie’s windows in this manner would allow for efficient, intuitive, and user-friendly navigation. Such a modification of Hanggie’s system would have involved incorporating additional code and instructions that would organize Hanggie’s windows chronologically, e.g., by using a date of creation or date of edit attribute as an ordering attribute—a feature that a POSITA would have been capable of implementing. APPLE1007, ¶[0042]. The Hanggie-Anthony combination would effectively result in a similar system and interface (shown below) as the Anthony-Hanggie combination described in §IX.C.



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

69. Moreover, the POSITA would have found it obvious to implement Hanggie's maximize control button such that manual user selection of that button would result in Hanggie's user interface switching from a 3D timeline view, to a 2D view of the maximized window. APPLE1006, ¶[0092]. Indeed, the same advantages to implementing a maximize button described in §IX.C in connection with the Anthony-Hanggie combination apply equally to the Hanggie-Anthony combination.

70. A POSITA would have reasonably expected success in combining Hanggie and Anthony in the above-noted manner at least because doing so would have involved nothing more than combining prior art elements according to known

methods to yield predictable results. For example, applying Anthony's teachings to Hanggie's system would have yielded the predictable result of Hanggie's windows being arranged chronologically in a timeline, thereby providing a logical, intuitive, and user-friendly interface for 3D navigation between multiple windows in Hanggie's system. APPLE1007, ¶[0042], FIG. 4.

71. The Hanggie-Anthony combination would have been foreseeable and predictable as Hanggie and Anthony are directed to similar systems and use the same or similar software for rendering 3D graphics (Direct3D®, OpenGL®) to enable 3D viewing of images. APPLE1006, ¶[0047]; APPLE1007, ¶[0043]. For instance, as noted above, Hanggie and Anthony are based on the same/similar system, share one common inventor, have a common assignee, and are both directed to a GUI and system for 3D viewing of data. APPLE1006, cover, title, abstract; APPLE1007, cover, title, abstract.

72. As noted above, the combination of Hanggie and Anthony or the combination of Anthony and Hanggie (collectively referred to as "**HAC**" hereinafter) would have effectively resulted in the same features being combined in a similar manner to yield a combined system. Thus, although separate asserted combinations are identified in this Petition, the mapping of the prior art references to the Challenged Claims is the same under either combination. Such mapping is described in §X.

73. To simplify which reference of the combination I am relying upon in describing the prior art mapping below in §X, I will often refer to a particular reference from which disclosure is being relied upon. However, it should be understood that although a single reference is referenced in my remarks in §X, the single reference is part of the HAC system described in §IX.

E. Overview of Matthews

74. Matthews discloses a method and apparatus for transforming a work area using a 3D transformation to move a displayed work area, such as a desktop with open windows, to reveal additional information. APPLE1008, Abstract. In particular, Matthews discloses that an **image of a work area 302 that includes an image of a desktop 307 and images of one or more open windows 305** can be tilted away from the user in response to a user selection of a button, such as the Start button 306. APPLE1008, ¶¶[0049]-[0050], [0056], [0060], FIGS. 3A, 3B, 4A, 5A. The work area 302, desktop 307, and window(s) 305 “are virtually depicted in 3D space” in presentation area 303. APPLE1008, ¶[0058].

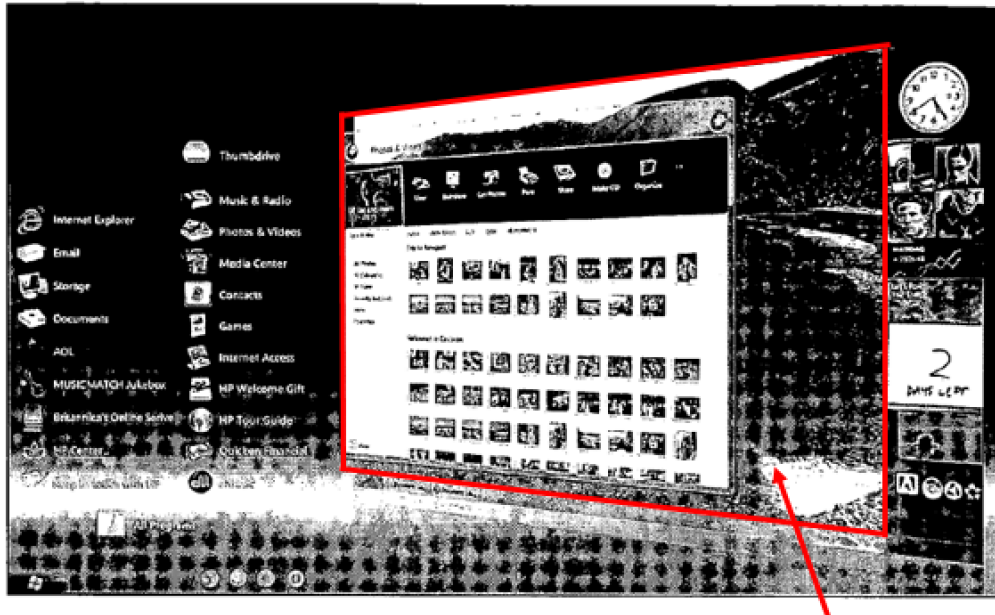


FIG. 3A

"image of a desktop having at least one other application"

APPLE1008 (Matthews), FIG. 3A.

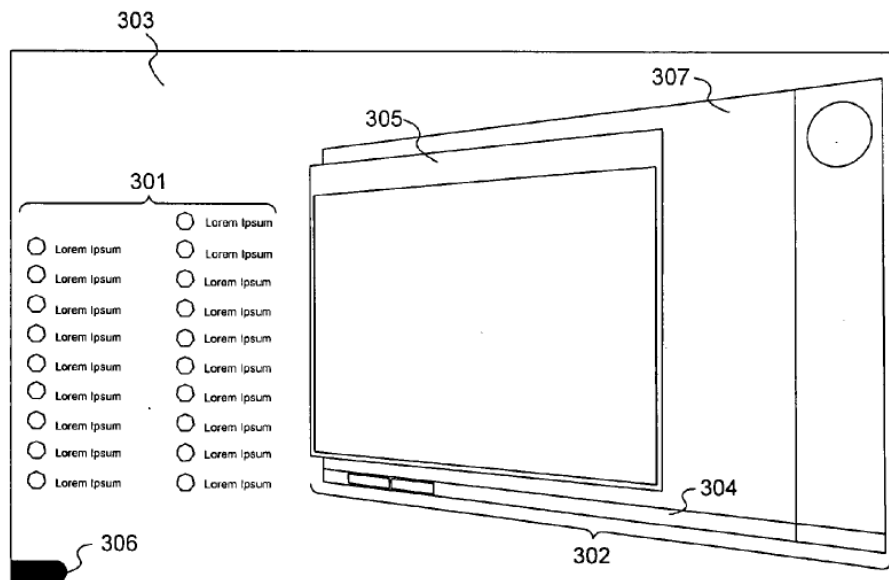
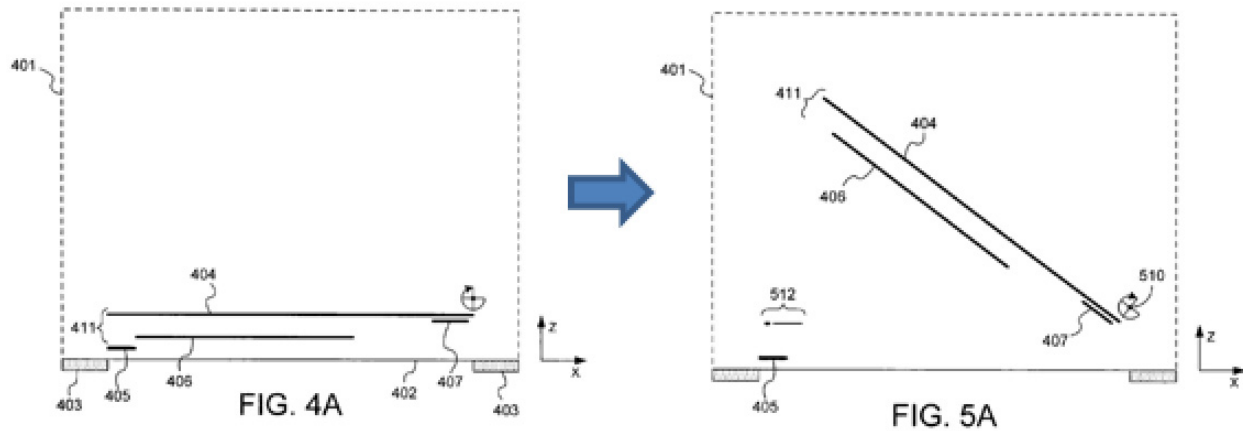


FIG. 3B

APPLE1008 (Matthews), FIG. 3B.



APPLE1008 (Matthews), FIG. 4A (left), FIG. 5A (right).

F. Combination of Matthews with HAC

75. Matthews explicitly teaches that Matthews' invention is to be used in Hanggie's CWDM system and in doing so, explicitly notes Hanggie's patent application number. APPLE1008, ¶[0041]. Matthews' FIGS. 1A and 1B, which describe the operating environment and system components, are the same as Hanggie's FIGS. 1A and 1B, and Hanggie's FIG. 1A is also almost identical to Anthony's FIG. 1. Thus, not only would it have been obvious and predictable to combine the teachings of the three references, but Matthews explicitly discloses that its teachings can be combined and implemented in Hanggie's system.

76. A POSITA would have combined Matthews's teachings with the Anthony-Hanggie system so that information that can get hidden behind a work area can be revealed by the tilting of a desktop display. APPLE1008, ¶¶[0010], [0011].

Moreover, Matthews' teachings "decouple[] the operating system from the

applications ... and prevents visual clutter while taking full advantage of the graphics capabilities of the host computer.” APPLE1008, ¶[0052].

77. A POSITA would have combined the teachings of HAC and Matthews because doing so would merely involve combining prior art elements according to known methods to yield predictable results. Here, as called for by Matthews, Matthews’ known method would have been combined with Hanggie’s CWDM system in HAC’s system to yield the predictable result of rendering a 3D display with a transformable desktop display.

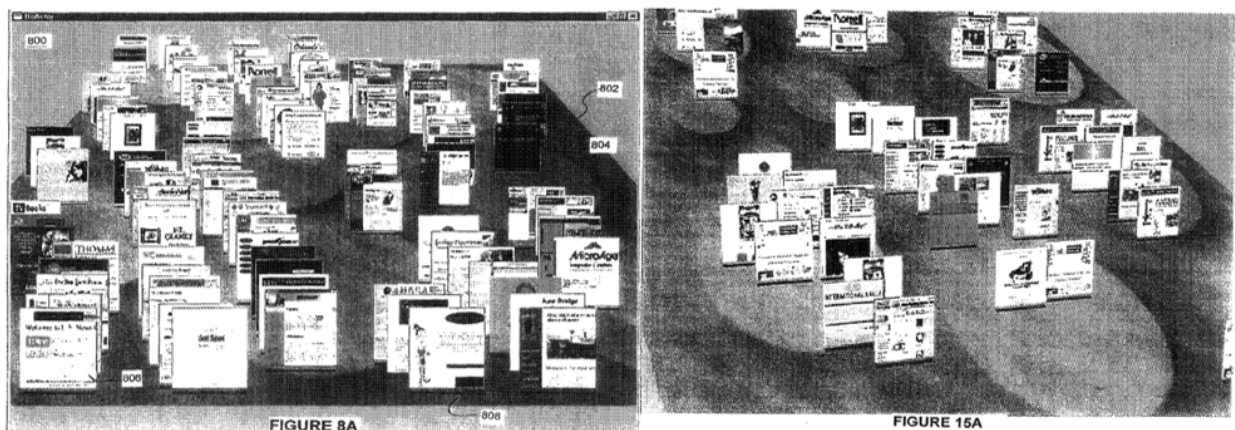
G. Overview of Robertson

78. The explosive popularity of the Internet led more and more “people [to] us[e] computers to access information...created by unrelated third parties (or content providers).” APPLE1009, 2:26-65. From this premise, Robertson reasoned that “[n]ew GUIs should therefore help people find information that they want.” APPLE1009, 2:66-67. For example, a user may want to “‘go back’ to (or ‘relocate’) information (or content), to revisit that information or to revisit a familiar content provider to view new information (or content)” without “navigating through a hierarchy of menus, or entering a search query.” APPLE1009, 3:36-46.

79. While “[s]ome so-called ‘Internet browser’ program services, such as Microsoft’s Internet Explorer” help with relocating information or content

providers by “permit[ting] people to create lists of favorite Internet locations...represented by bookmarks,” the “person’s ability to find a desired bookmark becomes more difficult” when “the number of bookmarks in a list increases.” APPLE1009, 3:47-66. To improve upon these and other GUIs for accessing information over the Internet, Robertson proposed an interface that “exploit[s] spatial memory” by “simulat[ing] three dimensions” and representing webpages in the 3D space as object thumbnails bearing a low resolution image of the corresponding content. APPLE1009, 6:15-28; *see also id.*, 6:30-67, 9:11-50, 12:54-13:4 (“the object thumbnails 806 represent web (or hypertext markup language or ‘HTML’) pages”).

80. Figures 8A and 15A (below) are two of several exemplary 3D-GUIs described by Robertson where webpages are represented by object thumbnails on a simulated 3D landscape. APPLE1009, 12:54-13:4, 17:21-45, Figures 8A-18.



APPLE1009 (Robertson), FIG. 8A (left), FIG. 15A (right).

81. Like the '868 Patent, Robertson recognized that it may not be feasible to interact with web content in the form of relatively small object thumbnails. Thus, “for editing or otherwise working on a selected object,” Robertson provides “‘live’ objects within an associated application.” APPLE1009, 13:55-67. For example, when a thumbnail is selected by a user, “the Internet Explorer browser...render[s] [the corresponding] web page, with the [3D] user interface...in the background.” APPLE1009, 13:67-14:14. “The application can be maximized...to substantially fill the screen of the video monitor.” *Id.*

H. Combination of Robertson with HAC and Matthews

82. As disclosed by Robertson, using an Internet Explorer window to browse the Internet and access information was well known in the art. APPLE1009, 2:26-67. To avoid “navigating through a hierarchy of menus, or entering a search query,” it would have been obvious to a POSITA to display multiple browser application windows (e.g., 4 browser windows when visiting 4 web pages) in a 3D display. APPLE1009, 3:36-46. Displaying multiple browsers is also beneficial because the user can avoid wasting time trying to find the relevant bookmark from among multiple bookmarks. APPLE1009, 3:47-66.

83. Anthony, Hanggie, and Matthews render obvious multiple windows being displayed in 3D environment. Robertson explains that, for a user interesting in browsing the Internet, it would have been obvious to display the multiple windows

are separate web browsers corresponding to web browser applications used to browse the Internet. APPLE1009, FIGS. 8A, FIG. 15A.

84. Combining the teachings of Anthony, Hanggie, Matthews, and Robertson would have been obvious as it merely involves combining prior art elements according to known methods to yield predictable results. Here, the HAC-Matthews system would have been used to display web browser windows, as disclosed by Robertson, to yield the predictable result that a user can view multiple browser windows at one time. The windows would have been arranged in a chronological order, as taught by Anthony, so that the user can see which windows the user interacted with at what time and can then also more easily navigate to the window of interest.

85. Moreover, all of the references are directed to rendering windows in 3D space and have the same assignee (Microsoft). Indeed, Robertson's computer system (shown in FIG. 1A) is similar to Anthony, Hanggie, and Matthews' FIG. 1A, thus making the combination of these references predictable and foreseeable.

X. MANNER IN WHICH THE PRIOR ART REFERENCES RENDER THE '868 CLAIMS UNPATENTABLE

A. Claim 1

[1pre] A method for using a two-dimensional (2D) space to selectively interact with a plurality of applications open on a device and a three-dimensional (3D) immersive space to switch between said plurality of application⁵, said device having a fixed resolution display, comprising:

86. As explained above in §IX.B, Hanggie's CDWM 190 "provide[s] a rich, full featured operating system ... to provide a desktop that uses advanced textures, lighting, and 3D transformations, yet supports legacy applications." APPLE1006, ¶¶[0012], [0015], [0026], [0039], [0040]. The CDWM 190 may include an Application Programming Interface 190a through which a composition-ware Application software 191 obtains CDWM window and content creation and management services. APPLE1006, ¶[0041]. HAC's computer system 110 implements a method in which a monitor's 2D space display is used to selectively interact with a plurality of applications through displayed window. For instance, a user may choose to display a plurality of windows, respectively associated with an

⁵ The word "application" appears to be a typo and is missing an "s" at the end. Because "said" precedes recitation of "plurality of application," I believe this "plurality of application" refers to the previously recited "plurality of applications."

application, in a 2D legacy drawing mode, and 2D graphics can be provided for legacy applications using the Legacy Graphics Device Interface 192b⁶ in the Legacy Graphical User Interface subsystem. APPLE1006, ¶¶[0092], [0042]; *see above* §IX.B, *below* [1b]. Hanggie’s FIG. 3 depicts an example of such a window. As shown below in FIG. 3, each window 301 includes buttons 305 (e.g., used to restore, maximize, minimize, close the window), scrollbars 309, menu bar 311, and primary content object area 315 to facilitate user interaction with the window. APPLE1006, ¶[0058], FIG. 3;

⁶ Consistent with the construction of “2D” noted in §VIII, Hanggie’s Legacy Graphics Interface 192 is explicitly described as “provid[ing] 2D graphics services” to legacy applications and a Legacy Window Manager, and thus would have been understood by a POSITA to provide a 2D (“a finite graphical area defined by a two-dimensional coordinate system”) space. APPLE1006, ¶[0042].

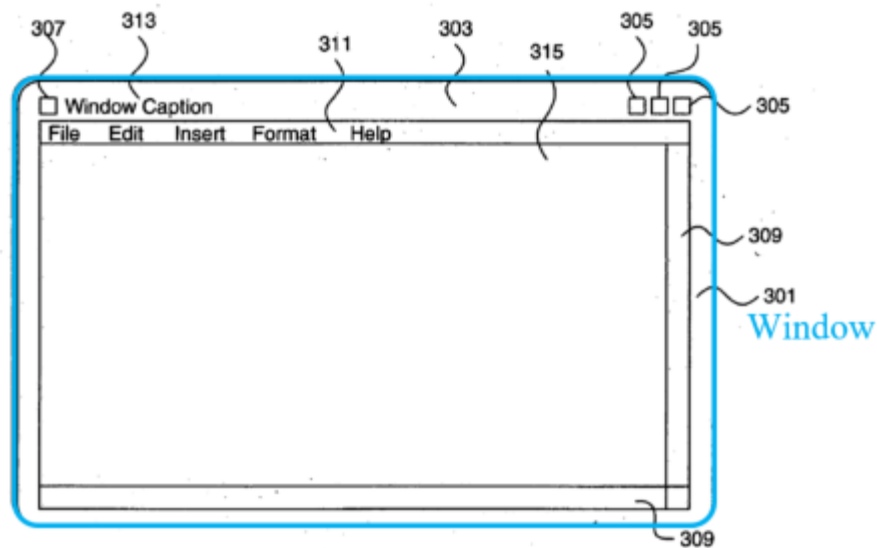
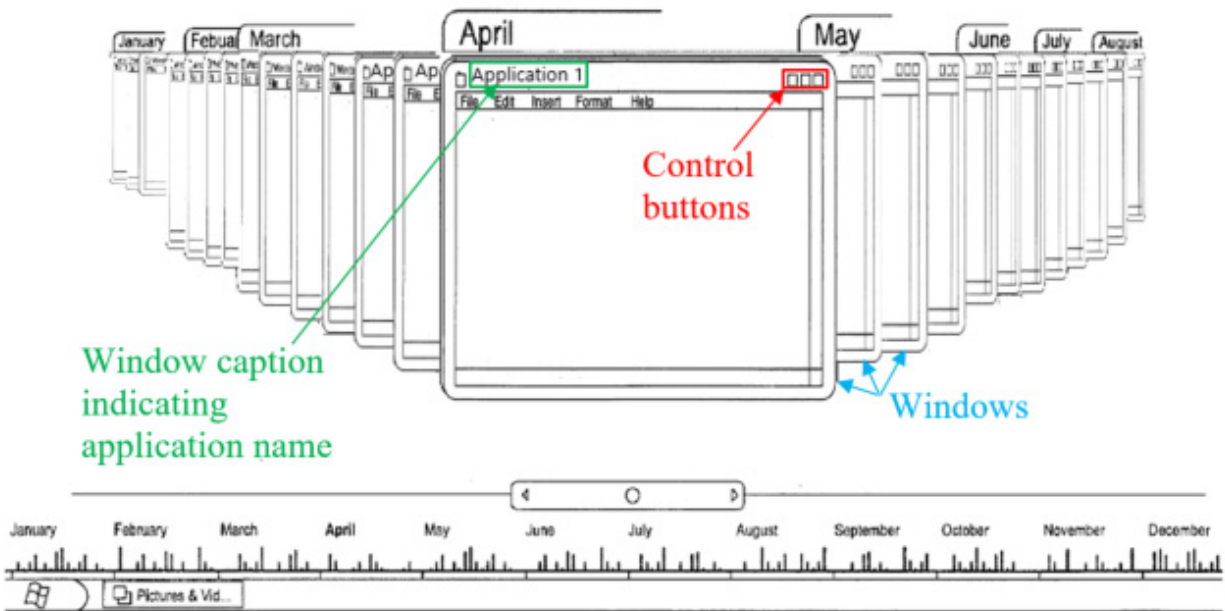


FIG. 3

APPLE1006 (Hanggie), FIG. 3.

87. As explained in §§IX.C- IX.D and shown in the figure below, in HAC, Hanggie’s windows can be displayed in a three-dimensional (3D)⁷ immersive space such as Anthony’s dynamic timeline view. APPLE1007, ¶[0042].

⁷ Consistent with the construction (“a virtual space defined by a three-dimensional coordinate system”) of “3D” noted in §VIII, Anthony’s timeline is explicitly described as being implemented in a 3D environment using 3D graphics technology. APPLE1007, ¶[0043].



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006)

88. Further, a POSITA would have understood and found it obvious that HAC's 191/184 monitor⁸ has a fixed resolution. For instance, Anthony discloses

⁸ As explained above in §§IX.C- IX.D, Hanggie and Anthony describe systems having similar architectures, and a POSITA would have understood and found it obvious to implement components shared commonly in both systems (e.g., input devices, monitors) within HAC, accounting for the descriptions provided by both references. APPLE1007, FIG. 1; APPLE1006, FIG. 1A.

displaying its windows on a 96 dpi (dots per inch) screen, and neither Anthony nor Hanggie teach or suggest that there is a modification in the monitor 191/184's resolution in different operating modes. APPLE1007, ¶[0050].

[1a] receiving a plurality of inputs from a user, said plurality of inputs comprising at least first, second, and third inputs;

89. As explained above in §§IX.C- IX.D, Hanggie and Anthony's systems have similar architectures and a POSITA would have understood that descriptions associated with components shared commonly in both systems (e.g., input devices, monitor) would have been implemented in HAC system whether described as being part of Hanggie's system or Anthony's system.

90. In HAC, user inputs can be received through input devices such as a keyboard 162, pointing device 161 (e.g., mouse), or stylus. APPLE1007, ¶[0038]; APPLE1006, ¶[0005]. Hanggie teaches that its CDWM receives requests to create a window and attach a content object. APPLE1006, ¶¶[0050], [0051], [0088].

Although Hanggie does not explicitly teach that the request is a user input, it would have been obvious to a POSITA that computer windows would have been generated in response to a user request to open the window (such as an application window) received through an input device. Moreover, it would have been obvious that a user interface, like the one in HAC, is configured to receive user inputs as receiving user input is what a user interface is designed to do.

91. Such a method for opening windows, such as application file windows, was well known in the art. Indeed, Anthony teaches that a user may navigate to a particular window and open a file within the window. APPLE1007, ¶¶[0038], [0043]-[0044], [0047] (“[i]f an icon 606a in the focal group 509 represents a file, double-clicking the file will cause the system to attempt to open the file”), [0084]. And while this disclosure is made with respect to Anthony’s 3D timeline, it would have been obvious to a POSITA that a similar operation would have been performed in a 2D environment such that a user would have provided an input to the HAC system when desiring to open a file, such as an application file.

92. In addition, it would also have been obvious to a POSITA that when a user opens three application files using an input device, HAC’s computer system would have received first, second, and third inputs. For instance, when a user selects three application files to open using an input device, e.g., by double clicking the mouse when it is positioned over icons corresponding to the three application files, HAC’s computer system would receive at least first, second, and third inputs from the mouse.

[1b] opening said plurality of applications in response to said plurality of inputs, said plurality of applications comprising at least first, second, and third applications, wherein for each one of said plurality of applications (i) an object is generated having application-specific data, (ii) said object is displayed in said 2D space on said fixed resolution display, and (iii) said user is allowed to modify at least a portion of said application-specific data by interacting with said object;

93. As noted in [1a], when a user double clicks on a file, HAC's computer system opens it. APPLE1007, ¶[0047]. When the file is an application file, Hanggie's CDWM generates a window having content ("*application-specific data*") corresponding to the application file selected by the user. APPLE1006, Abstract, ¶¶[0005], [0015] ("window content"), [0049]-[0050] ("content object"), [0060]. A user may choose to display the window in a legacy drawing mode, which is 2D, when desired (e.g., to preserve power) by making such a selection via a user control. APPLE1006, ¶¶[0092], [0042]; *see above* §IX.B. Thus, in HAC, the application window ("*object*") is displayed in said 2D space on a fixed resolution display, e.g., 96 dpi, of monitor 191. APPLE1007, ¶[0050], Abstract, FIG. 1.

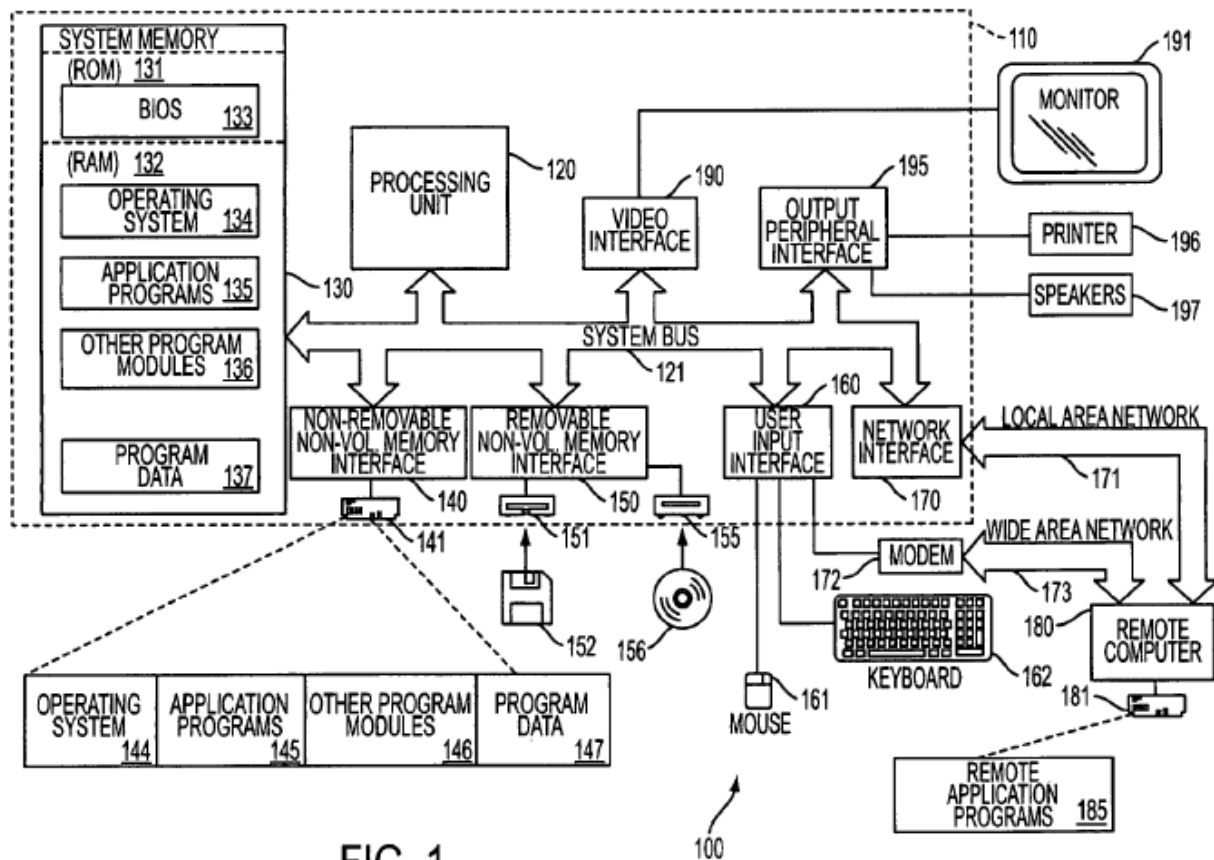


FIG. 1

APPLE1007 (Anthony), FIG. 1.

94. Hanggie also discloses that 2D graphics can be provided for legacy applications using the Legacy Graphics Device Interface 192b in the Legacy Graphical User Interface subsystem. APPLE1006, ¶[0042]. Content related to the applications can include “e.g., text by a word processor, numeric grid by a spreadsheet application, or images by a photo editing application.” APPLE1006, ¶[0060]. It would have been obvious to a POSITA and well known in the art, that a user can interact with 2D windows to modify at least a portion of the application

content (“application-specific data”). For instance, when using a word processor application or spreadsheet application, it is well known that a user can interact with the application and edit text and images in the application window using the computer’s keyboard, mouse, and/or other input devices. APPLE1011, ¶¶[0002] (“[a]n alphanumeric input device, such as a keyboard, is the most common way for a user to input textual data to a computing device”); [0018], [0026]; *see also generally* APPLE1012; APPLE1013, 4:35-39. Hanggie teaches that “[w]indows can typically be interactively resized, moved around the display, and arranged in stacked order so as to fully or partially overlap one another.” APPLE1006, ¶[0003]. A user can provide input for one or more windows using an input device such as a keyboard or mouse. APPLE1006, ¶[0003].

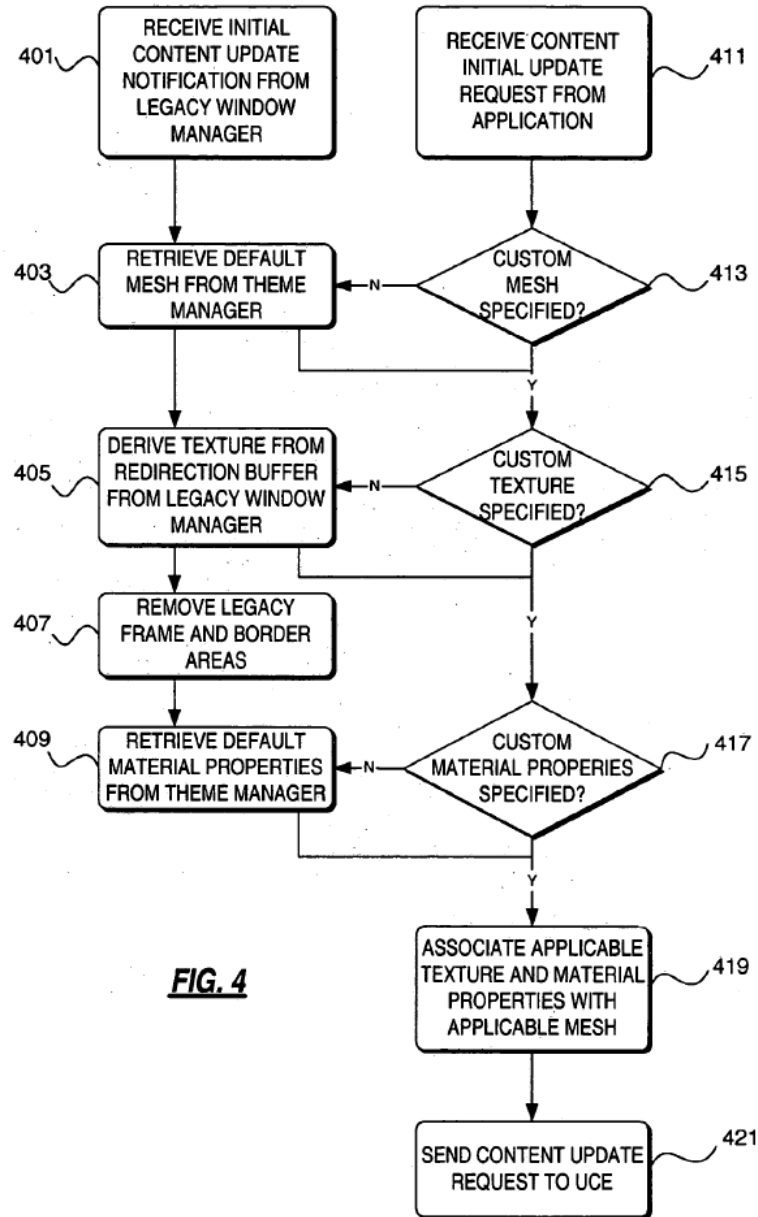
95. Hanggie’s FIG. 4 (reproduced below) illustrates a method by which windows can be created in a legacy mode using the Legacy Window Manager 192a. Hanggie discloses that “[s]teps 401–409 [in FIG. 4] represent the initial rendering of content associated with a legacy application window whose source rendering surface (or set if [sic] instructions required to generate the surface) is obtained from the Legacy Window Manager 192a.” APPLE1006, ¶[0087].

Hanggie explains that “a legacy application call[s] legacy APIs 192b to draw a window on the desktop according to the invalidation model for which the application was designed. For example, Microsoft® Word® XP may call the

legacy APIs so that the legacy DWM 192a draws text input by the user.”

APPLE1006, ¶[0088]. Operations 403-409 are then performed to render the application window with the desired content, properties, and parameters.

APPLE1006, ¶[0088].



APPLE1006 (Hanggie), FIG. 4.

[1c] allowing a user to switch between said plurality of application, comprising;

96. As explained in [1b], a user can interact with the 2D windows to switch between a plurality of applications. APPLE1006, ¶[0003] (“Windows can typically be interactively resized, moved around the display, and arranged in stacked order so as to fully or partially overlap one another.”) Anthony also discloses that a user can “freely navigate documents, files, or other data objects in a chronological manner,” and that the user can “change the point of focus to an arbitrary location on a timeline.” APPLE1007, ¶[0044]. As explained in more detail below in [1c-1]-[1c-5], HAC renders obvious allowing a user to switch between applications by implementing features [1c-1]-[1c-5].

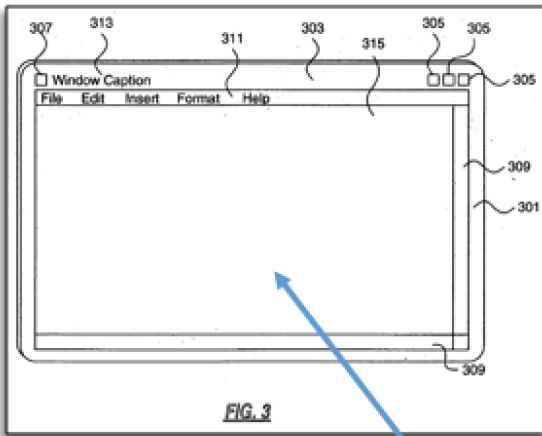
[1c-1] generating at least a plurality of images, said plurality of images comprising at least first, second, and third images, wherein said first image is an image of at least a portion of a first object generated by said first application and having first application-specific data, said second image is an image of at least a portion of a second object generated by said second application and having second application-specific data, and said third image is an image of at least a portion of a third object generated by said third application and having third application-specific data;

97. As explained above in §IX.B and [1b], Hanggie discloses that a user can select whether to operate the computer in DWM (legacy mode with 2D display of data) mode or in CDWM (3D display of data). APPLE1006, ¶¶[0092], [0042]. Operations 401-409 in FIG. 4 describe how a 2D window is rendered in the DWM

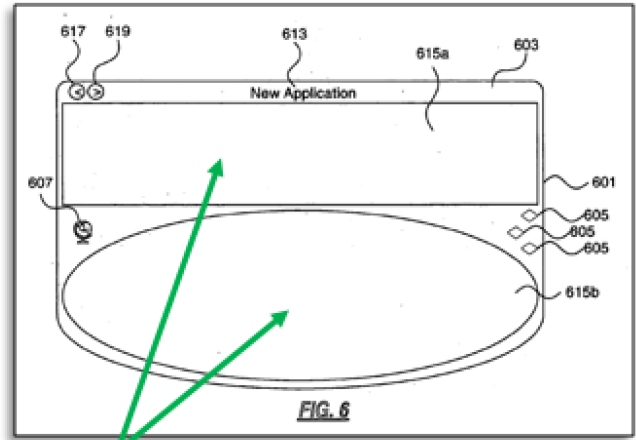
mode. *See above* [1b]; APPLE1006, ¶¶[0087], [0088], FIG. 4. It would have been obvious to a POSITA that when a user views the three 2D windows (as described above for [1b]) in the DWM mode and then selects the CDWM mode to interact and view the windows in 3D, HAC's computer would ***generate a plurality of images in the form of 3D windows that respectively correspond to the three 2D windows***. APPLE1006, ¶¶[0026], [0057] (“to draw the window in 3D, the CDWM may define the window anatomy using various components), [0058], [0059] (“[t]he CDWM may support multiple application created and rendered content areas, associated with a single window”); FIG. 3. Specifically, Hanggie discloses that an application can generate an application window and attach any number of content objects to the application window. APPLE1006, ¶¶[0049]-[0050], [0087]-[0092], FIGS. 2, 4. In generating a 3D composited window, the computer modifies various features of the (previous) 2D window such as the “content size, window position or scale, or a change to the pixels of the contents diffuse texture.” APPLE1006, ¶[0050]. “[T]he CDWM derives composited window attributes (frame and border style, caption, etc) and state (hidden/shown, minimized/maximized, etc) from existing legacy window properties” and “the legacy window manager 192a informs the CDWM 190 of any change affecting the redirected window content texture that may necessitate a visual update.” APPLE1006, ¶[0051].

98. Hanggie, like Anthony, teaches that a 3D graphics engine such as Microsoft Direct3D® can be used to render 3D objects. APPLE1006, ¶¶[0056]; APPLE1007, ¶[0043]. Hanggie explains that “[i]n order to draw the window in 3D, the CDWM may define the window anatomy using various components, include a base content object and one or more child content objects. The base content object defines the window frame, or border, and consists of a base geometry, base extent, base material properties and base content margins. The base and child content objects may each be entirely defined and managed by the system or in the case of custom content elements, may be managed by the application.” APPLE1006, ¶¶[0057]. Like Anthony, Hanggie, explains that multiple windows, applications, and frame contents can be displayed, removed, and repositioned, and that windows can be defined by an application. APPLE1006, ¶¶[0058]-[0060].

99. As an example of multiple windows created for respective applications, compare Hanggie’s FIG. 3 (reproduced below), which illustrates a window generated for one application, with Hanggie’s FIG. 6 (reproduced below), which illustrates a window generated for a second application. APPLE1006, ¶¶[0058], [0064]. The application window associated with FIG. 3 has a single object area 315 whereas the application window associated with FIG. 6 has “a dynamic non-standard anatomy” of two object areas 615a, 615b. APPLE1006, ¶¶[0058] (FIG. 3), [0064]-[0065] (FIG. 6).



Single Content Area



Multiple Content Areas

APPLE1006 (Hanggie), FIG. 3(left), FIG. 6 (right).

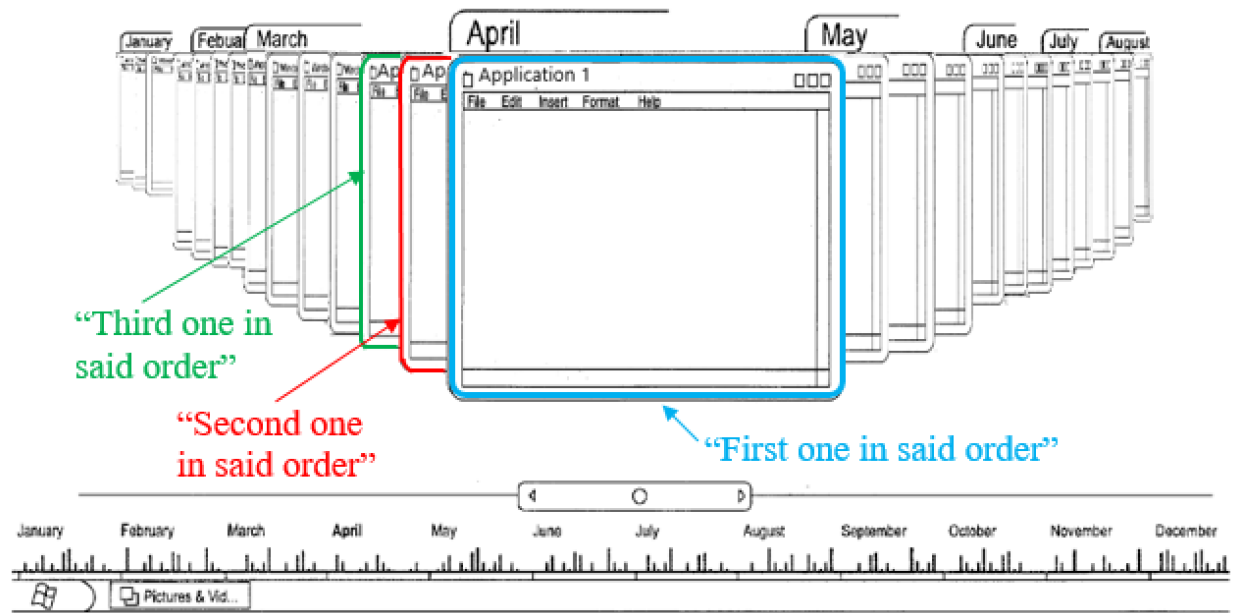
100. In the above-described manner, it would have been obvious to a POSITA that for each of the three 3D application windows that is generated and displayed, the respective first, second, or third application window is an image of at least a portion of an object (e.g., 2D window) generated by said the respective application and having respective application-specific data (e.g., application data, application content object).

[1c-2] replacing all objects corresponding to said plurality of applications that are visible in said 2D space with said plurality of images, said plurality of images being displayed in said 3D immersive space and in an order based on a last time that said user one of (i) opened said first application and interacted with said first object, (ii) opened said second application and interacted with said second object, and (iii) opened said third application and interacted with said third object, wherein a first one in said order is displayed in a foreground of said 3D immersive space, a second one in said order is displayed in a background of said 3D immersive space behind at least said first one in said order, and a third one in said order is displayed in said background of said 3D immersive space behind at least said second one in said order;

101. HAC renders obvious “replacing all objects corresponding to said plurality of applications that are visible in said 2D space with said plurality of images” for at least the reasons noted above in [1c-1].

102. Anthony explains that the multiple windows can be arranged according to a particular “ordering attribute,” which may be based on chronologically in time “e.g., by using a date of creation or date of edit attribute as the ordering attribute.” APPLE1007, ¶[0042]. It would have been obvious to a POSITA that the last date of edit of a window, in some cases, corresponds to the last time a user opened an application and interacted with the window associated with the application.

Accordingly, each of HAC’s 3D windows (“*plurality of images*”) are displayed in an order based on a last time that the user opened the application corresponding a window and interacted with the window. As shown in the combination figure below, the three windows can be displayed in an order from the foreground to behind the background such that “a first one in said order is displayed in a foreground of said 3D immersive space, a second one in said order is displayed in a background of said 3D immersive space behind at least said first one in said order, and a third one in said order is displayed in said background of said 3D immersive space behind at least said second one in said order.”



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

[1c-3] allowing said user to move said plurality of images, wherein (i) movement of one of said plurality of images results in movement of all of said plurality of images, and

103. Anthony teaches that a user can freely navigate through the files, folders, and objects in the timeline to focus on any point in the timeline. APPLE1007, ¶[0044]. To facilitate user navigation, Anthony discloses a scroll bar or wheel to shift to different points of the timeline. APPLE1007, ¶¶[0081], [0084]. When a user manipulates the timeline to change the focus onto a different window or focal group, all the windows in the timeline shift so that the window that the user wants to view is at the focal point displayed in front of the user's view. APPLE1007, ¶[0044], FIG. 5.

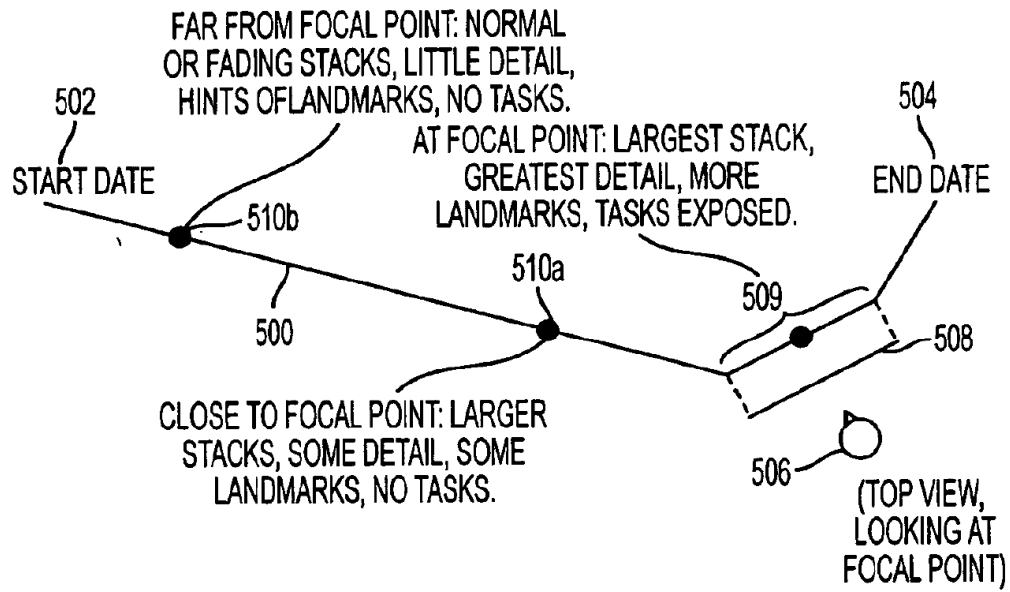
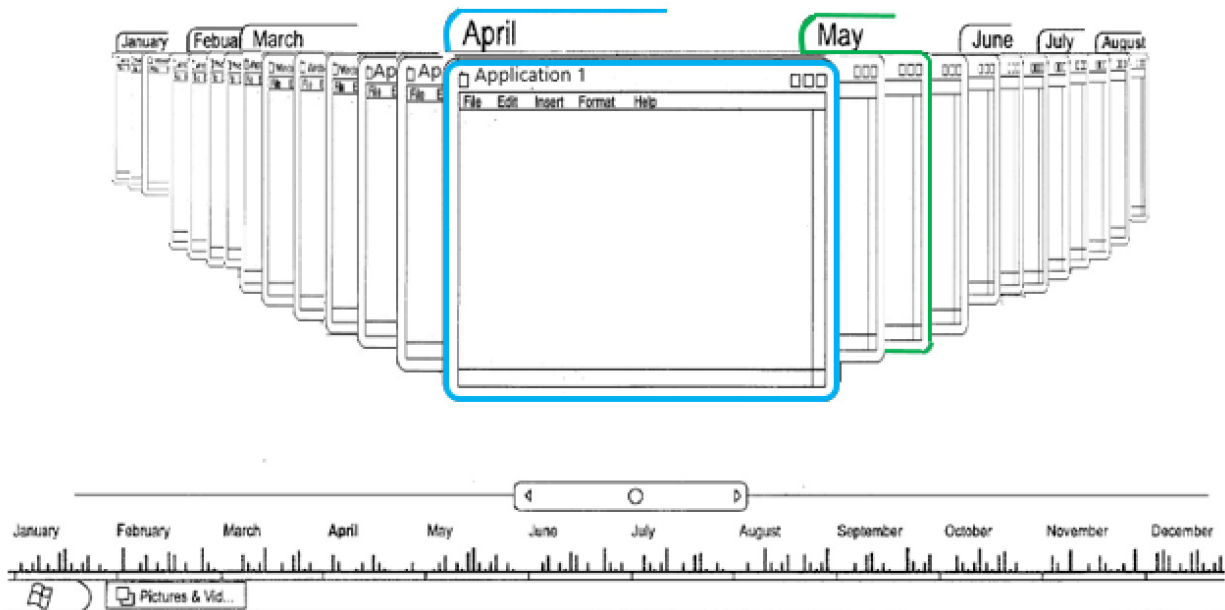


FIG. 5

APPLE1007 (Anthony), FIG. 5.

104. For example, referring to the combination figure below, when a user wants to shift from viewing a window in April to a window in May, all the windows shift to the left such that the May window now occupies the center of the screen instead of the April window. June and latter months shift closer to the center of the screen and April and earlier months shift away from the center of the screen.



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

[1c-4] (ii) continued movement in one direction of one of said plurality of images results in a perception to said user that said one of said plurality of images is moved off of said fixed resolution display; and

105. Anthony refers to the windows that are not displayed at the focal point as non-focal groups. APPLE1007, FIGS. 5, 6, ¶¶[0044], [0065]-[0066]. Anthony explains that “as the non-focal groups are set farther and farther away from the focal group 509, the non-focal groups may become blurred, fogged or transparent. If the number of intervals between a non-focal group and the focal group becomes large, the non-focal group might not be displayed, or it may simply become too small for the user to see on the screen.” APPLE1007, ¶[0066]. Referring to Anthony's FIG. 11, some windows are *continuously moved in one direction* so far

from the focal point that they no longer appear in the visible area of the timeline and *result in a perception that the windows have been moved off the display screen, which has a fixed resolution.* APPLE1007, ¶[0063], FIG. 11.

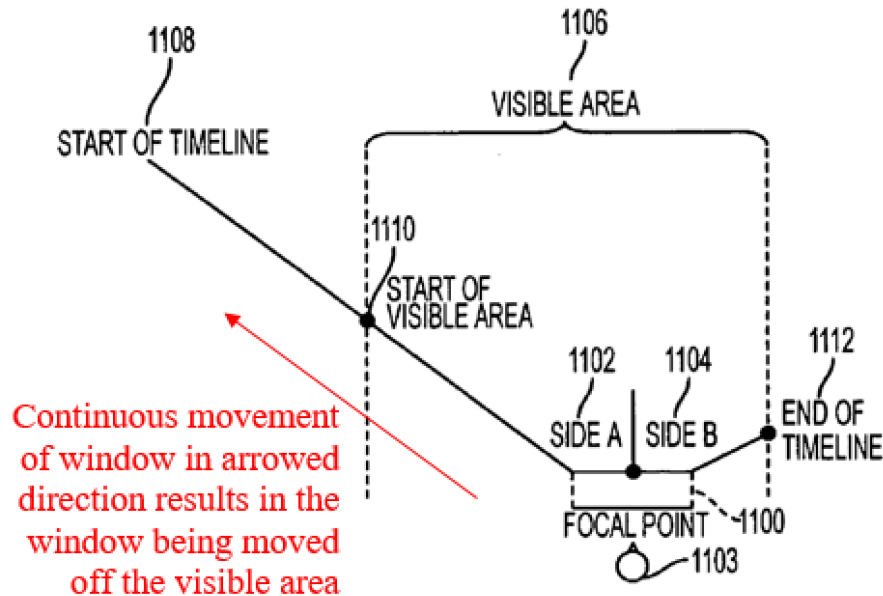


FIG. 11

APPLE1007 (Anthony), FIG. 11.

[1c-5] allowing said user to delete at least one of said plurality of images from said 3D immersive space, wherein deletion of said second one in said order results in said third one in said order being moved to a location in said 3D immersive space where said second one in said order was located prior to said deletion; and

106. As explained above in §§IX.A-IX.D and shown in the figures below, in HAC's system, HAC's 3D windows include Hanggie's buttons 305 that can be used to "used to restore, maximize, minimize, close the window, etc."

APPLE1006, ¶[0058]. It would have been obvious to a POSITA that a user would

have been allowed “*to delete at least one of said plurality of images from said 3D immersive space*” by selecting a button that closes the window. It is known in the art that closing a window results in deleting the window from display.

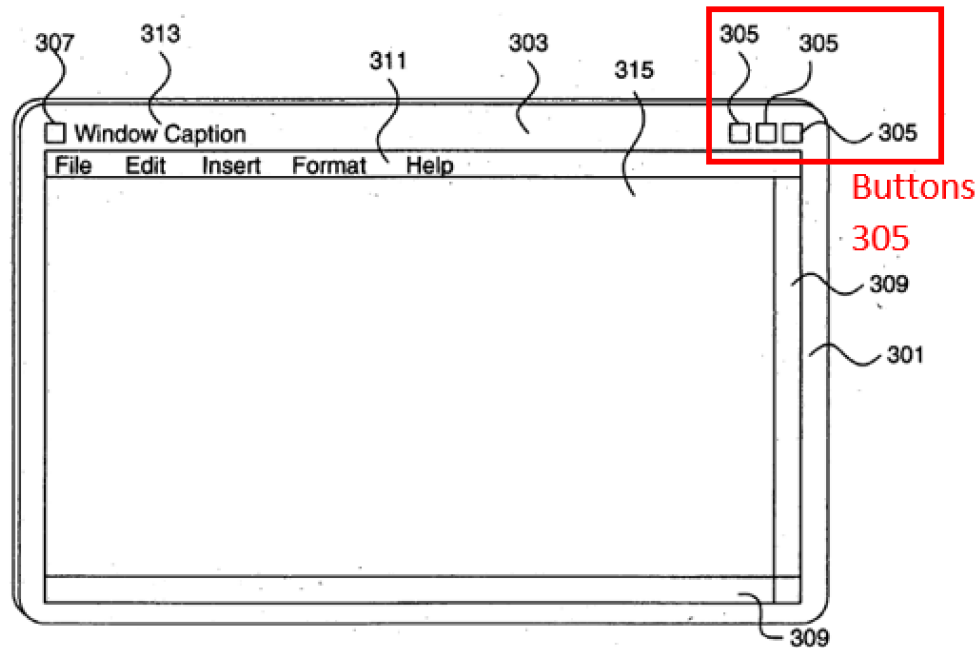
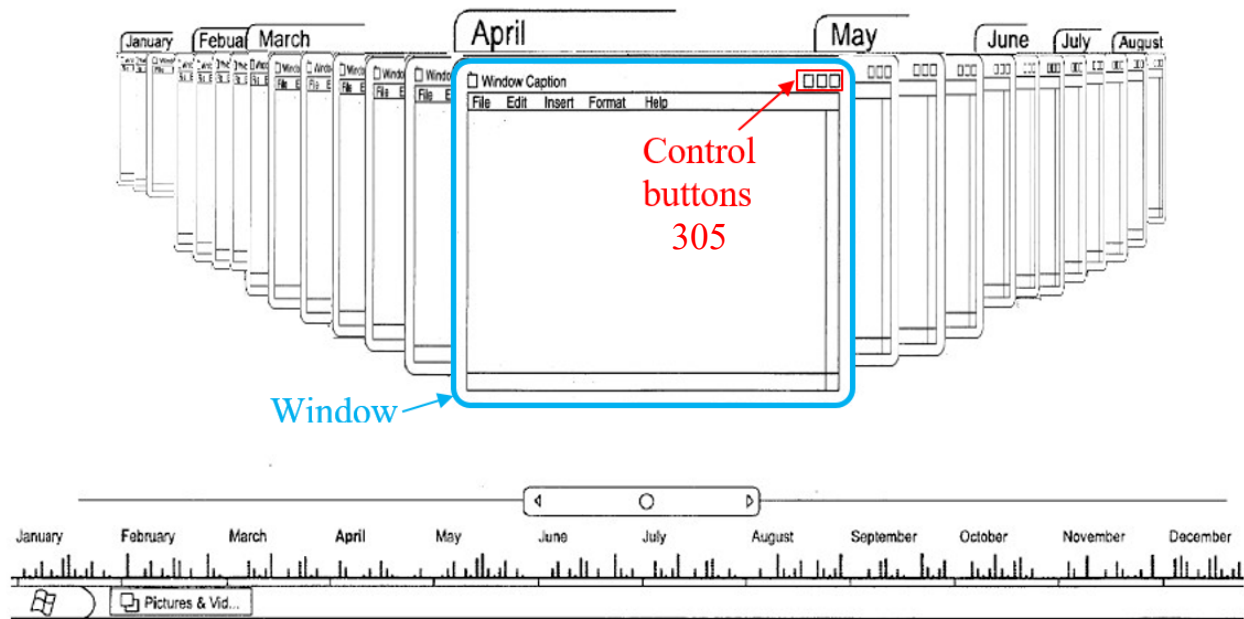


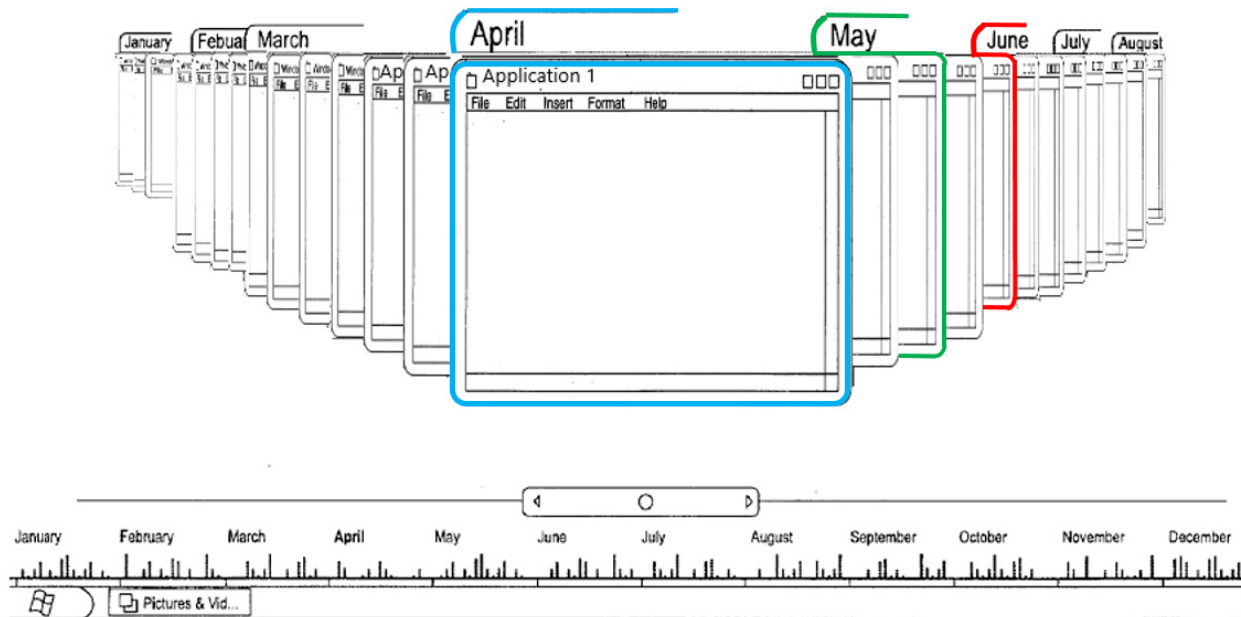
FIG. 3

APPLE1006 (Hanggie), FIG. 3.



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

107. When such a deletion is performed in Anthony's dynamic timeline, it would have been obvious that other windows behind the deleted window would move towards the focal point. For example, referring to the Anthony-Hanggie combination figure (shown below), when a window (e.g., May window) behind and to the right of the April window (focal point) is deleted, a window (e.g., a June window) behind the deleted window (deleted May window) would then move closer to the focal point at the location previously occupied by the deleted window.



Self-generated figure based on the combination of Anthony's FIG. 4

(APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

[1d] allowing said user to interact with one of said first, second, and third applications, comprising:

108. Anthony and Hanggie disclose several methods through which a user can interact with any one of the multiple displayed application windows corresponding to various applications. For example, as explained in [1c-3]-[1c-5], the windows can be moved, deleted, or minimized. HAC also renders obvious the interactions claimed in [1d-1]-[1d-4] as explained in detail below.

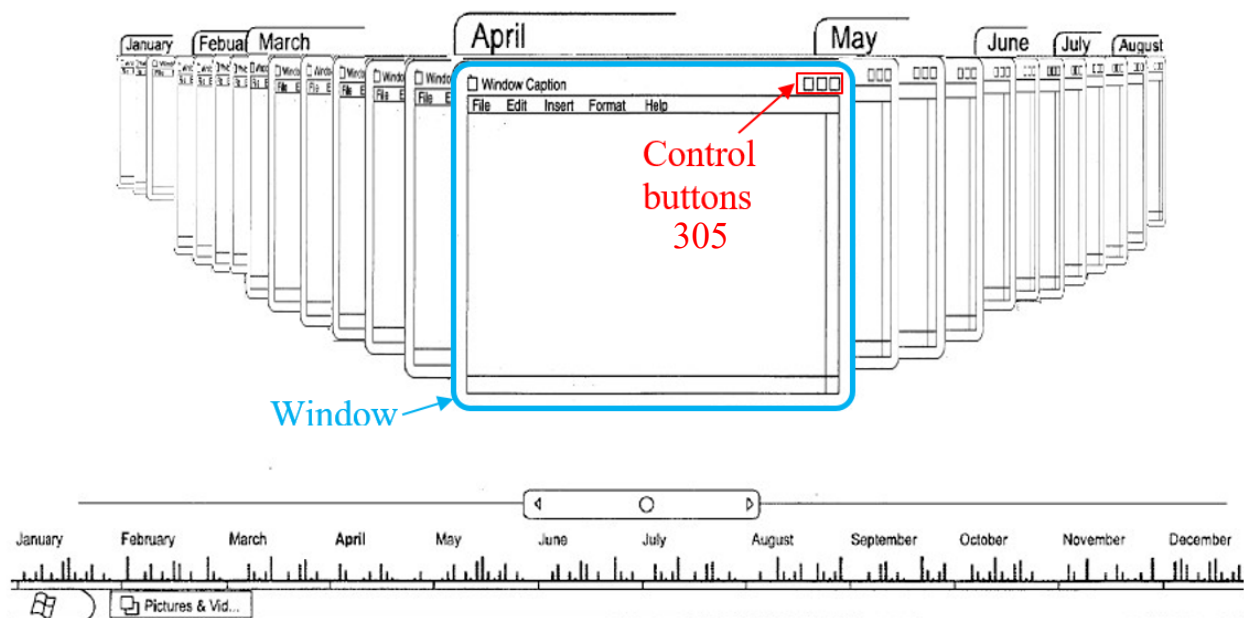
[1d-1] receiving a selection from said user of one of said plurality of images corresponding to one of said plurality of applications;

109. Recall that Hanggie discloses that a user can make a selection to operate in a 2D (DWM) or 3D (CDWM) mode. *See above* [1pre], [1b]; APPLE1006, ¶[0092].

Hanggie explains that, in some implementations, the selection can be made manually or “in accordance with the drawing mode defined by an activated visual style (theme) selected by the user.” APPLE1006, ¶[0092].

110. Recall from [1c-2] that HAC’s 3D windows include buttons 305 that can be used to “used to restore, maximize, minimize, close the window, etc.”

APPLE1006, ¶[0058], FIG. 3.



Self-generated figure based on the combination of Anthony’s FIG. 4 (APPLE1007) and Hanggie’s FIG. 3 (APPLE1006).

111. Upon *receiving a selection from a user* of the maximize button for a window (“*of one of said plurality of images corresponding to one of said plurality of applications*”), it would have been obvious to a POSITA that HAC’s computer would have allowed a user to view the window in a “maximum” capacity such that it occupies all or almost all parts of the computer display. And because the window occupies most, if not all, of the display screen, viewing the window in 2D would allow a user to more intuitively and easily interact with the window. Accordingly, using the maximize button to select 2D viewing of a window would have been an obvious choice to provide a manual selection option for a displayed window to be viewed in 2D. APPLE1006, ¶[0092]. Moreover, because the experience of viewing a maximized window in 2D or 3D would not have provided any substantial or perceived difference in viewing experience, using the maximize button to switch to a 2D viewing of the window would have been obvious. In this manner, by selecting a maximize button on a window in Anthony’s timeline, the window would be reconfigured in the legacy mode and displayed in 2D to occupy all or most parts of the screen in a “maximum” capacity. Such a maximized 2D window would then replace the display of the dynamic timeline and any windows within the timeline.

112. Indeed, using buttons such as the maximize button is consistent with the manner in which the ’868 Patent describes switching viewpoints. In particular, the

'868 Patent explains that by “clicking an icon or bottom [sic] (analogous to the minimize in windows operating system environment) triggers a change to the viewpoint of the end user” from 3D to 2D. APPLE1001, 22:7-30.

[1d-2] replacing said plurality of images within said 3D immersive space with one of said first, second, and third objects corresponding to said one of said plurality of applications within said 2D space in response to said selection;

113. *See above* [1d-1].

[1d-3] receiving at least one interaction by said user with said one of said first, second, and third objects within said 2D space; and

114. Hanggie discloses several ways in which the computer receives at least one user interaction with a 2D window, such as a maximized 2D window. For example, if the maximized window was a Microsoft® Word® application window, Hanggie discloses receiving text input from a user. APPLE1006, ¶[0088]. As is known in the art, in response to a user entering a key on a keyboard when interacting with a Microsoft® Word® application window, application-specific data, such as the text content in the window is modified to reflect the input key. It would also have been obvious to a POSITA that when a user would like to interact with multiple 2D windows, the computer would have received multiple user interactions for the user to interact with the multiple windows (e.g., second and third objects) in the 2D space. Subsequently, application-specific data in such windows would have been modified similar to the single window example.

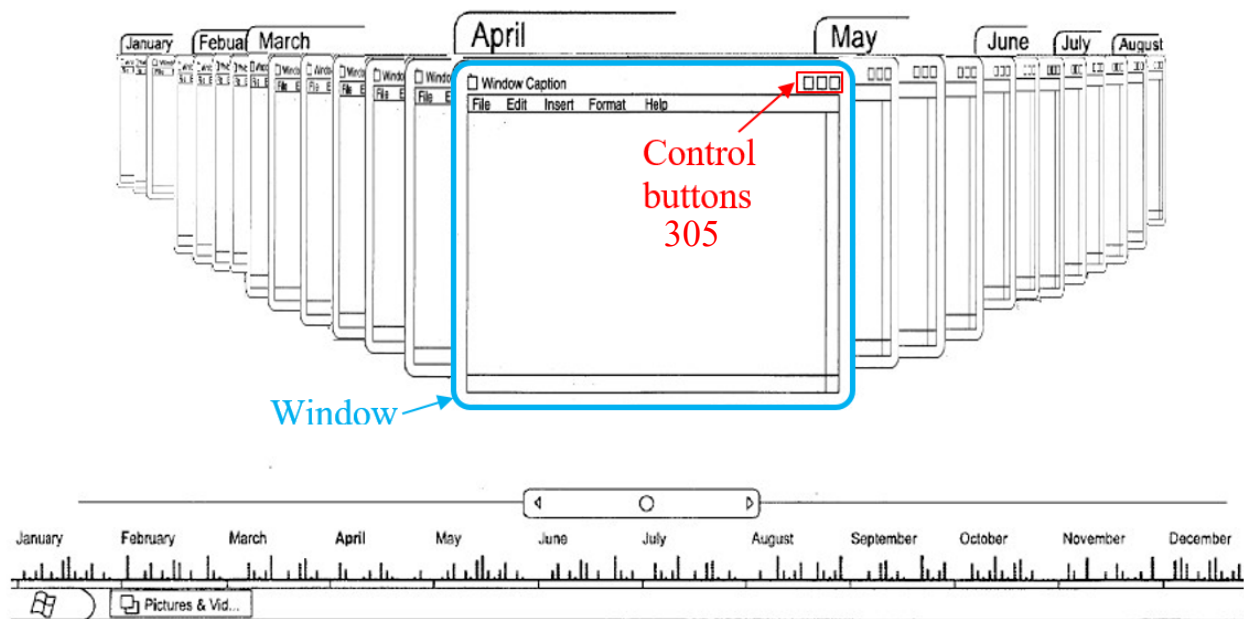
[1d-4] modifying said one of said first, second, and third application-specific data in response to said at least one interaction.

115. *See above* [1d-3].

B. Claim 2

[2] The method of claim 1, wherein said step of displaying said plurality of images on said display device further comprises displaying said plurality of images together with a plurality of icons, wherein each one of said plurality of images has a corresponding one of said plurality of icons.

116. As noted above in §§IX.A-IX.D and [1c-1], Hanggie teaches that “[t]he frame or base content 303 of the window 301 may host child content including **buttons 305 (e.g., used to restore, maximize, minimize, close the window, etc.),** an indicative icon 307, scrollbars 309, menu bar 311, and window caption text 313.” APPLE1006, ¶[0058], FIG. 3. *Any one of the buttons 305 is an icon* that is displayed together with each window (“*image*”). Accordingly, it would have been obvious to a POSITA that when a plurality of windows (“*images*”) is displayed in HAC, the plurality of windows is displayed together with a plurality of icons, and each of the windows has a corresponding one of the plurality of icons, as shown in the combined HAC figure below.



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

C. Claim 3

[3] The method of claim 1, wherein said step of displaying said plurality of images on said display device further comprises displaying said plurality of images together with a plurality of descriptions, wherein each one of said plurality of images has a corresponding one of said plurality of descriptions.

117. As noted above in §§IX.A-IX.D and [1c-1], Hanggie teaches that “[t]he frame or base content 303 of the window 301 may host child content including buttons 305 (e.g., used to restore, maximize, minimize, close the window, etc.), an **indicative icon 307**, scrollbars 309, menu bar 311, and **window caption text 313**.” APPLE1006, ¶[0058]. As shown in Hanggie’s FIG. 3 (reproduced below), each window (“*image*”) has a corresponding indicative icon 307 and window caption

text 313 (“*descriptions*”). It would have been obvious to a POSITA that when a plurality of windows (“*plurality of images*”) are displayed, each one of said plurality of windows has a corresponding one of said plurality of indicative icons 307 and window caption text 313 (“*plurality of descriptions*”).

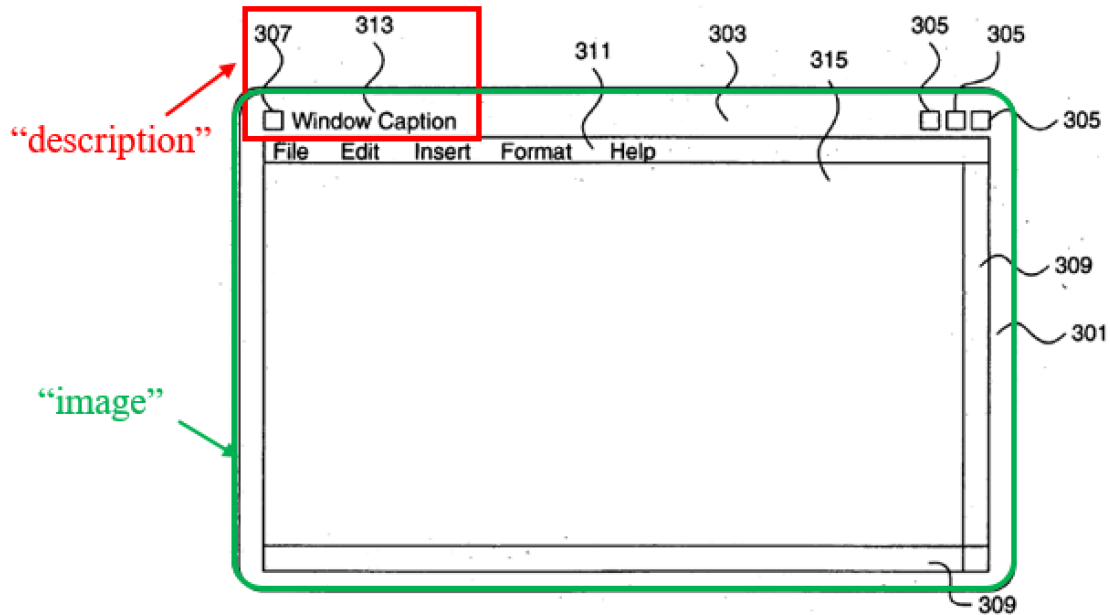


FIG. 3

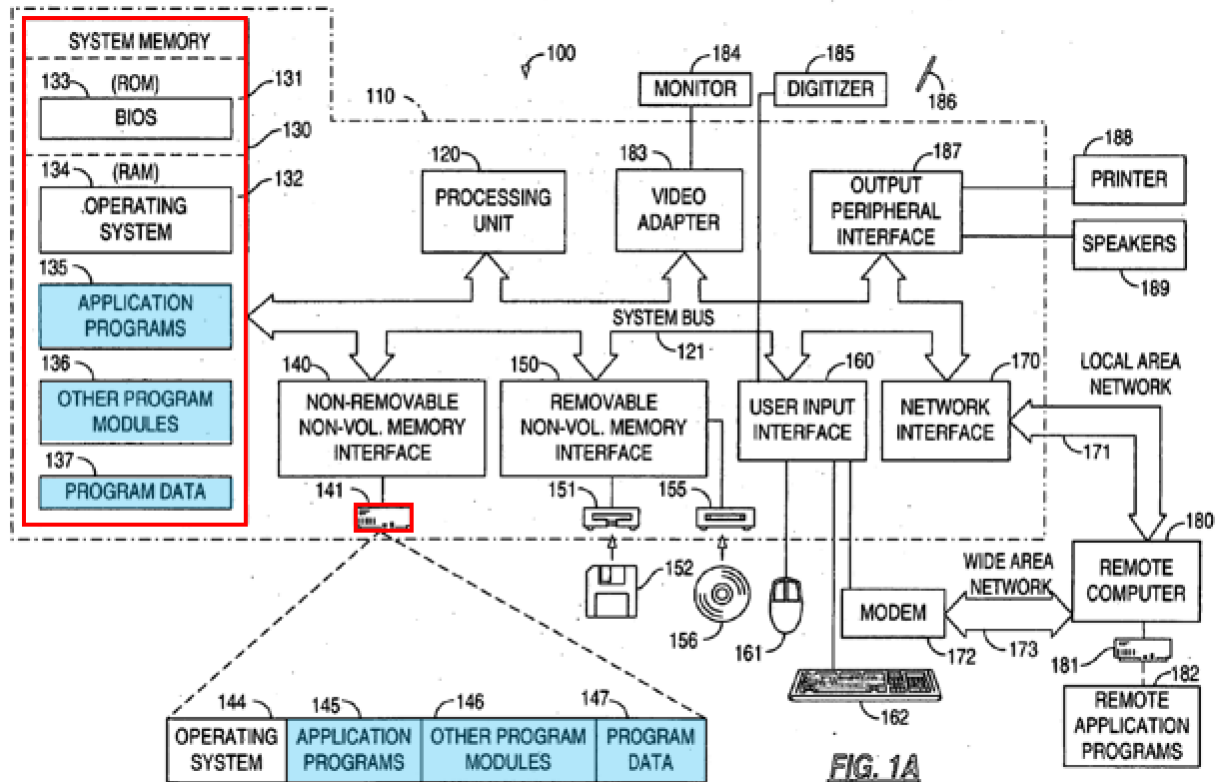
APPLE1006 (Hanggie), FIG. 3.

D. Claim 4

[4] The method of claim 1, further comprising the step of storing in a database data linking each one of said plurality of images with a corresponding one of said plurality of applications and a corresponding one of said order in which said plurality of images are displayed on said display device.

118. As shown in Hanggie’s FIG. 1A, Hanggie teaches that includes computer includes a system memory 130 and hard disk drive 141 that include application

APPLE1006, ¶¶[0033]-[0035].



APPLE1006 (Hanggie), FIG. 1A.

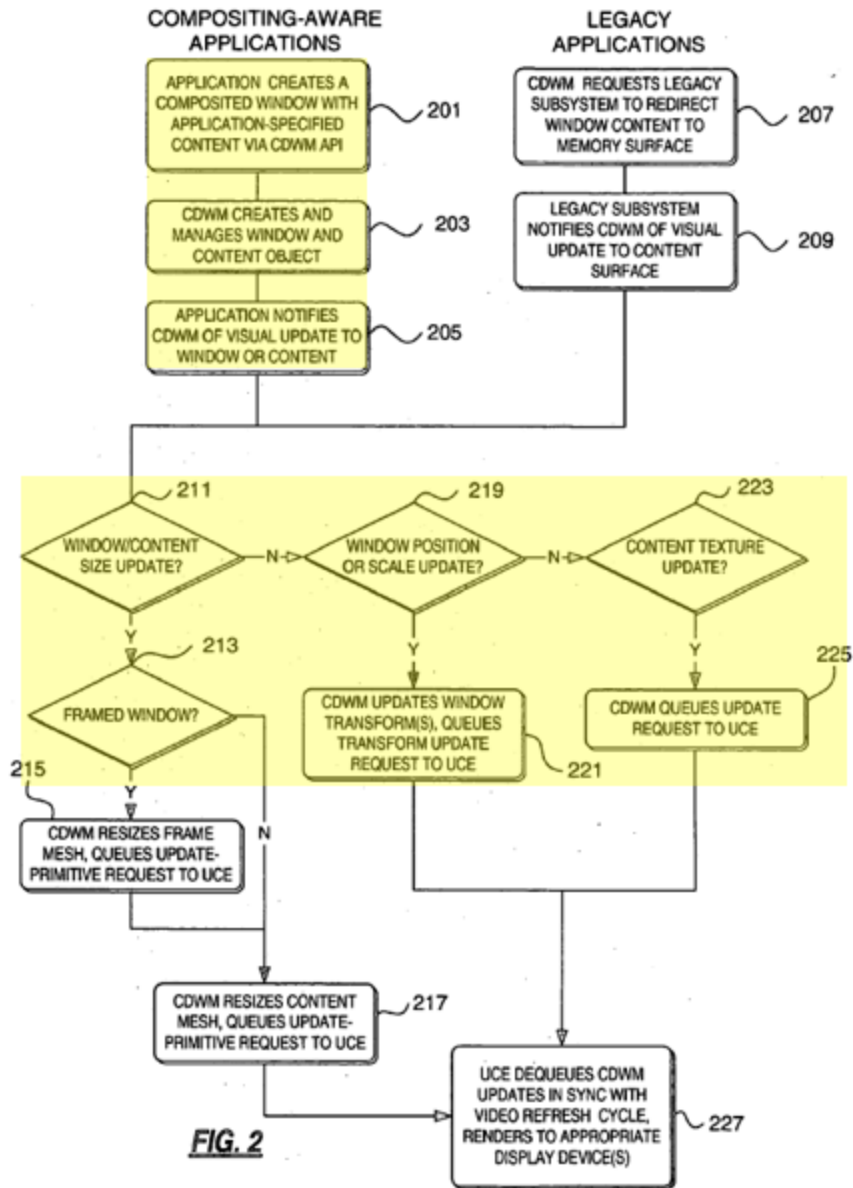
119. The stored application programs and program data are used to configure the displayed windows (images). APPLE1006, ¶¶[0049]-[0052], FIG. 2. For example, Hanggie teaches that “an application can dynamically create and attach to a window (as well as detach and destroy) any number of content objects.”

APPLE1006, ¶[0049]. Rendering features (e.g., transparency, size, orientation) of the window or any changes to the window or content therein can also be controlled

by an application program. *Id.*, ¶¶[0052], [0054], [0059], [0060]. Hanggie discloses that:

basic window elements, and that additional or different window elements may additionally or alternatively be used ... [and] may alternatively be provided by an application, e.g., to provide a distinct look and feel to an application program. An example would be where an application program provides the scroll bar elements as custom child content objects so that they manifest an appearance and behavior peculiar to the application program. Moreover, an application may elect to remove or reposition one or more of the stock frame elements using the CDWM API. An application need not be limited to a single primary content area, a restriction prevalent in the prior art.

APPLE1006, ¶[0058].



APPLE1006 (Hanggie), FIG. 2.

120. As can be appreciated from the foregoing, the RAM 132 or hard disk drive 141 (“*database*”) *store data*, such as the application programs 135/145 (optionally including program modules 136/146, and program 137) which are *linked to each one of the* displayed windows (“*plurality of applications*”) that a respective

application program controls. It would have been obvious to a POSITA that when a window corresponding to a particular application program is opened, the application program would have stored data linking the application to the window so that the application program can control and track the content and features of the window.

121. Note that “database” is defined as “a nonredundant collection of interrelated data items that can be shared and used by several different subsystems.”

APPLE1010, 136. Accordingly, a POSITA would have understood that HAC’s RAM 132 or hard disk drive 141 is a database because RAM 132 or hard disk drive 141 store data that is shared and used by several different subsystems in HAC’s system such as the processing unit 120 and monitor 184.

122. Recall that Anthony discloses an ordering attribute based on time, e.g., by using a date of creation or date of edit attribute as the ordering attribute.

APPLE1007, ¶[0042]. When displaying multiple windows, it would have been obvious to a POSITA that HAC’s computer determines and stores the ordering information providing by the ordering attribute to arrange and display the multiple windows. This order information would have been recalled from a database to support graphical rendering of the windows, and would have been dynamically updated as the ordering of windows changed over time based on user interaction with the windows. Accordingly, it would also have been to a POSITA that HAC’s

RAM 132 or hard disk drive 141 (“*database*”) would also store data for “*a corresponding one of said order in which said plurality of images are displayed on said display device.*”

E. Claim 5

[5] The method of claim 1, wherein a reduction in size of an object or portion thereof is used to depict said object or portion thereof as being behind at least one other object or other portion of said object.

123. Anthony teaches and describes in Fig. 5 (reproduced below), that “[a]ccording to an aspect of the invention, the point of view of the GUI may be based on a conceptual camera 506 pointed at the time interval containing the files or objects on which the user wishes to focus.” APPLE1007, ¶[0044]. In describing the time interval, Anthony discloses:

This time range is called the focal point 508 or focal point interval. The focal point 508 may represent a point in time or an interval of time on the timeline 500. Items that are within the time range covered by the focal point are collectively called the focal group 509. Items in the focal group 509 are typically presented to the user in greater detail than is shown for items in other time intervals on the timeline 500. ... **Items in non-focal groups relatively farther from the focal group 509 may be shown with very little detail, and may be smaller relative to the**

items in both those non-focal groups 510a that are closer in time to the focal point 508, as well as the focal group 509 itself. The smaller appearance may be produced automatically when a 3D rendering technology is used, or may be simulated in 2D by drawing the items smaller.

APPLE1007, ¶[0044].

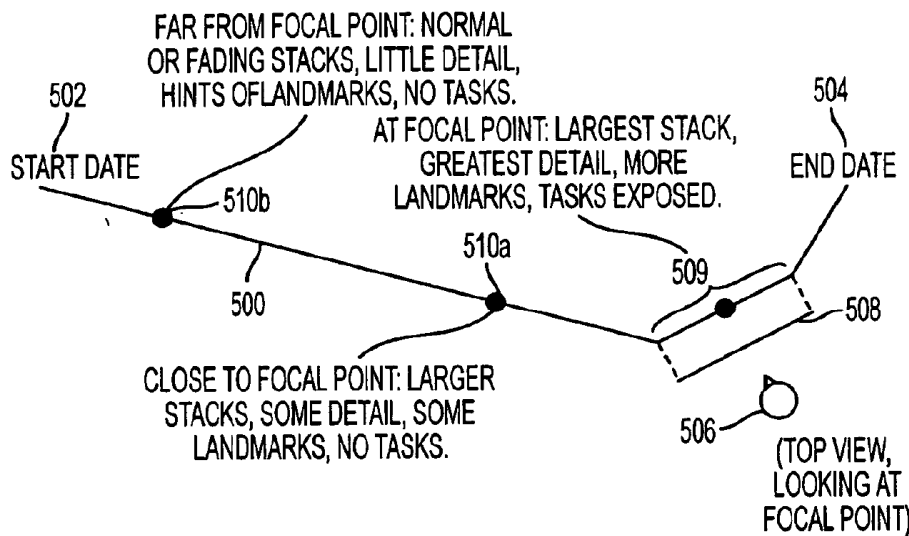
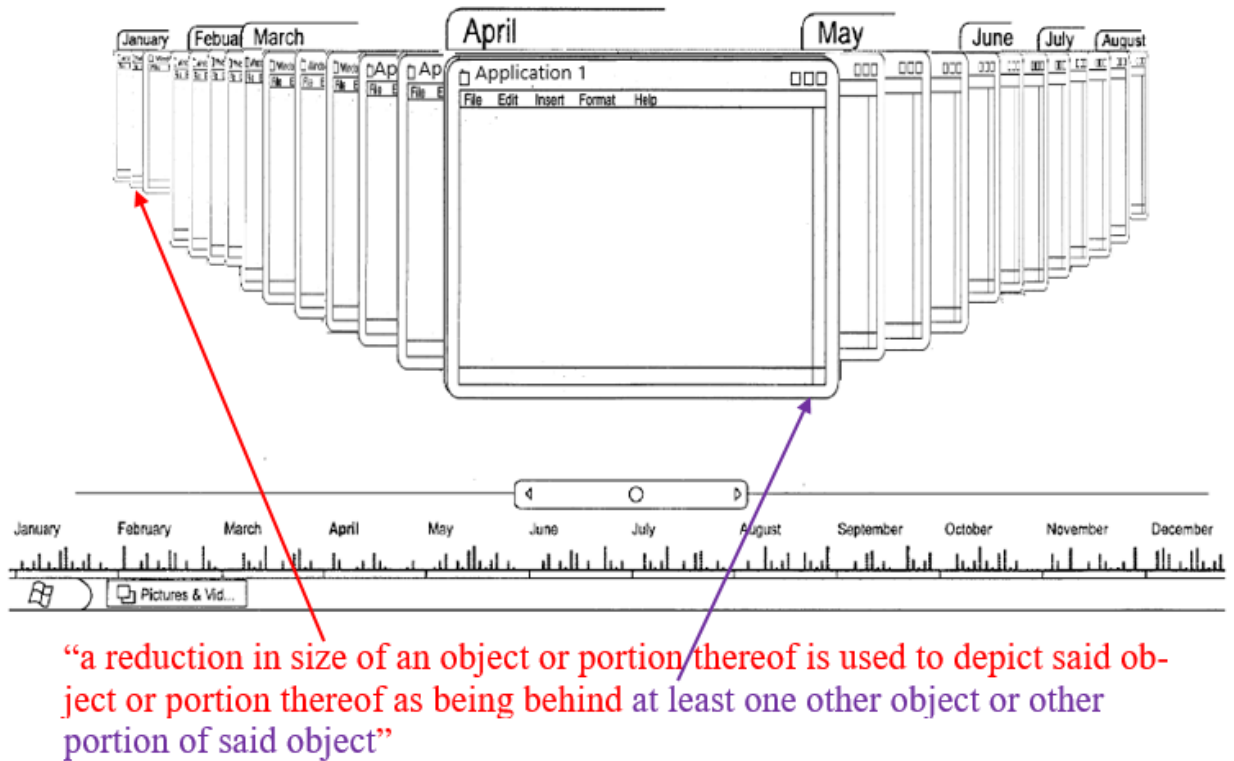


FIG. 5

APPLE1007 (Anthony), FIG. 5.

124. As can be seen in Anthony's FIG. 5 (reproduced above) and the HAC combination figure (reproduced below), in HAC's system, windows that are further away from the focal point are reduced in size to depict that they are behind the focal point. In this manner, HAC renders [5] obvious.



Self-generated figure based on the combination of Anthony’s FIG. 4

(APPLE1007) and Hanggie’s FIG. 3 (APPLE1006)

F. Claim 6

[6a] The method of claim 1, further comprising the steps of: displaying a fourth image on said display device, said fourth image being an image of a desktop having at least one other application; and

125. Matthews discloses a method and apparatus for transforming a work area using a 3D transformation to move a displayed work area, such as a desktop with open windows, to reveal additional information. APPLE1008, Abstract. In particular, Matthews discloses that an **image of a work area 302 that includes an image of a desktop 307 and images of one or more open windows 305** can be

tilted away from the user in response to a user selection of a button, such as the Start button 306. APPLE1008, ¶¶[0049]-[0050], [0056], [0060], FIGS. 3A, 3B, 4A, 5A (reproduced below). The work area 302, desktop 307, and window(s) 305 “are virtually depicted in 3D space” in presentation area 303. APPLE1008, ¶[0058].

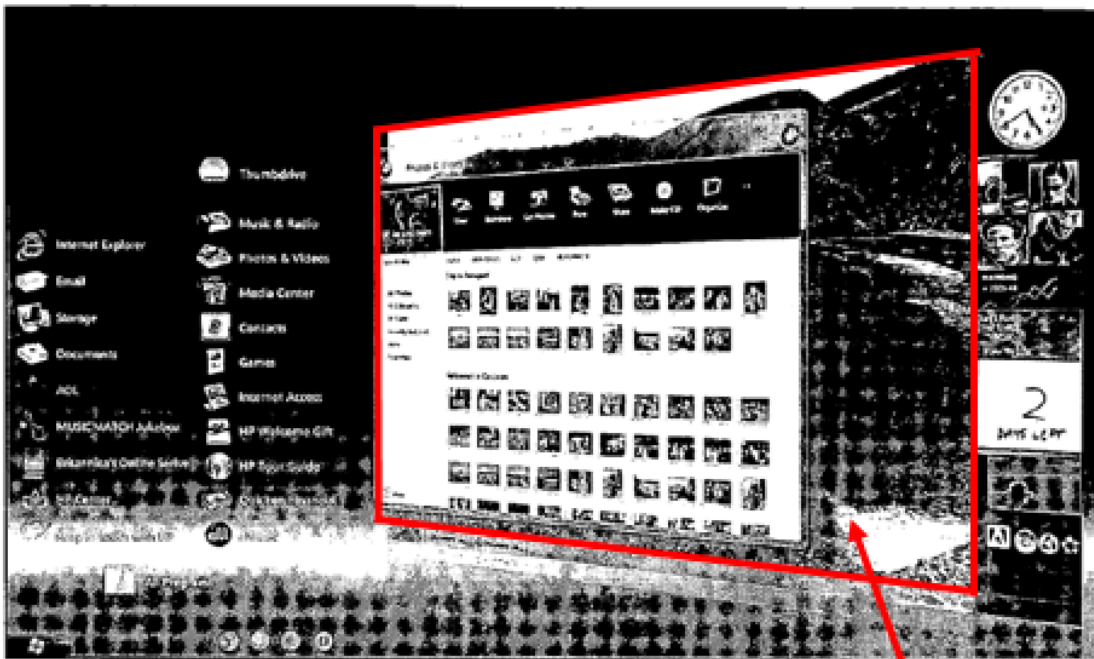


FIG. 3A

“image of a desktop having at least one other application”

APPLE1008 (Matthews), FIG. 3A.

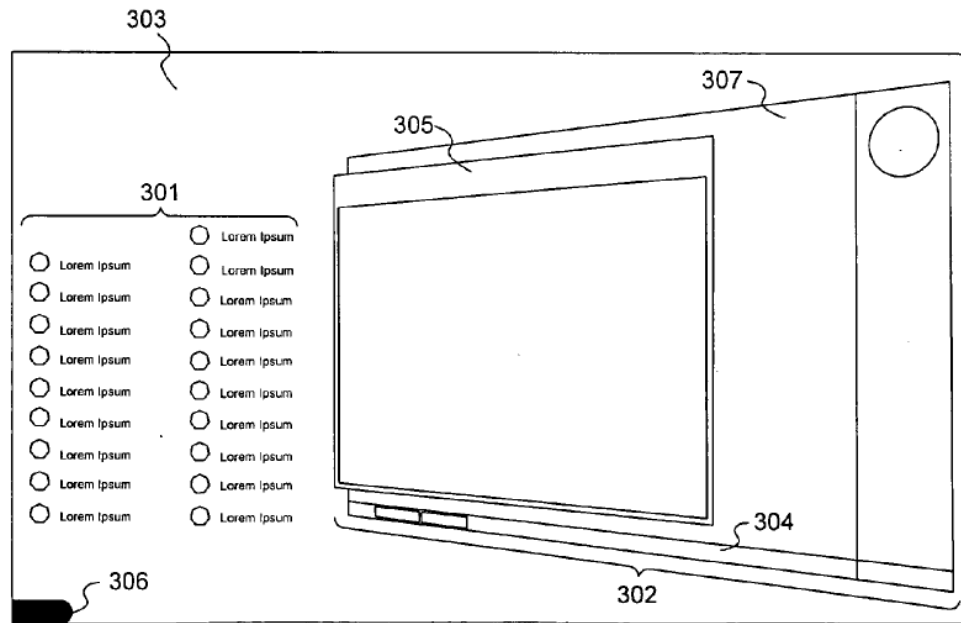
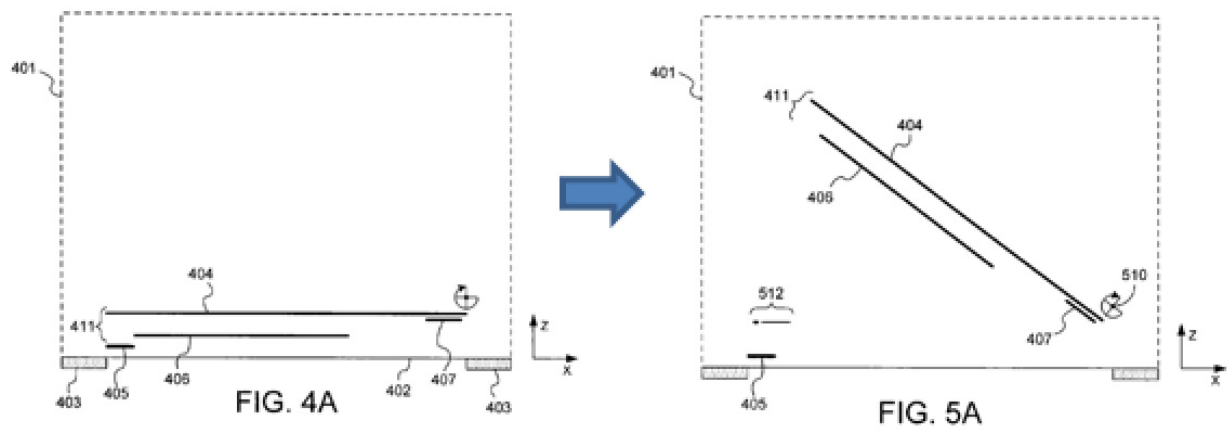


FIG. 3B

APPLE1008 (Matthews), FIG. 3B.



APPLE1008 (Matthews), FIG. 4A (untransformed display) (left), FIG. 5A (transformed display) (right).

[6b] allowing said user to open said other application by allowing said user to select said fourth image, replacing said fourth image with said desktop in response to said selection, receiving an interaction from said user with said other application, and opening said other application in response to said interaction.

126. Once in the transformed display (*see* FIGS. 5A and 3B above), Matthews teaches that a user can click on the work area 302 to return to an untransformed display to focus on applications in the work area. APPLE1008, ¶[0051]. A user can also select a particular application window and continue working on that application window after the work area is untransformed. APPLE1008, ¶[0053] (“At a minimum, if the user points the mouse in the work area and clicks, the work area can be returned to its initial un-transformed state, and the user may resume normal manipulation of the work area.”), ¶[0070].

127. As can be appreciated from the foregoing, Matthews teaches that by clicking on the image of the desktop in the transformed work area 302 and untransforming the work area 302, the computer display would then “replac[e] said fourth image with said desktop in response to said selection” of the user. Matthews explains that the user can then “resume normal manipulation of the work area.” APPLE1008, ¶[0053]. It would have been obvious to a POSITA that the “normal manipulation of the work area” includes “receiving an interaction from said user with said other application, and opening said other application in response to said interaction” when a user selects an icon representing an application to open the application

window, as described above in [1b] and [1c]-[1c-5]. For example, Anthony discloses that “[i]f an icon 606a in the focal group 509 represents a file, double-clicking the file will cause the system to attempt to open the file.” APPLE1007, ¶[0047]. In this manner, the HAC-Matthews combination renders obvious “allowing said user to open said other application,” as recited in [6b].

G. Claim 7

[7] The method of claim 1, wherein each one of said plurality of applications comprises a web browser application, and each one of said first, second, and third objects comprises a web browser window.

128. Matthews gives examples of a web browser application, such as the Internet Explorer, as one example of a window that can be opened in a computer.

APPLE1008, FIGS. 2, 8, 9, ¶[0070]. Although not explicitly stated, it would have been obvious to a POSITA that when a user desires to open three web pages in a new window, the HAC-Matthews system would have displayed three windows corresponding to three web browser applications such that “each one of said first, second, and third objects comprises a web browser window.”

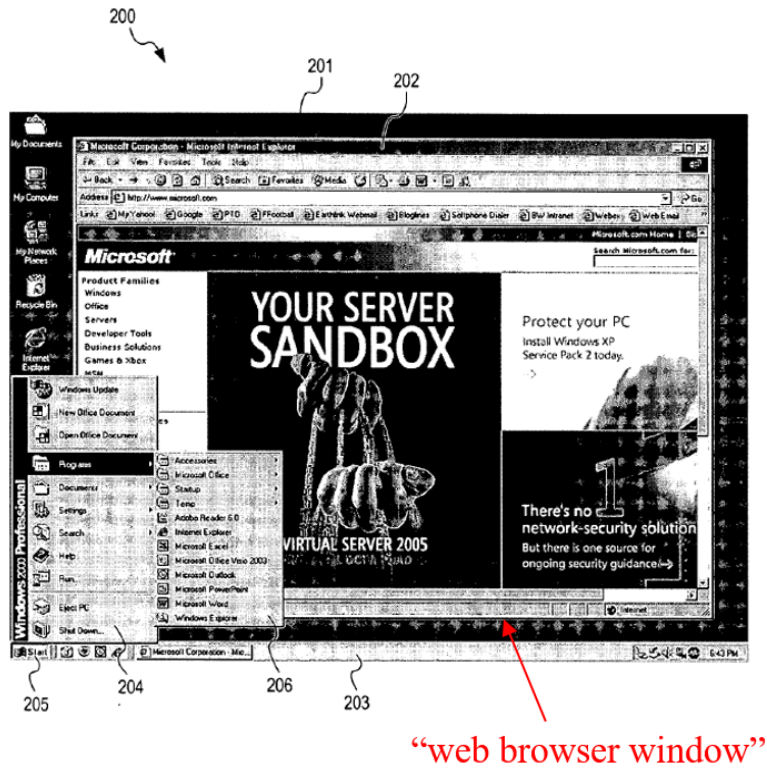
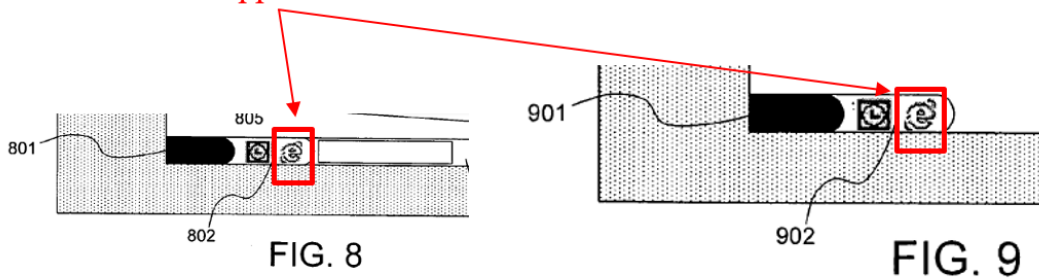


FIG. 2
(PRIOR ART)

APPLE1008 (Matthews), FIG. 2.

Icon representing a “web
browser application”

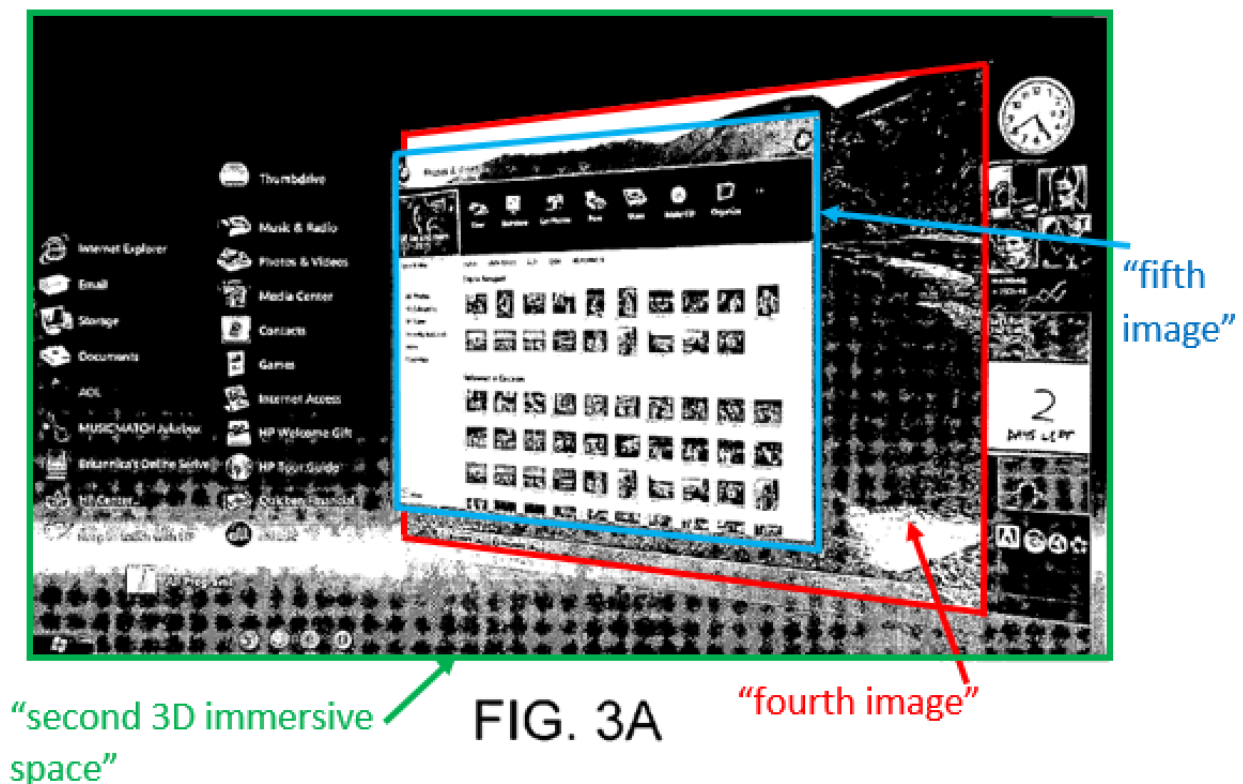


Portion of APPLE1008 (Matthews), FIGS. 8 (left), 9 (right).

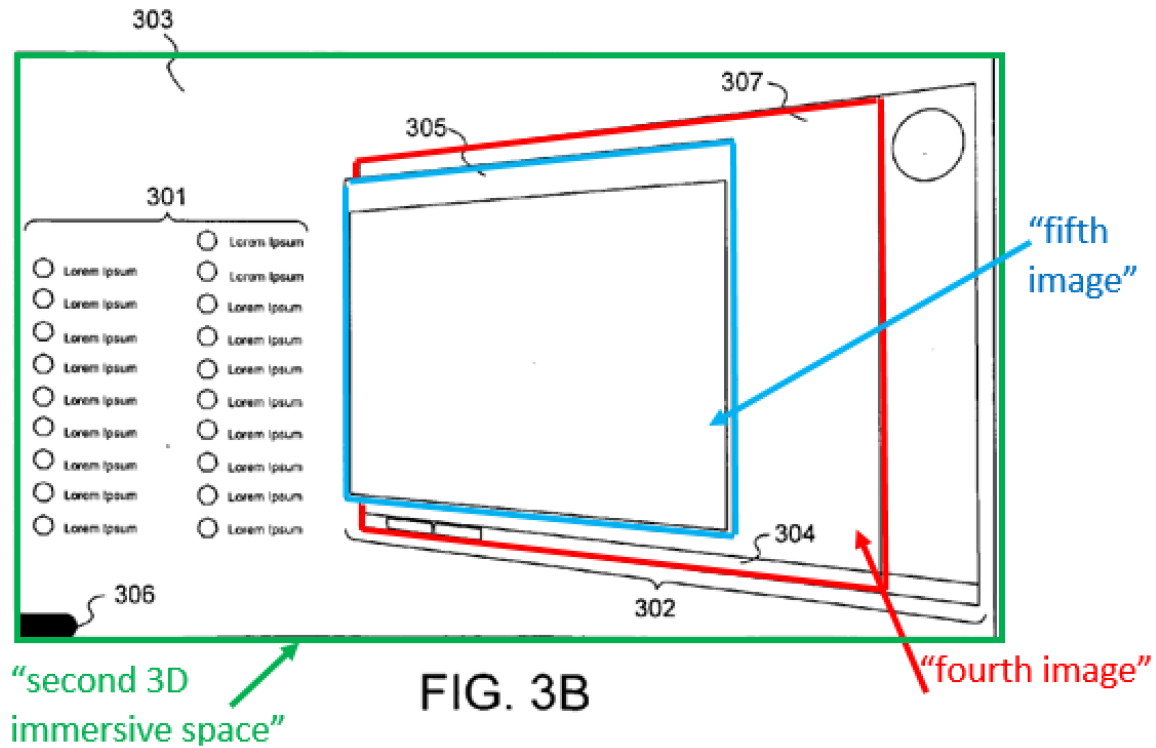
H. Claim 8

[8a] The method of claim 7, further comprising the steps of: displaying at least fourth and fifth images in a second 3D immersive space, wherein said fourth image is an image of said plurality of images within said 3D immersive space and said fifth image is an image of at least a portion of a fourth object generated by a fourth application previously opened by said user; and

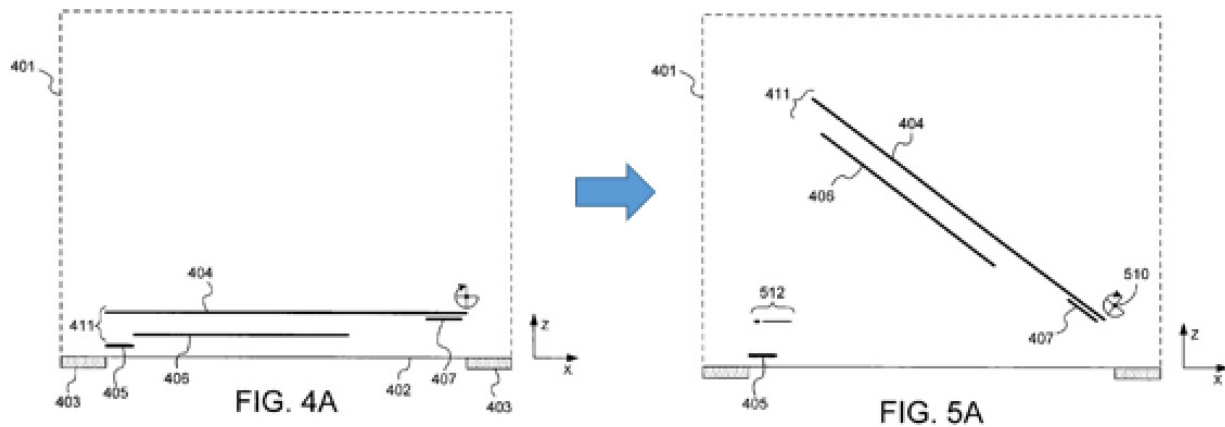
129. As explained in [6a] and [6b], Matthews discloses transforming a computer display to a second 3D immersive space (presentation area 303) that includes an image of a work area 302 that includes images of a desktop 307 and one or more windows 305. APPLE1008, ¶¶[0049]-[0050], [0056], [0060], FIGS. 3A, 3B, 4A, 5A (reproduced below).



APPLE1008 (Matthews), FIG. 3A.



APPLE1008 (Matthews), FIG. 3B.

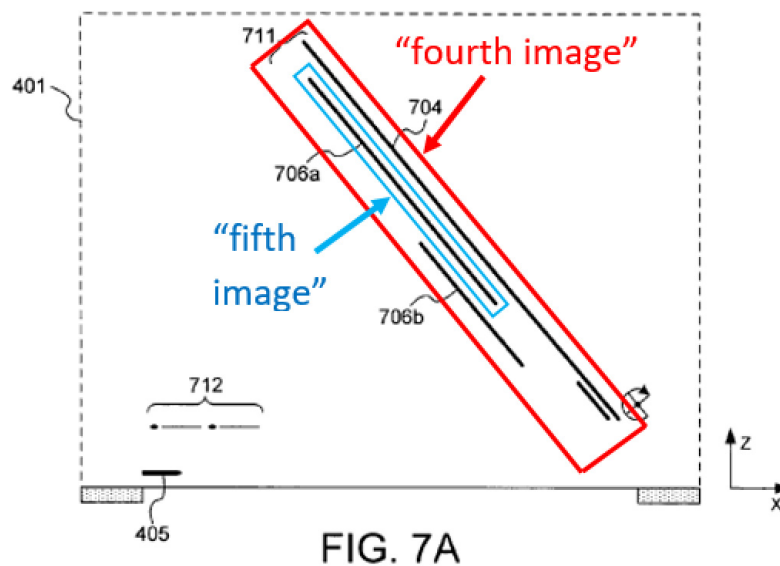


APPLE1008 (Matthews), FIG. 4A (left), FIG. 5A (right).

130. FIG. 7A more clearly illustrates the mapping of the fourth and fifth images.

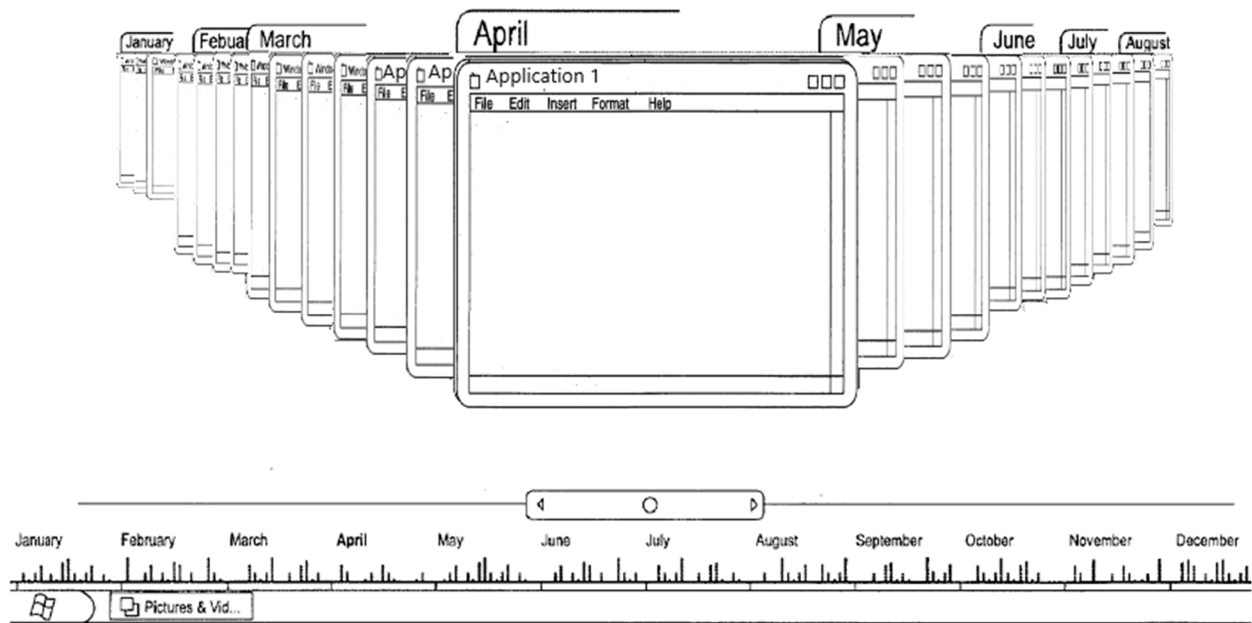
As shown in FIG. 7A, the fourth image includes a plurality of images, such as

images 704, 706a, and 706b. The transformed space corresponds to the “second 3D immersive space.” When multiple windows are displayed, e.g., 4 application windows, it would have been obvious to a POSITA that the four application windows would form part of the fourth image similar to the manner in which windows 706a and 706b are displayed. Moreover, it would also have been obvious to a POSITA that when a fourth application (different from the other three open applications), such as a picture viewer, is previously opened by a user, a fifth image, such as image 706a, is displayed and is also a portion of the fourth object and is generated by a fourth application (e.g., picture viewer) previously opened by said user.



APPLE1008 (Matthews), FIG. 7A.

131. In the HAC-Matthews combination, it would have been obvious to a POSITA that multiple windows would be displayed in a similar manner as windows 706a, 706b but in a timeline, as shown below in the combined HAC figure. The timeline would have been tilted in the manner shown in Matthew's FIG. 7A when in the transformed display mode.



Self-generated figure based on the combination of Anthony's FIG. 4 (APPLE1007) and Hanggie's FIG. 3 (APPLE1006).

132. Matthews explains that the presentation area 303 is a second 3D immersive space by explicitly stating that “a three dimensional rendering system is used here” and that the “[t]he presentation area [] is virtual ...; it is a virtual 3D space in which items can be presented to a user.” APPLE1008, ¶¶[0052], [0054], [0059]. Matthews also teaches that “[t]ransforming the presently displayed work area can

be accomplished using a 3D graphics system.” APPLE1008, ¶[0052]. This system is described as using a 3D graphics video card, a series of 3D meshes, a high level graphics API, such as Java 3D™, and X, Y, and Z coordinates to render a 3D scene. APPLE1008, ¶[0055].

[8b] allowing said user to interact with said one of said first, second, and third applications by selecting said fourth image, selecting said one of said plurality of images corresponding to said one of said plurality of applications, and interacting with said one of said first, second, and third objects corresponding to said one of said plurality of applications.

133. *See above* [6b], [1b], [1c].

I. Claim 9

[9] The method of claim 1, wherein said step of replacing said plurality of images with one of said first, second, and third objects, further comprises enlarging a size of at least said one of said plurality of images before replacing said one of said plurality of images with said one of said first, second, and third objects, thereby simulating movement of said one of said plurality of images in a z-axis of said display device.

134. As explained in [1d-1], a maximize button is included on each window (image) corresponding to the first, second, and third applications. It would have been obvious to a POSITA that maximizing a window involves enlarging the size of the window (image) until it covers most if not all the display area of the display screen. In gradually increasing its size to cover the display area, the computer simulates movement of said one (window whose maximize button has been selected) of said plurality of images in a z-axis of said display device.

J. Claim 10

[10pre] A system for using a two-dimensional (2D) space to selectively interact with at least one of a plurality of applications open on a computing device and a three-dimensional (3D) space to switch between said plurality of application, comprising:

135. [10pre] is a system claim preamble corresponding to [1a] (a method claim preamble). HAC renders obvious [10pre] for the same reasons as [1pre]. §§IX.A-IX.D.

[10a] a display device;

136. HAC's system includes a computer 110 connected to a monitor 191/184 ("*display device*"). APPLE1007, FIG. 1, ¶¶[0034], [0038], [0039]; APPLE1006, ¶[0035], FIG. 1A.

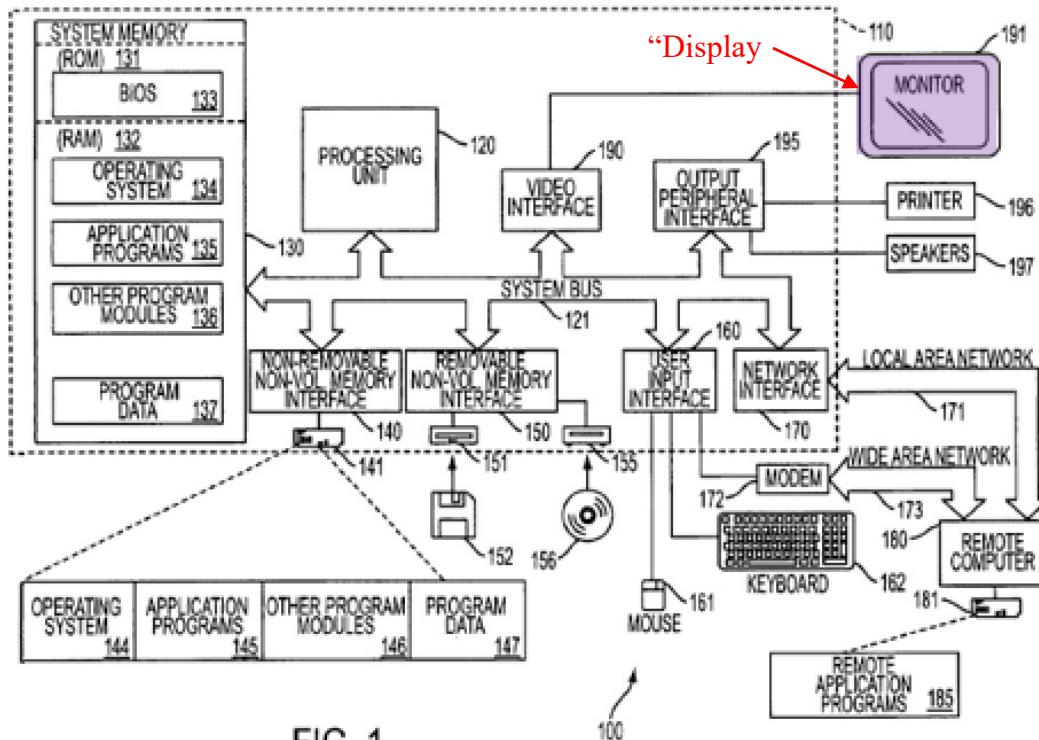
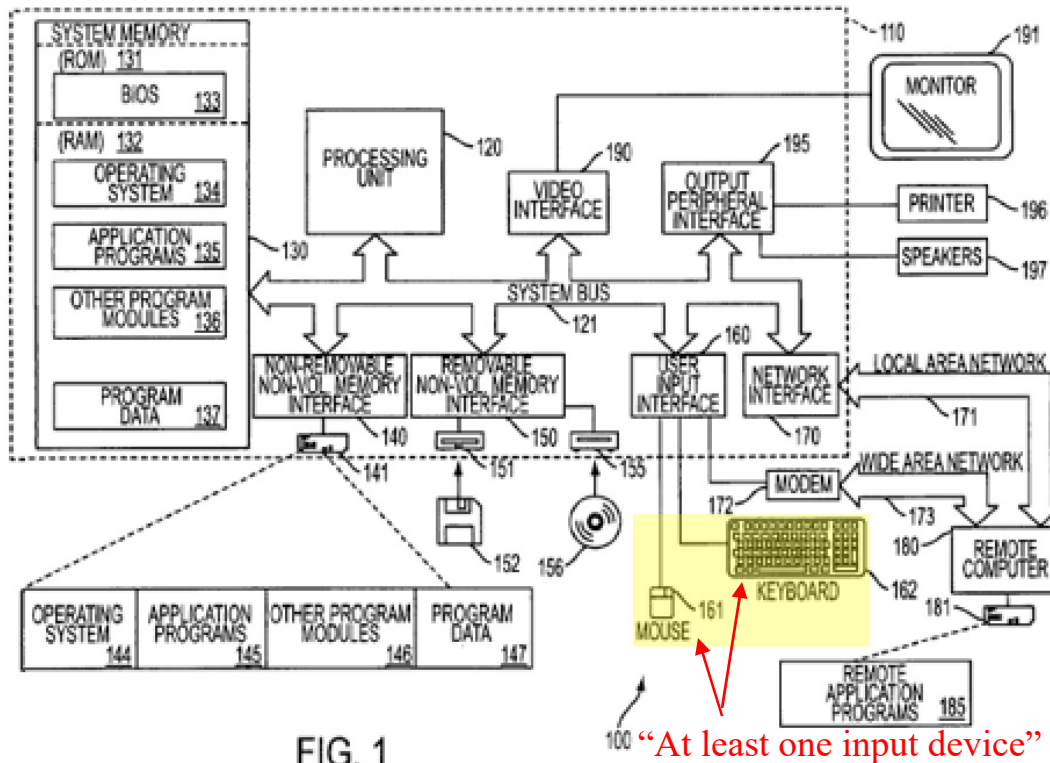


FIG. 1

APPLE1007 (Anthony), FIG. 1.

[10b] at least one input device;

137. HAC's system includes at least one input device such as "a keyboard 162 and pointing device 161, commonly referred to as a mouse, trackball or touch pad. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like." APPLE1007, FIG. 1, ¶¶[0038], [0034], [0039]; APPLE1006, ¶¶[0005], [0035], FIG. 1A.

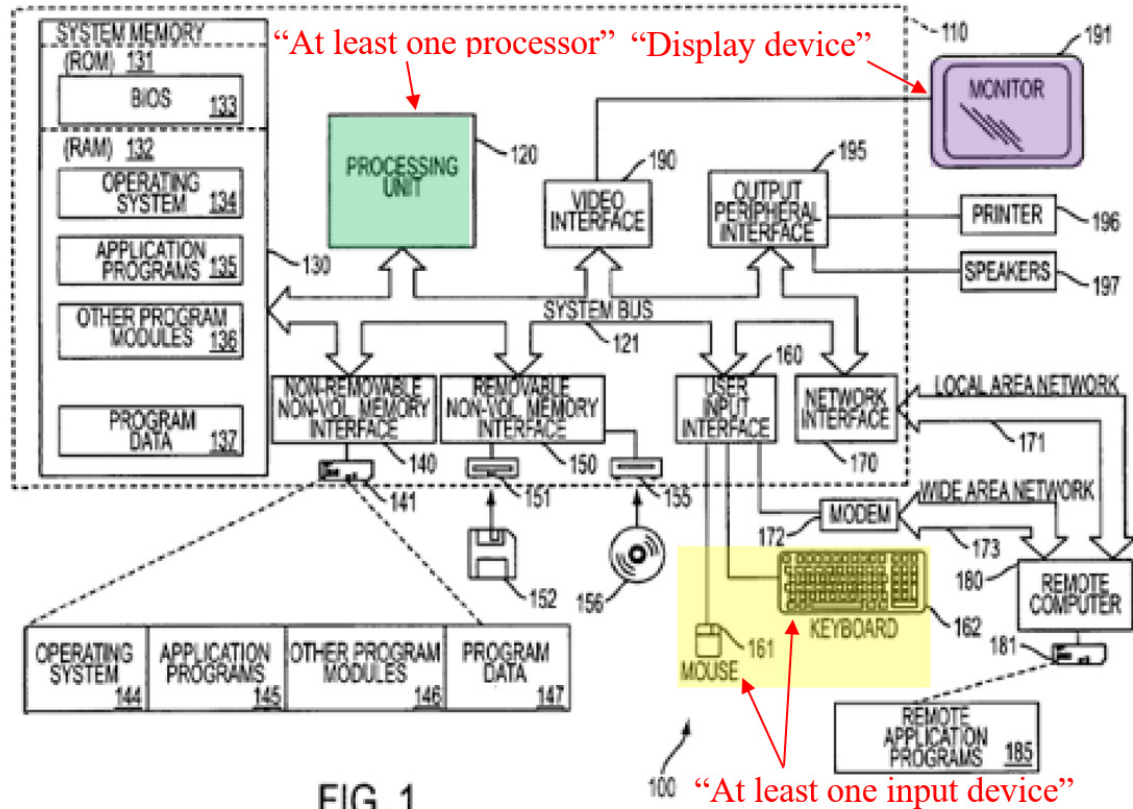


APPLE1007 (Anthony), FIG. 1.

[10c] at least one processor operatively coupled to said display device and said at least one input device; and

138. HAC discloses that “[c]omponents of computer 110 may include, but are not limited to, a *processing unit 120*, a system memory 130, and a system bus 121 that couples *various system components including the system memory to the processing unit 120.*” APPLE1007, FIG. 1 (reproduced below), ¶[0034]; APPLE1006, ¶[0031], FIG. 1A. More specifically, HAC’s system includes a processing unit 120 (“*at least one processor*”) operatively coupled to monitor 191 (“*said display device*”) and mouse 161, and keyboard 162 (“*said at least one input*

device”). APPLE1007, FIG. 1, ¶¶[0038], [0034], [0039]; APPLE1006, ¶[0031], FIG. 1A.



APPLE1007 (Anthony), FIG. 1.

[10d] a memory device comprising executable code for:

139. HAC’s system includes a memory device, such as system memory 130 that executes code for performing the operations recited in [10e-1]-[10i-4].

APPLE1007, FIG. 1, ¶¶[0034]-[0039]; APPLE1006, ¶[0031], FIG. 1A. For example, Anthony discloses that system memory 130 includes (i) a RAM 132 that “typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit 120;” and “operating system

134, application programs 135, other program modules 136, and program data 137.” APPLE1007, ¶¶[0036].

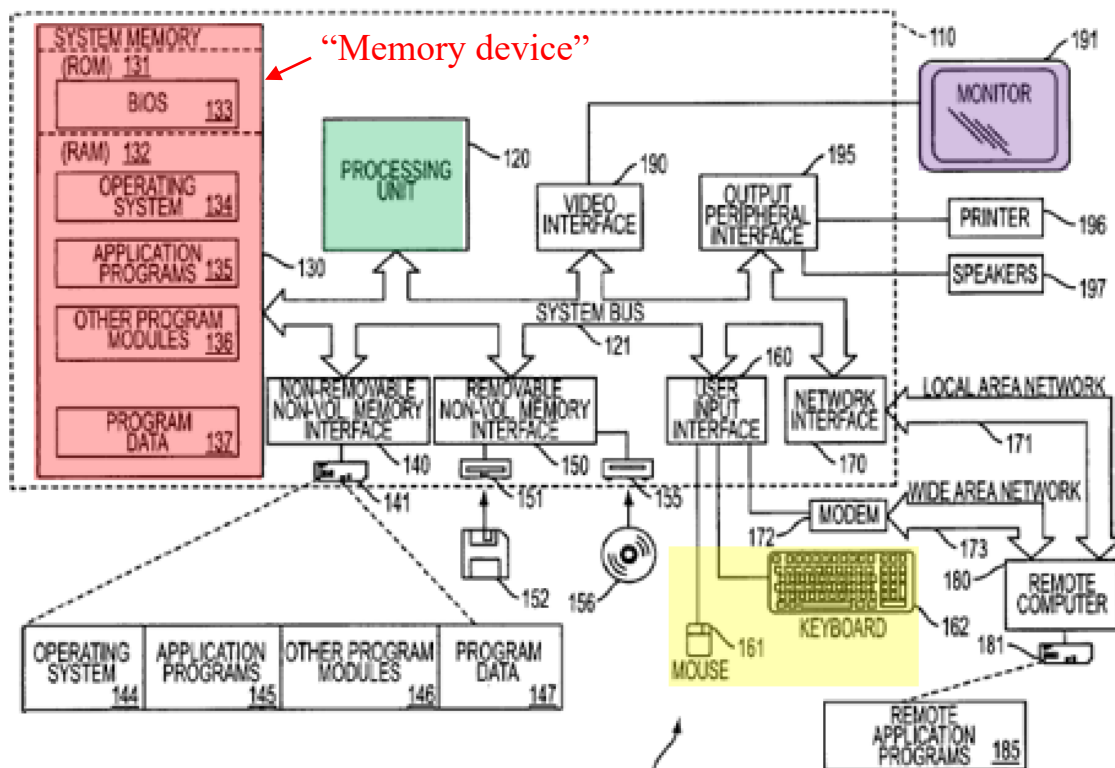


FIG. 1

APPLE1007 (Anthony), FIG. 1.

140. The memory device can include computer-readable medium for storage of information such as computer readable instructions, data structures, and program modules. APPLE1007, ¶[0035]. “A basic input/output system 133 (BIOS), containing the basic routines that help to transfer information between elements within computer 110, ... is typically stored in ROM 131.” APPLE1007, ¶[0036]. It would have been obvious to a POSITA that for HAC’s system to operate, Anthony’s processor would have executed operations according to instructions or

code that are stored in a memory device, such as system memory 130, which provides instructions for the processor and applications to execute operations, e.g., operations [10e-1]-[10i-4].

[10d-1] receiving a plurality of inputs from a user, said plurality of inputs comprising at least first, second, and third inputs;

141. *See above* [1a].

[10d-2] opening said plurality of applications in response to said plurality of inputs, said plurality of applications comprising at least first, second, and third applications, wherein for each one of said plurality of applications (i) an object is generated having application-specific data, (ii) said object is displayed in said 2D space on said fixed resolution display, and (iii) said user is allowed to modify at least a portion of said application-specific data by interacting with said object;

142. *See above* [1b].

[10d-3] allowing a user to switch between said plurality of application, comprising;

143. *See above* [1c].

[10d-3i] generating at least a plurality of images, said plurality of images comprising at least first, second, and third images, wherein said first image is an image of at least a portion of a first object generated by said first application and having first application-specific data, said second image is an image of at least a portion of a second object generated by said second application and having second application-specific data, and said third image is an image of at least a portion of a third object generated by said third application and having third application-specific data;

144. *See above* [1c-1].

[10d-3ii] replacing said object corresponding to one of said plurality of applications that is being interacted with by said user in said 2D space with

said plurality of images, said plurality of images being displayed in said 3D space and in an order based on a last time that said user one of (i) opened said first application and interacted with said first object, (ii) opened said second application and interacted with said second object, and (iii) opened said third application and interacted with said third object, wherein a first one in said order is displayed in a foreground of said 3D space in front of at least said second one in said order, said second one in said order is displayed in said 3D space behind at least said first one in said order, and a third one in said order is displayed in said 3D space behind at least said second one in said order;

145. *See above* [1c-2].

[10d-3iii] allowing said user to move said plurality of images, wherein (i) movement of one of said plurality of images results in movement of all of said plurality of images, and

146. *See above* [1c-3].

[10d-3iv] (ii) continued movement in one direction of one of said plurality of images results in a perception to said user that said one of said plurality of images is moved off of said fixed resolution display; and

147. *See above* [1c-4].

[10d-3v] allowing said user to delete at least one of said plurality of images from said 3D space, wherein deletion of said second one in said order results in said third one in said order being moved to a location in said 3D space where said second one in said order was located prior to said deletion; and

148. *See above* [1c-5].

[10d-4] allowing said user to interact with one of said first, second, and third applications, comprising:

149. *See above* [1d].

[10d-4i] receiving a selection from said user of one of said plurality of images corresponding to one of said plurality of applications;

150. *See above* [1d-1].

[10d-4ii] replacing said plurality of images within said 3D space with one of said first, second, and third objects corresponding to said one of said plurality of applications within said 2D space in response to said selection;

151. *See above* [1d-2].

[10d-4iii] receiving at least one interaction by said user with said one of said first, second, and third objects within said 2D space; and

152. *See above* [1d-3].

[10d-4iv] modifying said one of said first, second, and third application-specific data in response to said at least one interaction.

153. *See above* [1d-4].

K. Claim 11

[11] The system of claim 10, wherein said step of displaying said plurality of images on said display device further comprises displaying said plurality of images together with a plurality of icons and a plurality of descriptions, wherein each one of said plurality of images has a corresponding one of said plurality of icons and a corresponding one of said plurality of descriptions.

154. *See above* [3].

L. Claim 12

[12] The system of claim 10, further comprising periodically replacing at least one of said plurality of images with at least one other image, said other image showing at least one change to application specific data of a corresponding to one of said plurality of applications while said plurality of images are being displayed in said 3D space.

155. Hanggie discloses that its windows may be periodically updated. For example, Hanggie teaches that “a change to the window icon or caption text may also necessitate a redraw of the CDWM-managed icon or caption content object, respectively, associated with the window.” APPLE1006, ¶[0055]. When a video is being rendered in a video, Hanggie teaches that “the UCE processes incoming composition and resource updates from the CDWM, and **at intervals synchronized with the video refresh rates of each active video graphics adapter participating in the composition of the desktop, re-renders the desktop** (or the appropriate portion thereof in a multiple-display configuration) to a display-sized backing buffer. This is accomplished using the immediate-mode rendering services provided by a 3D graphics engine (such as Microsoft Direct3D®, which in turn transfers the desktop to a primary display surface.” APPLE1006, ¶[0056]. As is known in the art, video refresh rates are periodic. Accordingly, it would have been obvious to a POSITA that Hanggie’s disclosure of re-rendering the desktop at intervals synchronized with the video refresh rates would have included “periodically replacing at least one of said plurality of images

with at least one other image, said other image showing at least one change to application specific data of a corresponding to one of said plurality of applications while said plurality of images are being displayed in said 3D space.” It would also have been obvious to a POSITA that a composition and resource update, such as a change in video composition data, corresponds to “at least one change to application specific data” when one of the displayed windows is showing a video.

M. Claim 13

[13] The system of claim 12, further comprising the step of receiving a request from said user to switch from said 2D space to said 3D space, wherein said step of replacing said object in said 2D space with said plurality of images further comprises replacing said object in said 2D space with said plurality of images in response to receiving said request to switch from said 2D space to said 3D space.

156. *See above* [1c-2].

N. Claim 14

[14] The system of claim 10, wherein a reduction in size of an object or portion thereof is used to depict said object or portion thereof as being behind at least one other object or other portion of said object.

157. *See above* [5].

O. Claim 15

[15a] The system of claim 10, wherein said executable code is further configured to: display a fourth image on said display device in said 3D space, said fourth image being an image of a desktop having at least one other application; and

158. *See above* [6a].

[15b] allow said user to open said other application by allowing said user to select said fourth image, replacing said fourth image with said desktop in response to said selection, receiving an interaction from said user with said other application, and opening said other application in response to said interaction.

159. *See above* [6b].

P. Claim 16

[16] The system of claim 10, wherein each one of said plurality of applications comprises a web browser application, and each one of said first, second, and third objects comprises a web browser window.

160. *See above* [7].

Q. Claim 17

[17a] The system of claim 16, wherein said executable code is further configured to: display at least fourth and fifth images in a second 3D space, wherein said fourth image is an image of said plurality of images within said 3D space and said fifth image is an image of at least a portion of a fourth object generated by a fourth application previously opened by said user; and

161. *See above* [8a].

[17b] allow said user to interact with said one of said first, second, and third applications by selecting said fourth image, selecting said one of said plurality of images corresponding to said one of said plurality of applications, and interacting with said one of said first, second, and third objects corresponding to said one of said plurality of applications.

162. *See above* [8b].

R. Claim 18

[18] The system of claim 10, wherein said step of replacing said plurality of images with one of said first, second, and third objects, further comprises enlarging a size of at least said one of said plurality of images before replacing said one of said plurality of images with said one of said first, second, and third objects, thereby simulating movement of said one of said plurality of images in a z-axis of said display device.

163. *See above* [9].

S. Claim 19

[19pre] A method for using a two-dimensional (2D) space to selectively interact with at least one of a plurality of applications open on a device and a three-dimensional (3D) space to switch between said plurality of application, comprising:

164. *See above* [1pre].

[19a] receiving a plurality of inputs from a user, said plurality of inputs comprising at least first, second, and third inputs;

165. *See above* [1a].

[19b] opening said plurality of applications in response to said plurality of inputs, said plurality of applications comprising at least first, second, and

third applications, wherein for each one of said plurality of applications (i) an output is generated having application-specific data, (ii) displaying said output in said 2D space on said fixed resolution display, and (iii) allowing said user to modify at least a portion of said application-specific data by interacting with said output;

166. *See above* [1b].

[19c] allowing a user to view information on said plurality of application, comprising;

167. *See above* [1c].

[19c-1] generating at least a plurality of images, said plurality of images comprising at least first, second, and third images, wherein said first image is an image of at least a portion of a first object generated by said first application and having first application-specific data, said second image is an image of at least a portion of a second object generated by said second application and having second application-specific data, and said third image is an image of at least a portion of a third object generated by said third application and having third application-specific data;

168. *See above* [1c-1].

[19c-2] replacing said output corresponding to one of said plurality of applications that is being interacted with by said user in said 2D space with said plurality of images, said plurality of images being displayed in said 3D space and in an order based on a last time that said user one of (i) opened said first application and interacted with said first object, (ii) opened said second application and interacted with said second object, and (iii) opened said third application and interacted with said third object, wherein said 3D space comprises at least a foreground and a background, a first one in said order is displayed in said foreground, and second and third ones in said order are displayed in one of a foreground and a background;

169. *See above* [1c-2].

[19c-3] allowing said user to move said plurality of images, wherein (i) movement of one of said plurality of images results in movement of all of said plurality of images, and

170. *See above* [1c-3].

[19c-4] (ii) continued movement in one direction of one of said plurality of images results in a perception to said user that said one of said plurality of images is moved off of said fixed resolution display; and

171. *See above* [1c-4].

[19c-5] allowing said user to delete at least one of said plurality of images from said 3D space, wherein deletion of said second one in said order results in said third one in said order being moved to a location in said 3D space where said second one in said order was located prior to said deletion; and

172. *See above* [1c-5].

[19d] allowing said user to interact with one of said first, second, and third applications, comprising:

173. *See above* [1d].

[19d-1] receiving a selection from said user of one of said plurality of images corresponding to one of said plurality of applications;

174. *See above* [1d-1].

[19d-2] replacing said plurality of images within said 3D space with one of said first, second, and third outputs corresponding to said one of said plurality of applications within said 2D space in response to said selection;

175. *See above* [1d-2].

[19d-3] receiving at least one interaction by said user with said one of said first, second, and third outputs within said 2D space; and

176. *See above* [1d-3].

[19d-4] modifying said one of said first, second, and third application-specific data in response to said at least one interaction.

177. *See above* [1d-4].

T. Claim 20

[20] The method of claim 19, wherein said step of replacing said plurality of images with one of said first, second, and third objects, further comprises enlarging a size of at least said one of said plurality of images before replacing said one of said plurality of images with said one of said first, second, and third objects, thereby simulating movement of said one of said plurality of images in a z-axis of said display device.

178. *See above* [9].

XI. CONCLUSION

179. For all the reasons I have noted in the foregoing paragraphs, claims 1-20 of the '868 Patent are obvious in view of the references discussed above.

APPENDIX A

HENRY FUCHS

Federico Gil Distinguished Professor of Computer Science
University of North Carolina at Chapel Hill

Emails: fuchs@cs.unc.edu henry.fuchs@gmail.com

Office: +1.919-590-6211
Mobile: +1.919-971-4951

Brooks Computer Science Building, Room 216
201 S. Columbia St.
Chapel Hill, NC 27599-3175 USA

Citizenships: USA and Hungary

Education

- 1975 Ph.D, Computer Science, University of Utah
- 1970 B.A., Information and Computer Science, University of California at Santa Cruz

Positions Held

- 2017-2018 Guest Professor, TU Wien
- 2003-2004 Guest Professor, ETH Zurich
- 1978 - present University of North Carolina at Chapel Hill
 Federico Gil Distinguished Professor (1988-present)
 Adjunct Professor of Biomedical Engineering (2000-2019)
 Adjunct Professor of Radiation Oncology (1988-2008)
 Professor of Computer Science (1983-1988)
 Associate Professor of Computer Science (1978-83)
- 1975 -1982 University of Texas at Dallas, Programs in Mathematical Sciences
 Adjunct Associate Professor (1978-82)
 Computer Science Coordinator (1977-78)
 Assistant Professor (1975-78)
- 1979 -1982 University of Texas Health Science Center at Dallas, Southwestern Medical School
 Adjunct Associate Professor of Medical Computer Science
- 1970 - 1974 University of Utah, Department of Computer Science
 Research Assistant and Teaching Fellow
- 1976 - Present Former consulting and advisory board memberships (selected):
 Expert witness, various law firms
 Fraunhofer: IGD, Darmstadt, Germany; and CROG, USA
 Harvard Neuroimage Analysis Center
 Lockheed-Georgia

Mersive Technologies
Mitsubishi Electric Research Lab
RAND Corp.
Research Triangle Institute
ShoGraphics
Stellar Computer
Thomson Corp.
Xerox Palo Alto Research Center

1968 - 74 Caltech / NASA Jet Propulsion Lab
 Engineer and Consultant (mostly summers)

1968 - 70 University of California at Santa Cruz
 Programmer and Consultant, Computer Center
 Undergraduate Research Assistant for Prof. Harry Huskey

Honors

- Fellow, Eurographics, European Association for Computer Graphics, 2020 (two or three fellows elected each year)
- Career Impact Award, ISMAR 2018 ("Based on the profound impact that he has continued to have on AR/MR for well over forty years and on ISMAR since its inception")
- Honorary doctorate (Dr. h.c.), TU Wien, 2018.
- ACM SIGGRAPH Academy - Inaugural Class, 2018 ("For contributions to augmented and virtual reality, telepresence and graphics hardware, and for educating the leaders in the field of computer graphics.")
- The 2015 ACM SIGGRAPH Steven A. Coons Award (Considered the most prestigious award in the field of computer graphics; awarded once every two years.)
- Fellow, IEEE 2015 ("For contributions to computer graphics, virtual and augmented reality")
- The 2013 IEEE VGTC Virtual Reality Career Award ("In recognition of his lifetime contributions to research and practice of virtual environments, telepresence and medical applications").
- Fellow, American Academy of Arts and Sciences, 1997.
- Member, National Academy of Engineering, 1997.
- The 1997 Satava Award, Medicine Meets Virtual Reality Conferences. ("For your commitment to the transformation of medicine through visionary applications of interactive technology").
- ACM Fellow, 1994. ("For distinguished contributions in the field of computer graphics").
- The 1992 Computer Graphics Achievement Award, ACM/SIGGRAPH. ("In recognition of his outstanding contribution to high-performance, parallel display architecture").
- The 1992 National Computer Graphics Association (NCGA) Academic Award. ("For his outstanding leadership in the development and promotion of computer graphics applications in the academic community").

Patents Awarded

20. H. Fuchs, A. Lastra, J. T. Whitted, F. Zheng, A. State, G. Welch, "Minimal-Latency Tracking and Display for Matching Real And Virtual Worlds in Head-Worn Displays," US Patent No. 11,049,476 (June 29, 2021).
19. H. Fuchs, M. Dou, G. Welch, J. M. Frahm, "Methods, Systems, and Computer Readable Media for Unified Scene Acquisition and Pose Tracking in a Wearable Display," US Patent No. 10,365,711 (July 30, 2019).
18. H. Fuchs, G. Welch, "Methods, Systems, and Computer Readable Media for Improved Illumination of Spatial Augmented Reality Objects," US Patent No. 10,321,107 (June 11, 2019).
17. P. K. Chakravarthula, H. Fuchs, "Methods, Systems, and Computer Readable Media for Dynamic Vision Correction for In-focus Viewing of Real and Virtual Objects," US Patent 10,319,154 (June 11, 2019).
16. H. Fuchs, D. Dunn, C. Tippetts, "Wide Field of View Augmented Reality Head- Mounted Display with Distance Accommodation," US Patent No. 9,983,412 (May 29, 2018).
15. H. Fuchs, N. Dierk, J. M. Frahm, A. Lastra, D. Perra, "Low-Latency Stabilization for Head-Worn Displays," US Patent No. 9,898,866 (Feb. 20, 2018).
14. A. Maimone, H. Fuchs, "Methods, Systems, and Computer Readable Media for Generating an Augmented Scene Display," US Patent No. 9,858,721 (Jan. 2, 2018).
13. G. Welch, K. Keller, A. State, H. Fuchs, R. Schubert, "Methods, Systems, and Computer Readable Media for Utilizing Synthetic Animatronics," US Patent No. 9,792,715 (Oct. 17, 2017).
12. G. Welch, H. Fuchs, P. Lincoln, A. Nashel, A. State, "Methods, Systems, and Computer Readable Media for Shader-Lamps Based Physical Avatars of Real and Virtual People," US Patent No. 9,538,167 (Jan. 3, 2017).
11. H. Fuchs, L. McMillan, A. Nashel, "Methods, systems, and computer readable media for generating autostereo three-dimensional views of a scene for a plurality of viewpoints using a pseudo-random hole barrier," US Patent No. 9,361,727 B2 (June 7, 2016).
10. H. Fuchs, H. Yang, T. Peck, A. Bulysheva, A. State, "Methods, systems, and computer readable media for image guided ablation," US Patent No. 9,265,572 B2 (Feb. 23, 2016).
9. J. M. Frahm, H. Fuchs, M. Marathe, B. Mauchly, "System and Method for providing depth adaptive video conferencing," U.S. Patent No. 8,896,655 (Nov. 25, 2014).
8. K. Keller, H. Fuchs, L. McMillan, L. Vicci, "Methods, systems, and computer program products for full spectrum projection," U.S. Patent No. 8,152,305 (April 10, 2012).
7. H. Fuchs, D. Cotting, M. Naef and M. Gross, "Methods, systems and computer program products for imperceptibly embedding structured light patterns in projected color images for display on planar and nonplanar surfaces," U.S. Patent No. 7,182,465 (Feb. 27, 2007).
6. K. Keller, J. Ackerman, M. Rosenthal, H. Fuchs and A. State, "Methods and systems for real-time structured light depth extraction, and endoscope using real-time structured light depth extraction," U.S. Patent No. 6,503,195 (Jan. 7, 2003).

5. H. Fuchs, M. Livingston, T. Bishop, and G. Welch, "Dynamic generation of imperceptible structured light for tracking and acquisition of three dimensional scene geometry and surface characteristics in interactive three dimensional computer graphics applications," U.S. Patent No. 5,870,136 (Feb. 9, 1999).
4. H. Fuchs, "Image buffer having logic-enhanced pixel memory cells and method for setting values therein," U.S. Patent No. 4,827,445 (May 2, 1989).
3. H. Fuchs and J. Poulton, "VLSI Graphic Display Image Buffer Using Logic Enhanced Pixel Memory Cells," U.S. Patent No. 4,783,649 (Nov. 8, 1988).
2. H. Fuchs and S. Pizer, "Three Dimensional Display Using a Varifocal Mirror" U.S. Patent No. 4,607,255 (Aug. 19, 1986).
1. H. Fuchs, "Graphics Display System Using Logic-Enhanced Pixel Memory Cells," U.S. Patent No. 4,590,465 (May 20, 1986).

Recent Grants & Contracts (Selected)

1. National Institutes of Health: "SCH: An Augmented Reality Neurorehabilitation System for Monitoring and Management of Motor Symptoms of Parkinson's Disease" R01HD111074, July 2022- June 2026 (Fuchs, PI).
2. National Science Foundation: "HCC: Medium: Deep Learning-Based Tracking of Eyes and Lens Shape from Purkinje Images for Holographic Augmented Reality Glasses," IIS-2107454, Oct. 2021 - Sept. 2024 (Fuchs, PI).
3. Facebook/Meta: "Towards a Physics-based Understanding of Holographic Image Quality," Dec. 2020 - July 2022 (Fuchs, PI)
4. National Science Foundation: "FW-HTF: Collaborative Research: Enhancing Human Capabilities through Virtual Personal Embodied Assistants in Self-Contained Eyeglasses-Based Augmented Reality (AR) Systems," CMMI-1840131, Sept. 2018 - Aug. 2022 (Fuchs, PI)
5. National Science Foundation: "CHS: Small: Collaborative Research: 3D Audio Augmentation for Limited Field of View Augmented Reality Systems for Medical Training," IIS-1718313, Sept. 2017 - Aug. 2021 (Fuchs, UNC PI; collaboration with University of Florida)
6. National Science Foundation: "SCH: INT: Collaborative Research: Computer Guided Laparoscopy Training" IIS-1622515, Aug. 2016 - July 2021 (Fuchs, UNC PI; collaboration with University of Arizona)
7. National Science Foundation: "EAGER: Wide Field of View Augmented Reality Display with Dynamic Focus" IIS-1645463, Aug. 2016 - July 2018 (Fuchs, PI)
8. National Science Foundation: "CHS: CGV: Small: Minimal-latency Tracking and Display for Matching Real and Virtual Worlds in Head-worn Displays" IIS-1423059, Sept. 2014 – Aug. 2017 (Fuchs, PI)
9. National Science Foundation: "II-New: Seeing the Future: Ubiquitous Computing in EyeGlasses" CRI-1405847, Sept. 2014 – Aug. 2017 (Fuchs, Co-PI)
10. National Science Foundation: "HCC: CGV: Small: Eyeglass-Style Multi-Layer Optical See-Through Displays for Augmented Reality" CHS-1319567, Sept. 2013 - Aug. 2016 (Fuchs, PI).
11. NVIDIA Research: Cooperative Agreement & Support (Fuchs, PI) ca. 2013 - current

12. Cisco Systems: "Telepresence Systems," 2006 – 2015; 2017 (Fuchs, PI).
13. National Science Foundation: "II-NEW: A Robot Testbed for Real-time Motion Strategies and Autonomous Personal Assistants" CRI-1305286, Sept. 2013 - Aug. 2015 (Fuchs, co-PI)

OTHER FORMER GRANTS AND CONTRACTS (selected): DARPA (Defense Advanced Research Projects Agency), DOE (U.S. Dept. of Energy), NIH (National Institutes of Health), NCI (National Cancer Institute), NSF (National Science Foundation), ONR (Office of Naval Research); U.S. Air Force.

Recent Award-Winning Exhibits

Best in Show at Siggraph 2018 Emerging Technologies Exhibition (led by my student Kishore Rathinavel and NVIDIA's Kaan Aksit, in collaboration with NVIDIA Research)

<https://s2018.siggraph.org/conference/conference-overview/emerging-technologies/>

DCEXpo/DCAJ prize at Siggraph 2017 Emerging Technologies Exhibition (led by my student David Dunn, in collaboration with NVIDIA Research) <http://s2017.siggraph.org/content/emerging-technologies.html>

Professional Activities (Selected)

- Chair of VR Awards Program, IEEE VGTC (Visualization and Graphics Technical Community), 2020-present
- Member, Editorial Advisory Board, Computers & Graphics, 2013-present
- Member, Steering Committee, IEEE International Symposium on Mixed and Augmented Realities (ISMAR) 2008 - present.
- Member, External Advisory Board, Harvard's Neuroimage Analysis Center, 2004-2012.
- Member, External Advisory Board, Mersive Technologies. ~2008 - ~2010.
- Member, Dept. of Energy Blue Ribbon Panel for Evaluation of ASCI Program, 1998-1999.
- UNC Delegate, New Vistas in Transatlantic Science and Tech Cooperation, Washington D.C., 1998.
- Member, DARPA's Information Science and Technology Study Group, (Defense Advanced Research Projects Agency), 1994.
- Member, Computer Science and Telecommunications Board, National Research Council of the National Academies, 1993-1997.
- Co-Director (with Gary Bishop), NSF Invitational Workshop on Research Directions in Virtual Environments, Chapel Hill, NC, March 1992.
- Co-Director (with K.H. Höhne and Steve Pizer), NATO Advanced Research Workshop in 3D Imaging in Medicine, Travemünde, Germany, June 1990.
- Chairman, 1986 Workshop on Interactive 3D Graphics, UNC Chapel Hill, Oct. 1986 (the initial meeting of what has become the annual ACM Symposium on Interactive 3D Graphics and Games).
- Distinguished Visitor, IEEE Computer Society, 1985-1986.

- Chairman, 1985 Chapel Hill Conference on VLSI, May 1985. (7th Annual. All previous conferences held at Caltech and MIT). Conference now called S.I.S.
- Chairman, Tutorial on VLSI and Computer Graphics, SIGGRAPH'83, SIGGRAPH'84, SIGGRAPH'85.
- Associate Editor, ACM Transactions on Graphics, 1983-1988.
- Guest Editor, ACM Transactions on Graphics, Vol.1, No. 1, January 1982.
- Technical Program Chairman, SIGGRAPH'81.
- Member, Advisory Committee, National Science Foundation, Division of Microelectronic Information Processing Systems.
- Member, Special Study Sections, National Institutes of Health; Review Panels and Site Visit Committees, National Science Foundation: 1978-Present.

Program Committee Memberships (Selected)

- ACM SIGGRAPH Asia (2013)
- ACM SIGGRAPH (1979, 1980, 1981, 1985-1992, 1998-2001, 2005) Annual Conferences on Computer Graphics and Interactive Techniques
- Symposium on Interactive 3D Graphics, 2001 in Chapel Hill, N.C.
- Symposium on Interactive 3D Graphics, 1990 at Snowbird, Utah
- Workshop on Volume Visualization, 1989 at UNC-Chapel Hill
- Conference on Advanced Research in VLSI (1986 at MIT, 1987 at Stanford, 1988 at MIT, 1989 at Caltech)
- Eurographics, 1997
- International Electronic Image Week (CESTA, SIGGRAPH) FRANCE (1986 and 1987)
- Computer Graphics International (1987 in Japan; 1988 in Switzerland)

Publications

256. Praneeth Chakravarthula, Ethan Tseng, Henry Fuchs, Felix Heide, "Hogel-free Holography." ACM Transactions on Graphics (TOG), March 2022 and ACM SIGGRAPH 2022, <https://doi.org/10.1145/3516428>.

255. Youngjoong Kwon, Stefano Petrangeli, Dahun Kim, Haoliang Wang, Vishy Swaminathan, Henry Fuchs. "Tailor Me: An Editing Network for Fashion Attribute Shape Manipulation." IEEE WACV 2022.

254. C Lu, Q Zhang, K Krishnakumar, J Chen, H Fuchs, S Talathi, K Liu. "Geometry-Aware Eye Image-To-Image Translation." 2022 Symposium on Eye Tracking Research and Applications.

253. Praneeth Chakravarthula, Zhan Zhang, Okan Tursun, Piotr Didyk, Qi Sun, Henry Fuchs, "Gaze-contingent Retinal Speckle Suppression for Perceptually-Matched Foveated Holographic Displays." IEEE TVCG 2021.

252. Youngjoong Kwon, Dahun Kim, Duygu Ceylan, Henry Fuchs. "Neural Human Performer: Learning Generalizable Radiance Fields for Human Performance Rendering." NeurIPS 2021. Spotlight presentation (Acceptance: < 3.0%)

251. Young-Woon Cha, Husam Shaik, Qian Zhang, Fan Feng, Andrei State, Adrian Ilie, Henry Fuchs. "Mobile. Egocentric Human Body Motion Reconstruction Using Only Eyeglasses-mounted Cameras and a Few Body-worn Inertial Sensors." Proceedings IEEE Virtual Reality and 3D User Interfaces (27 March-1 April 2021)
Winner: A Best Conference Paper Award (1 of 3).

250. P. Chakravarthula, Ethan Tseng, Tarun Srivastava, Henry Fuchs, Felix Heide. "Learned Hardware-in-the-loop Phase Retrieval for Holographic Near-Eye Displays." SIGGRAPH Asia 2020.

249. X. Lu, Praneeth Chakravarthula, Yujie Tao, Steven Chen, Henry Fuchs. "Improved Vergence and Accommodation via Purkinje Image Tracking with Multiple Cameras for AR Eyeglasses." Proceedings IEEE International Symposium on Mixed and Augmented Reality (ISMAR) 2020.

248. X. Xia, Yunqing Guan, Andrei State, Praneeth Chakravarthula, Tat-Jen Cham, Henry Fuchs, "Towards Eyeglasses-style Holographic Near-eye Displays with Static Expanded Eyebox." Proceedings IEEE International Symposium on Mixed and Augmented Reality (ISMAR) 2020.

247. Youngjoong Kwon, Stefano Petrangeli, Dahun Kim, Haoliang Wang, Henry Fuchs, Viswanathan Swaminathan. "Rotationally-Consistent Novel View Synthesis for Humans." Proceedings of the 28th ACM International Conference on Multimedia Oct. 2020.

246. Youngjoong Kwon, Stefano Petrangeli, Dahun Kim, Haoliang Wang, Eunbyung Park, Viswanathan Swaminathan, Henry Fuchs. "Rotationally-Temporally Consistent Novel View Synthesis of Human Performance Video" Proceedings of the European Conference on Computer Vision (ECCV) 2020. Spotlight Presentation (Acceptance: 265/5025 $\approx$ 5.3%)

245. Hanseul Jun, Jeremy N. Bailenson, Henry Fuchs, Gordon Wetzstein. "An Easy-to-use Pipeline for an RGBD Camera and an AR Headset" PRESENCE: Teleoperators and Virtual Environment 2020.

244. P. Chakravarthula, Yifan Peng, Joel Kollin, Felix Heide, Henry Fuchs. "Computing high quality phase-only holograms for holographic displays." Optical Architectures for Displays and Sensing in Augmented, Virtual, and Mixed Reality (AR, VR, MR). Vol. 11310. International Society for Optics and Photonics, 2020. **Winner: an Optical Design Award at SPIE Photonics West 2020.**

243. K. Rathinavel, Hanpeng Wang, Henry Fuchs, "Optical Calibration and Distortion Correction for a Volumetric Augmented Reality Display", Emerging Digital Micromirror Device Based Systems and Applications XII, Photonics West 2020.

242. A. State, H. Towles, T. Johnson, R. Schubert, B. Walters, G. Welch, H. Fuchs. "The A-Desk: A Unified Workspace of the Future," IEEE Computer Graphics and Applications, vol. 40, issue 1, pp. 56-71, January 2020.

241. P. Chakravarthula, Y. Peng, J. Kollin, H. Fuchs, F. Heide. "Wirtinger Holography for Near-Eye Displays," ACM Trans. Graph., Vol. 38, No. 6, Art. 13, Nov. 2019.

240. K. Rathinavel, G. Wetzstein, and H. Fuchs. "Varifocal Occlusion-Capable Optical See-through Augmented Reality Display based on Focus-tunable Optics," IEEE Transactions on Visualization and Computer Graphics, Nov. 2019, vol. 25, issue 11, pp. 3125-3134, doi: [10.1109/TVCG.2019.2933120](https://doi.org/10.1109/TVCG.2019.2933120).

239. R. Chabra, J. Straub, C. Sweeney, R. Newcombe, H. Fuchs. "StereoDRNet: Dilated Residual Stereo Net", in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (pp. 11786 - 11795) 2019.
238. X. Xia, Y. Guan, A. State, P. Chakravarthula, K. Rathinavel, T.J. Cham, H. Fuchs. "Towards a Switchable AR/VR Near-eye Display with Accommodation-Vergence and Eyeglass Prescription Support," in IEEE Transactions on Visualizations and Computer Graphics, Nov. 2019, vol. 25, issue 11, pp 3114-3124, doi: 10.1109/TVCG.2019.2932238.
237. A.S. Rose, H. Kim, H. Fuchs, J.M. Frahm. "Development of Augmented Reality Applications in Otolaryngology-Head and Neck Surgery," The Laryngoscope, Jul. 2019.
236. K. Aksit, P. Chakravartula, K. Rathinavel, Y. Jeong, R. Albert, H. Fuchs, D. Luebke. "Manufacturing Application-Driven Foveated Near-Eye Displays," in IEEE Transactions on Visualization and Computer Graphics, vol. 25, no. 5, pp. 1928-1939, May 2019. doi: 10.1109/TVCG.2019.2898781
235. H. Jiang, S. Xu, A. State, F. Feng, H. Fuchs, M. Hong, and J. Rozenblit. "Enhancing a Laparoscopy Training System with Augmented Reality Visualization," 2019 Spring Simulation Conference (SpringSim), 29 April - 2 May, 2019, Tucson, Arizona. doi: 10.23919/SpringSim.2019.8732876
234. A. Blate, M. Whitton, M. Singh, G. Welch, A. State, T. Whitted, and H. Fuchs. "Implementation and Evaluation of a 50 kHz, 28 μ s Motion-to-Pose Latency Head Tracking Instrument," in IEEE Transactions on Visualization and Computer Graphics, vol. 25, 5 May 2019, pp. 1970-1980). doi: 10.1109/TVCG.2019.2899233
233. G. Song, J. Cai, T.J. Cham, J. Zheng, J. Zhang, H. Fuchs. "Real-time 3D Face-Eye Performance Capture of a Person Wearing a VR Headset," Proceedings of the 26th ACM International Conference on Multimedia, Oct. 28, 2018, pp. 923-391. doi: 10.1145/3240508.3240570
232. D. Dunn, P. Chakravarthula, Q. Dong, H. Fuchs. "Mitigating Vergence-Accommodation Conflict for Near-Eye Displays via Deformable Beamsplitters," SPIE Digital Optics for Immersive Displays 2018. **1st Place, DOID Student Optical Design Challenge.**
231. P. Chakravarthula, D. Dunn, K. Aksit, H. Fuchs. "FocusAR: Auto-focus Augmented Reality Eyeglasses for both Real and Virtual," Proceedings of ISMAR 2018 and IEEE Transactions on Visualization and Computer Graphics. **Best Paper Award.**
230. K. Rathinavel, H. Wang, A. Blate, H. Fuchs. "An Extended Depth-of-Field Volumetric Near-Eye Augmented Reality Display," Proceedings of ISMAR 2018 and IEEE Transactions on Visualization and Computer Graphics.
229. Y-W. Cha, T. Price, Z. Wei, X. Lu, N. Rewkowski, R. Chabra, Z. Qin, H. Kim, Z. Su, Y. Liu, A. Ilie, A. State, Z. Xu, J. Frahm, H. Fuchs. "Towards Fully Mobile 3D Face, Body, and Environment Capture Using Only Head-worn Cameras," Proceedings of ISMAR 2018 and IEEE Transactions on Visualization and Computer Graphics.
228. K. Rathinavel, P. Chakravarthula, K. Aksit, J. Spjut, B. Boudaoud, T. Whitted, D. Luebke, H. Fuchs. "Steerable Application-Adaptive Near Eye Displays," SIGGRAPH '18: ACM SIGGRAPH 2018 Emerging Technologies, August 2018, pp. 1-2. doi: 10.1145/3214907.3214911. **Best in Show Award.**
227. X. Xia, Y. Guan, A. State, T-J. Cham, H. Fuchs. "Towards Efficient 3D Calibration for Different Types of Multi-view Autostereoscopic 3D Displays," Proceedings of Computer Graphics International, CGI 2018, June 11-14, 2018, Bintan Island, Indonesia, pp. 169-174.

226. K. Kroesl, D. Bauer, M. Schwarzler, H. Fuchs, G. Suter, M. Wimmer. "A VR-based User Study on the Effects of Vision Impairments on Recognition Distances of Escape-Route Signs in Buildings," The Visual Computer, June 2018. Vo. 34, Issue 6-8, (Proceedings of Computer Graphics International, CGI 2018, June 11-14, 2018, Bintan Island, Indonesia), pp. 911-923
225. David Dunn, Praneeth Chakravarthula, Qian Dong, Kaan Aksit, Henry Fuchs. "Towards Varifocal Augmented Reality Displays using Deformable Beamsplitter Membranes," SID Display Week 2018 Digest, pp. 92-95.
224. H. Chen and H. Fuchs. "Supporting Free Walking in a Large Virtual Environment: Imperceptible Redirected Walking with an Immersive Distractor," Proceedings of Computer Graphics International (CGI '17),
223. H. Chen and H. Fuchs. "Towards Imperceptible Redirected Walking: integrating a distractor into the immersive experience," Proceedings of the 21st ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games (I3D 2017).
222. G. Avveduto, F. Tecchia, H. Fuchs. "Real-world Occlusion in Optical See-through AR Displays," ACM Symposium on Virtual Reality Software and Technology 2017 (Gothenburg, Sweden, Nov. 8-10, 2017).
221. T. Arce, H. Fuchs, K. McMullen. "The Effects of 3D Audio on Hologram Localization in Augmented Reality Environments," Proceedings of the Human Factors and Ergonomics Society 2017 Annual Meeting (Austin, TX, October 9–13, 2017) pp. 2115-2119.
220. R. Chabra, A. Illie, N. Rewkowski, Y. Cha, H. Fuchs. "Optimizing Placement of Commodity Depth Cameras for Known 3D Dynamic Scene Capture," IEEE Virtual Reality 2017 (Los Angeles, CA, March 18-22, 2017).
219. D. Dunn, C. Tippetts, K. Torell, P. Kelnhofer, K. Aksit, P. Didyk, K. Myszkowski, D. Luebke, H. Fuchs. "Wide Field of View Varifocal Near-Eye Display using See-Through Deformable Membrane Mirrors," IEEE Virtual Reality 2017 (Los Angeles, CA, March 18-22, 2017). **Best Paper Award.**
218. P. Lincoln, A. Bate, M. Singh, A. State, M. Whitted, T. Whitted, H. Fuchs. "Scene-Adaptive High Dynamic Range Display for Low Latency Augmented Reality," ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games 2017 (San Francisco, CA, Feb. 25-27, 2017). **2nd-Best Paper Award.**
217. Y-W. Cha, M. Dou, R. Chabra, F. Menozzi, A. State, E. Wallen, MD, H. Fuchs. "Immersive Learning Experiences for Surgical Procedures," Medicine Meets Virtual Reality / NextMed 2016 (Los Angeles, April 7-9, 2016).
216. Y. Ren and H. Fuchs. "Faster Feedback for Remote Scene Viewing with Pan-Tilt Stereo Camera," IEEE Virtual Reality 2016 Conference (Greenville, SC, March 19-23, 2016).
215. P. Lincoln, A. Bate, M. Singh, T. Whitted, A. State, A. Lastra, H. Fuchs. "From Motion to Photons in 80 Microseconds: Towards Minimal Latency for Virtual and Augmented Reality," IEEE Virtual Reality 2016 Conference (Greenville, SC, March 19-23). **Best Paper Award.**
214. M. Dou, J. Taylor, H. Fuchs, A. Fitzgibbon, S. Izadi. "3D Scanning Deformable Objects with a Single RGBD Sensor," CVPR 2015-Computer Vision and Pattern Recognition Conference (Boston, MA, June 7-12, 2015).
213. A. Ullah Naweed, L. Chen, M. Dou, H. Fuchs. "Enhancement of 3D Capture of Room-sized Dynamic scenes with Pan-Tilt-Zoom Cameras," International Symposium on Visual Computing (ISVC) 2014 (Las Vegas, Nevada, Dec. 8-10, 2014).

212. F. Zheng, T. Whitted, A. Lastra, P. Lincoln, A. State, A. Maimone, H. Fuchs. "Minimizing Latency for Augmented Reality Displays: Frames Considered Harmful," IEEE ISMAR, International Symposium on Mixed and Augmented Reality, September 2014.
211. H. Fuchs, A. State, J. Bazin. "Immersive 3D Telepresence," IEEE Computer. Vol.47, No. 7, pp. 46-52. July 2014.
210. D. Sonnenwald, H. Söderholm, G. Welch, B. Cairns, J. Manning, H. Fuchs. "Illuminating Collaboration in Emergency Health Care Situations: Paramedic-Physician Collaboration and 3D Telepresence Technology," Information Research, 19(2) paper 618, 2014.
209. C. Fleury, T. Popa, T. Cham, H. Fuchs. "Merging Live and pre-Captured Data to Support Full 3D Head Reconstruction for Telepresence," Eurographics 2014, (Strasbourg, France, April 7-11, 2014), pp. 9-12, 2014.
208. A. Maimone, D. Lanman, K. Rathinavel, K. Keller, D. Luebke, H. Fuchs. "Pinlight Displays: Wide Field of View Augmented Reality Eyeglasses Using Defocused Point Light Sources," SIGGRAPH 2014 (Vancouver, Canada, August 10-14, 2014)
207. M. Dou and H. Fuchs. "Temporally Enhanced 3D Capture of Room-sized Dynamic Scene with Commodity Depth Cameras," IEEE Virtual Reality 2014 Conference. **Best Short Paper Award.**
206. A. Maimone, R. Chen, H. Fuchs, R. Raskar, G. Wetzstein. "Wide Field of View Compressive Light Field Display using a Multilayer Architecture and Tracked Viewers," Society of Information Display Week 2014 (San Diego, CA, June 1-6, 2014)
205. T. Deng, H. Li, J. Cai, T. Cham, H. Fuchs. "Kinect Shadow Detection and Classification," 2013 IEEE International Conference on Computer Vision Workshops (ICCVW) 2013 (Sydney, Australia December 1-8, 2013)
204. A. Maimone and H. Fuchs. "Computational Augmented Reality Eyeglasses," International Symposium on Mixed and Augmented Reality (ISMAR) 2013 (Adelaide, Australia, October 1-4, 2013).
203. M. Dou, H. Fuchs, J.-M. Frahm. "Scanning and Tracking Dynamic Objects with Commodity Depth Cameras," International Symposium on Mixed and Augmented Reality (ISMAR) 2013 (Adelaide, Australia, October 1-4, 2013).
202. A. Sadagic, M. Kolsch, G. Welch, C. Basu, C. Darken, J. Wachs, H. Fuchs, H. Towles, N. Rowe, J.-M. Frahm, L. Guan, R. Kumar, H. Cheng. "Smart Instrumented Training Ranges: Bringing Automated System Solutions to Support Critical Domain Needs," The Journal for Defense Modeling and Simulation (JDMS), Vol. 10 No. 3, July 2013.
201. A. Maimone, G. Wetzstein, M. Hirsch, D. Lanman, R. Raskar, H. Fuchs. "Focus 3D: Compressive Accommodation Display," ACM Transactions on Graphics. 32, 5. Article 153 (September 2013).
200. A. Maimone, X. Yang, N. Dierk, A. State, M. Dou, H. Fuchs. "General-Purpose Telepresence with Head-Worn Optical See-Through Displays and Projector-Based Lighting," IEEE Virtual Reality 2013 (Orlando, FL, USA, March 16-23, 2013) **Best Short Paper Award.**
199. D. Rivera-Gutierrez, G. Welch, P. Lincoln, M. Whitton, J. Cendan, D. Chesnutt, H. Fuchs, B. Lok. "Shader Lamps Virtual Patients: The Physical Manifestation of Virtual Patients," Medicine Meets Virtual Reality 19 – NextMed, Studies in Health Technology and Informatics, IOS Press, 2012, 173:372-378.

198. R. Schubert, G. Welch, P. Lincoln, A. Nagendran, R. Pillat, and H. Fuchs. "Advances in Shader Lamps Avatars for Telepresence," Proceedings of 3DTV-Conference 2012: The True Vision: Capture, Transmission and Display of 3D Video, (ETH Zurich, Zurich, Switzerland), October 15-17 2012.
197. A. Maimone and H. Fuchs. "Real-Time Volumetric 3D Capture of Room-Sized Scenes for Telepresence," 3DTV Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON) 2012 (Zurich, Switzerland, October 15-17, 2012). doi: 10.1109/3DTV.2012.6365430
196. A. Maimone, J. Bidwell, K. Peng, H. Fuchs. "Enhanced Personal Autostereoscopic Telepresence System using Commodity Depth Cameras," Computers & Graphics, Volume 36, Issue 7, November 2012, pp. 791-807.
195. T. Peck, H. Fuchs, and M. Whitton. "The Design and Evaluation of a Large-Scale Real-Walking Locomotion Interface," IEEE Transactions on Visualization and Computer Graphics 18(7), July 2012, 1053-1067.
194. A. Maimone and H. Fuchs. "Reducing Interference Between Multiple Structured Light Depth Sensors Using Motion," IEEE Virtual Reality 2012 (Orange County, CA, USA, March 4-8, 2012) **Best Short Paper Award.**
193. M. Dou, L. Guan, J.-M. Frahm, H. Fuchs. "Exploring High-Level Plane Primitives for Indoor 3D Reconstruction with a Hand-held RGB-D Camera," ACCV (Asian Conference on Computer Vision) Workshops (2) 2012.
192. M. Dou, Y. Shi, J.-M. Frahm, H. Fuchs, B. Mauchly, M. Marathe. "Room-sized informal telepresence system," IEEE Virtual Reality 2012 Conference (Orange County, CA, March 4-8, 2012), pp. 15-18.
191. A. Maimone and H. Fuchs. "A First Look at a Telepresence System with Room-Sized Real-Time 3D Capture and Life-Sized Tracked Display Wall," 21st International Conference on Artificial Reality and Telexistence (ICAT) (Osaka, Japan, November 28-30, 2011).
190. P. Lincoln, G. Welch, A. Nashel, A. State, A. Ilie, H. Fuchs. "Animatronic shader lamps avatars," Virtual Reality 15(2-3): 225-238 (2011).
189. C. Burke, J. Cullen, A. State, S. Gadi, K. Wilber, R. Michael, A. Bulysheva, A. Pease, M. Mauro, H. Fuchs. "Development of an Animal Model for Radiofrequency Ablation of Primary, Virally Induced Hepatocellular Carcinoma in the Woodchuck," Journal of Vascular and Interventional Radiology, 22(11), p. 1613-1618, November 2011.
188. A. Maimone and H. Fuchs. "Encumbrance-free Telepresence System with Real-time 3D Capture and Display using Commodity Depth Cameras," International Symposium on Mixed and Augmented Reality (ISMAR) 2011 (Basel, Switzerland, October 26-29, 2011).
187. P. Lincoln, G. Welch, H. Fuchs. "Continual Surface-Based Multi-Projector Blending for Moving Objects," IEEE Virtual Reality 2011 (Singapore, March 19-23, 2011).
186. T. Peck, H. Fuchs, M. Whitton. "An Evaluation of Navigational Ability Comparing Redirected Free Exploration with Distractors to Walking-in-Place and Joystick Locomotion Interfaces," IEEE Virtual Reality 2011 (Singapore, March 19-23, 2011).
185. G. Ye, A. State, H. Fuchs. "A Practical Multi-viewer Tabletop Autostereoscopic Display," Proceedings of the International Symposium on Mixed and Augmented Reality (ISMAR) 2010 (Seoul, South Korea, October 13 -16, 2010).

184. T. Peck, H. Fuchs, M. Whitton. "Improved Redirection with Distractors: A Large-Scale-Real-Walking Locomotion Interface and its Effect on Navigation in Virtual Environments," IEEE Virtual Reality 2010.
183. P. Lincoln, G. Welch, A. Nashel, A. State, A. Ilie, H. Fuchs. "Animatronic Shader Lamps Avatars," Virtual Reality (2010), Springer, London, pp. 10-14.
182. T. Peck, H. Fuchs, M. Whitton. "Evaluation of Reorientation Techniques and Distractors for Walking in Large Virtual Environments," IEEE Transactions on Visualization and Computer Graphics, pp. 383-394, May/June, 2009.
181. A. Nashel and H. Fuchs. "Random Hole Display: A Non-Uniform Barrier Autostereoscopic Display," 3DTV 2009 Conference: The True Vision - Capture, Transmission and Display of 3D Video.
180. G. Welch, D. Sonnenwald, H. Fuchs, B. Cairns, K. Mayer-Patel, H. Soderholm, R. Yang, A. State, H. Towles, A. Ilie, M. Ampalam, S. Krishnan, V. Noel, M. Noland, J. Manning. "3D Medical Collaboration Technology to Enhance Emergency Healthcare," The Journal of Biomedical Discovery and Collaboration 4:4 (2009).
179. H. Towles, T. Johnson, H. Fuchs. "Projector Based Displays," The PSI Handbook of Virtual Environments for Training and Education Vol. 2 (2009). D. Nicholson, D. Schmorow and J. Cohn (editors), Westport, Praeger Security International. pp. 63-89.
178. A. Sadagic, G. Welch, C. Basu, C. Darken, R. Kumar, H. Fuchs, H. Cheng, J.-M. Frahm, M. Kolsch, N. Rowe, H. Towles, J. Wachs, A. Lastra. "New Generation of Instrumented Ranges: Enabling Automated Performance Analysis," Interservice/ Industry Training, Simulation, and Education Conference (I/ITSEC-2009), Orlando, FL.
177. P. Lincoln, G. Welch, A. Nashel, A. Ilie, A. State, H. Fuchs. "Animatronic Shader Lamps Avatars," 8th IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR) 2009, Orlando, FL.
176. P. Lincoln, A. Nashel, A. Ilie, H. Towles, G. Welch, H. Fuchs. "Multi-view lenticular display for group teleconferencing," IMMERSCOM 2009, Berkeley, CA.
175. T. Johnson, G. Welch, H. Fuchs, E. LaForce, H. Towles. "A Distributed Cooperative Framework for Continuous Multi-Projector Pose Estimation," IEEE Virtual Reality 2009 Conference (Lafayette, LA).
174. D. Sonnenwald, H. Soderholm, J. Manning MD, B. Cairns MD, H. Fuchs, G. Welch. "Exploring the potential of video technologies for collaboration in emergency medical care. Part I: Information sharing," Journal of the American Society for Information Science and Technology, Dec. 2008, vol.59, pp. 2320-2334.
173. D. Sonnenwald, H. Soderholm, J. Manning MD, B. Cairns MD, H. Fuchs, G. Welch. "Exploring the potential of video technologies for collaboration in emergency medical care. Part II: Task performance." Journal of the American Society for Information Science and Technology, Dec. 2008, vol.59, pp. 2335-2349.
172. K. Keller, A. State, H. Fuchs. "Head Mounted Displays for Medical Use," Journal of Display Technology, IEEE and OSA, Vol. 4, November 2008.
171. A. State, H. Yang, H. Fuchs, S. Woo Lee, P. McNeillie, C. Burke. "Contextually Enhanced 3D Visualization for Multi-burn Tumor Ablation Guidance." Proc. AML-ARCS Workshop, September 2008 (New York, NY), pp.70-77.
170. T. Peck, M. Whitton, H. Fuchs. "Evaluation of Reorientation Techniques for Walking in Large Virtual Environments," IEEE Virtual Reality 2008 Conference, March 2008.

169. G. Welch, D. Sonnenwald, H. Fuchs, B. Cairns, K. Mayer-Patel, R. Yang, A. State, H. Towles, A. Ilie, S. Krishnan, et al. "Remote 3D Medical Consultation," *Virtual Realities 2008*, 139-159.
168. H. Fuchs, A. State, H. Yang, T. Peck, S. Lee, M. Rosenthal, A. Bulysheva, C. Burke. "Optimizing a Head-Trackted Stereo Display System to Guide Hepatic Tumor Ablation," *Medicine Meets Virtual Reality (MMVR) 2008 Conference. Studies in Health Technology Informatics*, vol. 132, pp. 126-131.
167. H. Soderholm, D. Sonnenwald, B. Cairns, J. Manning, G. Welch, H. Fuchs. "The Potential Impact of 3D Telepresence Technology on Task Performance in Emergency Trauma Care," *Group '07 – Proceedings of the 2007 International ACM Conference on Supporting Group Work*, Sanibel Island, FL (November 2007).
166. S. Larsen, P. Mordohai, M. Pollefeys, H. Fuchs. "Temporally Consistent Reconstruction from Multiple Video Streams using Enhanced Belief Propagation," *Proc. ICCV 2007 (International Conference on Computer Vision)*.
165. T. Johnson, F. Gyarfas, R. Skarbez, H. Towles, and H. Fuchs. "A Personal Surround Environment: Projective Display with Correction for Display Surface Geometry and Extreme Lens Distortion," *IEEE Virtual Reality 2007*, pp. 147–154.
164. T. Johnson and H. Fuchs. "Real-Time Projector Tracking on Complex Geometry Using Ordinary Imagery," *Proceedings of CVPR 2007, IEEE Conference on Computer Vision and Pattern Recognition (June 2007)*, pp. 1-8.
163. T. Johnson and H. Fuchs. "A Unified Multi-Surface, Multi-Resolution Workspace with Camera-Based Scanning and Projector-Based Illumination," *Eurographics Symposium on Virtual Environments/Immersive Projections Technology Workshop 2007*, Wiemar, Germany, July 2007.
162. F. Brooks Jr., J. Cannon-Bowers, H. Fuchs, L. McMillan, and M. Whitton. "Virtual Environment Training for Dismounted Teams-Technical Challenges," *Human Factors & Medicine Panel Workshop on Virtual Media for Military Applications*, U.S. Military Academy, West Point, NY, June 2006, pp. 13–15.
161. G. Burdea, Z. Cohen, H. Fuchs, R. Satava. "VR Support of Clinical Applications: Collaboration, Politics, and Ethics," *Virtual Reality 2007 Conference*, 311-312.
160. E. Larsen, P. Mordohai, M. Pollefeys, H. Fuchs. "Simplified Belief Propagation for Multiple View Reconstruction," *3DPVT 2006 Conference*, 342-349.
159. H. Maurin, D. Sonnenwald, B. Cairns, J. Manning, E. Freid, H. Fuchs. "Exploring Gender Differences in Perceptions of 3D Telepresence Collaboration Technology: an Example from Emergency Medical Care," *NordiCHI 2006*. 381-384.
158. D. Sonnenwald, H. Maurin, B. Cairns, J. Manning, E. Freid, G. Welch, H. Fuchs. "Experimental Comparison of the Use of 2D and 3D Telepresence Technologies in Distributed Emergency Medical Situations", In *Proceedings of the American Society of Information Science and Technology (ASIS&T 2006)*, Austin, TX, November 3-9, 2006.
157. T. Johnson, F. Gyarfas, R. Skarbez, P. Quirk, H. Towles, H. Fuchs. "Multi-Projector Image Correction on the GPU," *Workshop on Edge Computing Using New Commodity Architectures (EDGE)*, Chapel Hill, NC, (May 2006).
156. P. Quirk, T. Johnson, R. Skarbez, H. Towles, F. Gyarfas, and H. Fuchs. "RANSAC-Assisted Display Model Reconstruction for Projective Display," *Virtual Reality 2006 Conference (March 25-29, 2006)*, Emerging Display Technologies, p. 318.

155. G. Welch, H. Fuchs, B. Cairns, K. Mayer-Patel, D. Sonnenwald, R. Yang, A. State, H. Towles, A. Ilie, M. Noland, V. Noel, H. Yang. "Improving, Expanding, and Extending 3D Telepresence," 2005 International Workshop on Advanced Information Processing for Ubiquitous Networks, with ICAT 2005, Christchurch, New Zealand, December 8, 2005.
154. L. Kohli, E. Burns, D. Miller, H. Fuchs. "Combining Passive Haptics with Redirected Walking," ICAT 2005, 21st International Conference on Artificial Reality and Telexistence.
153. F. Brooks, J. Cannon-Bowers, H. Fuchs, L. McMillan, M. Whitton. "A New VE Challenge: Immersive Experiences for Team Training," Proceedings of HCI, Human Computer Interaction International 2005.
152. D. Cotting, M. Naef, M. Gross, H. Fuchs. "Imperceptible Patterns for Reliable Acquisition of Mixed Reality Environments," International Workshop on Image Analysis for Multimedia Interactive Services, Montreux, Switzerland, 2005.
151. D. Cotting, R. Ziegler, M. Gross, H. Fuchs. "Adaptive Instant Displays: Continuously Calibrated Projections Using Per-Pixel Light Control," Eurographics 2005, Dublin, Ireland.
150. A. State, K. Keller, H. Fuchs. "Simulation-Based Design and Rapid Prototyping of a Parallax-Free Orthoscopic Video See-Through Head-Mounted Display," Proceedings of the Fourth IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR), October 5-8, 2005, pp. 28-31.
149. G. Welch, R. Yang, S. Becker, A. Ilie, D. Russo, J. Funaro, A. State, K. Low, A. Lastra, H. Towles, M. D. Bruce Cairns, H. Fuchs, A. van Dam. "Immersive Electronic Books for Surgical Training," IEEE Multimedia, vol. 12, pp. 22-35, 2005.
148. G. Welch, H. Fuchs, B. Cairns, K. Mayer-Patel, D. Sonnenwald, R. Yang, A. State, H. Towles, A. Ilie, M. Ampalam, S. Krishnan, H. Maurin, V. Noel, and M. Noland. "Remote 3D Medical Consultation," Chapter in BROADMED: 1st IEEE/CreateNet International Conference on Telemedicine over Broadband and Wireless Networks. (Boston: Omnipress 2005), pp. 103-110.
147. G. Welch, R. Yang, B. Cairns, H. Towles, A. State, A. Ilie, S. Becker, D. Russo, J. Funaro, D. Sonnenwald, K. Mayer-Patel, B. Danette Allen, H. Yang, E. Freid, A. van Dam, H. Fuchs. "3D Telepresence for Off-Line Surgical Training and On-Line Remote Consultation," Proceedings of ICAT CREST Symposium on Telecommunication, Teleimmersion, and Telexistence, The University of Tokyo, Toyko, Japan, December 2004.
146. D. Cotting, M. Naef, M. Gross, H. Fuchs. "Embedding Imperceptible Patterns into Projected Images for Simultaneous Acquisition and Display," International Symposium on Mixed and Augmented Reality (ISMAR), Arlington, VA USA, 2004.
145. A. Ilie, K. Low, G. Welch, A. Lastra, H. Fuchs, B. Cairns. "Combining Head-Mounted and Projector-Based Displays for Surgical Training," Teleoperators and Virtual Environments, Vol. 13, 2004.
144. O. Schreer, H. Fuchs, W. IJsselsteijn, H. Yasuda. "Introduction to the Special Issue on Immersive Telecommunications," IEEE Trans. Circuits Syst. Video Techn. 14(3): 285-287 (2004)
143. W.-C. Chen, L. Nyland, A. Lastra, H. Fuchs. "Acquisition of Large-Scale Surface Light Fields," Technical Sketch, SIGGRAPH International Conference on Computer Graphics (San Diego, 2003), p. 1.
142. N. Kelshikar, X. Zabulis, J. Mulligan, K. Daniilidis, V. Sawant, S. Sinha, T. Sparks, S. Larsen, H. Towles, K. Mayer-Patel, H. Fuchs, J. Urbanic, K. Benninger, R. Reddy, and G. Huntoon. "Real-time Terascale Implementation of Tele-immersion," International Conference on Computation Science 2003, Melbourne, Australia, 2003.

141. S.-U. Kum, K. Mayer-Patel, and H. Fuchs. "Real-time Compression for Dynamic 3D Environments," Eleventh ACM International Conference on Multimedia, Berkeley, CA. 2003, pp. 185-194.
140. A. Raij, G. Gill, A. Majumder, H. Towles, and H. Fuchs. "PixelFlex2: A Comprehensive, Automatic, Casually-Aligned Multi-Projector Display," IEEE International Workshop on Projector-Camera Systems (PROCAMS-2003), Nice, France, 2003.
139. A. State, K. Keller, M. Rosenthal, H. Yang, J. Ackerman, H. Fuchs. "Stereo Imagery from the UNC Augmented Reality System for Breast Biopsy Guidance," Medicine Meets Virtual Reality (MMVR), Newport Beach, CA, 2003.
138. J. Ackerman, K. Keller, and H. Fuchs. "Surface Reconstruction of Abdominal Organs Using Laparoscopic Structured Light for Augmented Reality Applications," Electronic Imaging 2002 - Photonics West, 2002.
137. M. Rosenthal, A. State, J. Lee, G. Hirota, J. Ackerman, K. Keller, E. Pisano, M. Jiroutek, K. Muller, H. Fuchs. "Augmented Reality Guidance for Needle Biopsies: An Initial Randomized, Controlled Trial in Phantoms," Medical Image Analysis, vol. 6, pp. 313-320, 2002.
136. H. Towles, W.-C. Chen, R. Yang, S.-U. Kum, H. Fuchs, N. Kelshikar, J. Mulligan, K. Daniilidis, L. Holden, B. Zeleznik, A. Sadagic, J. Lanier. "3D Tele-Collaboration Over Internet2," International Workshop on Immersive Telepresence (ITP2002), Juan Les Pins, France, 2002.
135. A. van Dam, H. Fuchs, S. Becker, L. Holden, A. Ilie, K.-L. Low, A. Spalter, R. Yang, G. Welch. "Immersive Electronic Books for Teaching Surgical Procedures," Pre-ICAT CREST Symposium on Telecommunication, Teleimmersion, and Telexistence, Tokyo, Japan, 2002.
134. K. Keller, J. Ackerman, H. Fuchs. "Switched Pattern Laser Projection for Real-time Depth Extraction and Visualization through Endoscopes," International Symposium on Optical Science and Technology SPIE's 47 annual meeting, 2002.
133. R. Yang, C. Kurashima, A. Nashel, A. Lastra, H. Fuchs. "Creating Adaptive Views for Group Video Teleconferencing -- An Image-Based Approach," International Workshop on Immersive Telepresence (ITP2002), Juan Les Pins, France, 2002.
132. J. Ackerman, K. Keller, H. Fuchs. "Real-time Anatomical 3D Image Extraction for Laparoscopic Surgery," Medicine Meets Virtual Reality 2001, pp 18-22.
131. D. Bandyopadhyay, R. Raskar, H. Fuchs. "Dynamic Shader Lamps: Painting on Movable Objects," International Symposium on Augmented Reality (ISAR 2001), New York City, NY, 2001. **Long Lasting Impact Paper Award, ISMAR 2016.**
130. H. Fuchs, "Omnidirectional Vision and Tele-Presence," International Conference on Advanced Robotics 2001 Workshop (ICAR), Budapest, Hungary, 2001.
129. G. Hirota, S. Fisher, C. Lee, A. State, H. Fuchs, "An Implicit Finite Element Method for Elastic Solids in Contact," Computer Animation 2001, Seoul, South Korea, 2001.
128. K.-L. Low, G. Welch, A. Lastra, and H. Fuchs. "Life-Sized Projector-Based Dioramas," ACM Symposium on Virtual Reality Software and Technology, Banff, Alberta, Canada, 2001.
127. L. S. Nyland, A. Lastra, D. K. McAllister, V. Popescu, C. Mccue, H. Fuchs. "Capturing, Processing, and Rendering Real-World Scenes," Videometrics and Optical Methods for 3D Shape Measurement Techniques, Electronic Imaging Photonics, 2001.

126. M. Rosenthal, A. State, J. Lee, G. Hirota, J. Ackerman, K. Keller, E. Pisano, M. Jiroutek, K. Muller, and H. Fuchs, "Augmented Reality Guidance for Needle Biopsies: A Randomized, Controlled Trial in Phantoms," Medical Image Computing and Computer-Assisted Intervention (MICCAI), Utrecht, The Netherlands, 2001.
125. M. Rosenthal, S. Weeks, S. Aylward, E. Bullitt, and H. Fuchs, "Intraoperative Tracking of Anatomical Structures Using Fluoroscopy and a Vascular Balloon Catheter," Medical Image Computing and Computer-Assisted Intervention (MICCAI) 2001, Utrecht, The Netherlands, 2001.
124. L. Clarke, R. Bucholz, H. Fuchs, R. Kikinis, R. Robb, R. Shahidi, M. Vannier. "White Paper: challenges and opportunities in computer-assisted interventions," CARS 2001 (Computer-Assisted Radiology and Surgery) 203-209.
123. A. State, J. Ackerman, G. Hirota, J. Lee, H. Fuchs. "Dynamic Virtual Convergence for Video See-through Head-mounted Displays: Maintaining Maximum Stereo Overlap throughout a Close-range Work Space," International Symposium on Augmented Reality (ISAR) 2001, New York, NY, 2001.
122. W.-C. Chen, H. Towles, L. Nyland, G. Welch, H. Fuchs. "Toward a Compelling Sensation of Telepresence: Demonstrating a Portal to a Distant (Static) Office," IEEE Visualization 2000, Salt Lake City, UT, 2000.
121. G. Welch, H. Fuchs, R. Raskar, M. Brown, and H. Towles. "Projected Imagery In Your Office in the Future," IEEE Computer Graphics and Applications, vol. 20, pp. 62-67, 2000.
120. J. Rolland and H. Fuchs. "Optical versus Video See-Through Head-Mounted Displays in Medical Visualization," Presence, June 2000, vol. 9, no. 3, pp. 287-309.
119. H. Fuchs. "Immersive Displays for the Individual, the Group, and for Networked Collaboration." Proceedings of Simulation and Visualization on the Grid, Seventh Annual Conference of Parallel Data Center Kungl Tekniska Högskolan, Stockholm, Sweden, December 1999. (Springer, Vol. 13, 2000, Lecture Notes in Computational Science and Engineering)
118. S. Feiner, H. Fuchs, T. Kanade, G. Klinker, P. Milgram, and H. Tamura. "Mixed Reality: Where Real and Virtual Worlds Meet," ACM SIGGRAPH 99 Conference abstracts and applications. Los Angeles, California, United States ACM Press, 1999.
117. K. Daniilidis, J. Mulligan, R. McKendall, A. Majumder, G. Kamberova, D. Schmid, R. Bajcsy, H. Fuchs. "Towards the Holodeck: An Initial Testbed for Real-Time 3D-Teleimmersion," ACM SIGGRAPH (1999)
116. H. Fuchs and J. Ackerman. "Displays for Augmented Reality: Historical Remarks and Future Prospects," 1st International Symposium on Mixed Reality (ISMIR'99), Yokohama, Japan, 1999.
115. A. Majumder, W. B. Seales, M. Gopi, H. Fuchs. "Immersive Teleconferencing: A New Algorithm to Generate Seamless Panoramic Video Imagery," Seventh ACM International Conference on Multimedia, 1999.
114. L. Nyland, D. McAllister, V. Popescu, C. McCue, A. Lastra, P. Rademacher, M. Oliveira, G. Bishop, G. Meenakshisundaram, M. Cutts, H. Fuchs. "The Impact of Dense Range Data on Computer Graphics," Multi-View Modeling and Analysis Workshop (MVIEW99), Fort Collins, CO, 1999.
113. R. Raskar, M. Brown, R. Yang, W.-C. Chen, G. Welch, H. Towles, B. Seales, H. Fuchs. "Multi-Projector Displays Using Camera-Based Registration," IEEE Visualization 99, San Francisco, CA, 1999.
112. R. Yang, M. Brown, W. Seales, H. Fuchs. "Geometrically correct imagery for Teleconferencing," ACM International Conference on Multimedia, Orlando, FL, 1999.

111. R. Yang, M. Brown, W. Seales, H. Fuchs. "Registering, Integrating, and Building CAD Models from Range Data," Seventh ACM International Conference on Multimedia, 1999.
110. E. Pisano MD, H. Fuchs, A. State, M. Livingston, G. Hitaro, W. Garrett, M. Whitton. "Augmented Reality Applied to Ultrasound-guided Breast Cyst Aspiration," Breast Disease, 1998, vol. 10, nos. 3-4, pp.
109. M. Bloomenthal, R. Zeleznik, R. Fish, L. Holden, A. Forsberg, R. Riesenfeld, M. Cutts, S. Drake, H. Fuchs, E. Cohen. "Sketch-N-Make: Automated Machining of CAD Sketches," 18th Computers In Engineering Conference, Part of DETC98, Atlanta, GA, 1998.
108. H. Fuchs. "Beyond the Desktop Metaphor: Toward More Effective Display, Interaction, and Telecollaboration in the Office of the Future via a Multitude of Sensors and Displays," Proceedings of the 1st International Conference on Advanced Multimedia Content Processing (AMCP) (Osaka, Japan, 1998). Springer Lecture Notes in Computer Science, vol. 1554, pp. 30-43.
107. H. Fuchs, M. Livingston, R. Raskar, D. Colucci, K. Keller, A. State, J. Crawford, P. Rademacher, S. Drake, A. Meyer. "Augmented Reality Visualization for Laparoscopic Surgery," First International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI '98), 1998.
106. R. Raskar, G. Welch, M. Cutts, A. Lake, L. Stesin, H. Fuchs. "The Office of the Future: A Unified Approach to Image-Based Modeling and Spatially Immersive Displays," Proceedings of the 25th International Conference on Computer Graphics, SIGGRAPH 1998. Computer Graphics (Orlando, FL, July 19-24, 1998), pp. 179-188.
105. R. Raskar, G. Welch, H. Fuchs. "Seamless Projection Overlaps Using Image Warping and Intensity Blending," Fourth International Conference on Virtual Systems and Multimedia (VSMM), Gifu, Japan, 1998.
104. R. Raskar, G. Welch, H. Fuchs. "Spatially Augmented Reality," First International Workshop on Augmented Reality (IWAR), San Francisco, CA, 1998. **Long Lasting Impact Paper Award, ISMAR 2016.**
103. M. Cutts, D. Conner, R. Fush, H. Fuchs, L. Holden, M. Jacobs, B. Loss, L. Markosian, R. Riesenfeld, G. Turk. "An Immersive Tool for Wide-Area Collaborative Design," TeamCAD, 1997.
102. V. Interrante, H. Fuchs, S. Pizer. "Conveying the 3D Shape of Smoothly Curving Transparent Surfaces via Texture," IEEE Transactions on Visualization and Computer Graphics (TVCG), 1997.
101. H. Fuchs, A. State, E. Pisano MD, W. Garrett, G. Hirota, M. Livingston, M. Whitton, S. Pizer. "Towards Performing Ultrasound-Guided Needle Biopsies from Within a Head-Mounted Display," Visualization in Biomedical Computing 1996, Hamburg, Germany, 1996.
100. H. Fuchs, A. State, M. Livingston, W. Garrett, G. Hirota, M. Whitton, E. Pisano MD. "Virtual Environments Technology to Aid Needle Biopsies of the Breast: An Example of Real-Time Data Fusion," Medicine Meets Virtual Reality:4, San Diego, CA, NextMed: Design for Well Being, 1996.
99. H. Fuchs. "Toward Virtual Teleconferencing for Telemedical Applications," Health Care in the Information Age, IOS Press, 1996.
98. W. F. Garrett, H. Fuchs, M. Whitton, A. State. "Real-Time Incremental Visualization of Dynamic Ultrasound Volumes Using Parallel BSP Trees," IEEE Visualization '96, San Francisco, CA, 1996.
97. V. Interrante, H. Fuchs, S. Pizer. "Illustrating Transparent Surfaces with Curvature-Directed Strokes," IEEE Visualization '96, San Francisco, CA, 1996.

96. A. Lastra, H. Fuchs, J. Poulton, "Harnessing Parallelism for High-Performance Interactive Computer Graphics," NSF Workshop on Experimental Systems, 1996.
95. E. Pisano, MD, H. Fuchs, A. State. "Virtual Reality Applied to Ultrasound-Guided Aspiration of Breast Cysts," Proceedings of the 1996 Annual Meeting of the American Roentgen Ray Society, San Diego, CA, 1996.
94. A. State, M. Livingston, W. Garrett, G. Hirota, M. Whitton, E. Pisano, H. Fuchs. "Technologies for Augmented Reality Systems: Realizing Ultrasound-Guided Needle Biopsies," SIGGRAPH 1996, New Orleans, LA, 1996.
93. V. Interrante, H. Fuchs, S. Pizer. "Enhancing Transparent Skin Surfaces with Ridge and Valley Lines," Proceedings of the 6th Conference on Visualization '95 (Atlanta, GA, Oct 30-Nov 3, 1995). Reprinted in IEEE Visualization 1995, p. 52-59.
92. A. State, J. McAllister, U. Neumann, H. Chen, T. Cullip, D. Chen, and H. Fuchs. "Interactive Volume Visualization on a Heterogeneous Message-Passing Multicomputer," 1995 Symposium on Interactive 3D Graphics, Monterey, CA, 1995.
91. G. Bishop, H. Fuchs, L. McMillan, E. Zagier. "Frameless Rendering: Double Buffering Considered Harmful," SIGGRAPH '94, Orlando, FL, 1994.
90. H. Fuchs, G. Bishop, K. Arthur, L. McMillan, R. Bajcsy, S. Lee, H. Farid, T. Kanade. "Virtual Space Teleconferencing Using a Sea of Cameras," First International Symposium on Medical Robotics and Computer-Assisted Surgery, Pittsburgh, PA, 1994.
89. V. Interrante, W. Oliver, S. Pizer, H. Fuchs. "Display Methods for Gray-Scale, Voxel-Based Data Sets," in Three-Dimensional Confocal Microscopy: Volume Investigation of Biological Specimens, L. M. J. Stevens and J. Trogadis, Eds. San Diego, CA: Academic Press, 1994, pp. 131-170.
88. S. Molnar, M. Cox, D. Ellsworth, H. Fuchs. "A Sorting Classification of Parallel Rendering," IEEE Computer Graphics and Applications: Special Issue on Rendering, vol. 14, pp. 23-32, 1994.
87. J. Rolland, R. Holloway, H. Fuchs. "A Comparison of Optical and Video See-Through Head-Mounted Displays," Proceedings of SPIE Telemicroscopy and Telepresence Technologies (Boston, MA, Oct 31-Nov 4, 1994), vol. 2351, pp. 293-307.
86. A. State, S. Balu, H. Fuchs. "Bunker View: Limited-Range Head-Motion-Parallax Visualization for Complex Biomedical Data Sets," Visualization in Biomedical Computing 1994, Rochester, MN.
85. A. State, D. Chen, C. Tector, A. Brandt, H. Chen, R. Ohbuchi, M. Bajura, H. Fuchs. "Case Study: Observing a Volume Rendered Fetus within a Pregnant Patient," IEEE Visualization 1994, Washington, DC.
84. A. State, M. Rosenman, H. Fuchs, J. Symon. "VISTAnet: Radiation Therapy Treatment Planning Through Rapid Dose Calculation and Interactive 3D Volume Visualization," Visualization in Biomedical Computing 1994, Rochester, MN.
83. U. Neumann and H. Fuchs, "A Vision of Telepresence for Medical Consultation and Other Applications," Sixth International Symposium on Robotics Research, Hidden Valley, PA, 1993.
82. J. Rosenman, M.D., E. Chaney, T. Cullip, J. Symon, V. Chi, H. Fuchs, D. Stevenson. "VISTAnet: Interactive Real-Time Calculation and Display of 3-Dimensional Radiation Dose: An Application of Gigabit Networking," International Journal of Radiation Oncology, Biology, Physics, vol. 25, 1993.

81. M. Bajura, H. Fuchs, R. Ohbuchi, "Merging Virtual Objects with the Real World: Seeing Ultrasound Imagery within the Patient," *Computer Graphics*, vol. 26, pp. 203 - 210, 1992.
80. G. Bishop and H. Fuchs. "Research Directions in Virtual Environments: Report of an NSF Invitational Workshop, March 23-24, 1992," *ACM Computer Graphics*, vol. 26, pp. 153-177, 1992.
79. R. Ohbuchi, D. Chen, H. Fuchs. "Incremental Volume Reconstruction and Rendering for 3D Ultrasound Imaging," *Visualization in Biomedical Computing 1992*, Bellingham, WA, 1992.
78. J. Poulton, J. Eyles, S. Molnar, H. Fuchs. "Breaking the Frame-Buffer Bottleneck with Logic-Enhanced Memories," *IEEE Computer Graphics and Applications*, vol. 12, pp. 65-74, 1992.
77. M. Ward, R. Azuma, R. Bennett, S. Gottschalk, H. Fuchs. "A Demonstrated Optical Tracker with Scalable Work Area for Head-Mounted Display Systems," *1992 Symposium on Interactive 3D Graphics*, Cambridge, MA, 1992.
76. T. Yoo, U. Neumann, H. Fuchs, S. Pizer, T. Cullip, J. Rhoades, R. Whitaker. "Direct Visualization of Volume Data," *IEEE Computer Graphics and Applications*, vol. 12, pp. 63 - 71, 1992.
75. R. Davis, M. Levoy, J. Rosenman, H. Fuchs, S. Pizer, A. Skinner, H. C. Pillsbury. "Three-Dimensional High Resolution Volume Rendering (HRVR) of Computed Tomography Data: Applications to Otolaryngology - Head and Neck Surgery," *Laryngoscope*, 1991.
74. R. Holloway, H. Fuchs, W. Robinett. "Virtual Worlds Research at the University of North Carolina at Chapel Hill," *Computer Graphics '91*, London, England, 1991.
73. U. Neumann, T. Yoo, H. Fuchs, S. Pizer, T. Cullip, J. Rhoades, R. Whitaker. "Achieving Direct Volume Visualization with Interactive Semantic Region Selection," *IEEE Visualization*, San Diego, CA, 1991.
72. R. Ohbuchi and H. Fuchs. "Incremental Volume Rendering Algorithm for Interactive 3D Ultrasound Imaging," *Information Processing in Medical Imaging (IPMI) Conference XII*, Wye, U.K., 1991.
71. R. Davis, M. Levoy, J. Rosenman (MD), H. Fuchs, S. Pizer, A. Skinner and H. Pillsbury. "Three-Dimensional High Resolution Volume Rendering (HRVR) of Computed Tomography Data: Applications to Otolaryngology--Head and Neck Surgery," *Laryngoscope*, June 1991, vol. 101, no. 6, pp. 573-582.
70. H. Fuchs. "Systems for Display of Three-Dimensional Medical Image Data," *3D Imaging in Medicine: Algorithms, Systems, Applications*, NATO Advanced Study Institute, Travemünde, Germany, 1990.
69. M. Levoy, H. Fuchs, S. Pizer, J. Rosenman, E. Chaney, G. Sherouse, V. Interrante, and J. Kiel. "Volume Rendering in Radiation Treatment Planning," *First Conference on Visualization in Biomedical Computing*, Atlanta, GA, 1990.
68. P. Mills and H. Fuchs. "3D Ultrasound Display Using Optical Tracking," *First Conference on Visualization in Biomedical Computing*, Atlanta, GA, 1990.
67. S. Molnar and H. Fuchs. "Chapter 18: Advanced Raster Graphics Architecture," in *Computer Graphics: Principles and Practice*, 2nd ed., J. Foley, A. van Dam, S. Feiner, and J. Hughes, Eds. Reading, MA: Addison-Wesley Publishers, 1990, pp. 855-922.
66. R. Ohbuchi and H. Fuchs. "Incremental 3D Ultrasound Imaging from a 2D Scanner," *First Conference on Visualization in Biomedical Computing '90*, Atlanta, GA, 1990.

65. J.-F. Wang, R. Azuma, G. Bishop, V. Chi, J. Eyles, and H. Fuchs. "Tracking a Head-Mounted Display in a Room-Sized Environment with Head-Mounted Cameras," 1990 Technical Symposium on Optical Engineering and Photonics in Aerospace Sensing, Orlando, FL, 1990.
64. J.-F. Wang, V. Chi, and H. Fuchs. "A Real-Time Optical 3D Tracker for Head-Mounted Display Systems," Proceedings of ACM Siggraph 1990 Symposium on Interactive 3D Graphics, Snowbird, UT, 1990.
63. J. Chung, M. Harris, F. Brooks, H. Fuchs, M. Kelley, J. Hughes, M. Ouh-young, C. Cheung, R. Holloway, and M. Pique. "Exploring Virtual Worlds With Head-Mounted Displays," SPIE: Non-Holographic True Three-Dimensional Displays, 1989.
62. H. Fuchs. "An Interactive Display for the 21st Century: Beyond the Desktop Metaphor," Computer Graphics International '89 Conference, Leeds, UK, 1989.
61. H. Fuchs, M. Levoy, S. Pizer. "Interactive Visualization of 3D Medical Data," IEEE Computer Graphics and Applications, vol. 22, pp. 46 - 51, 1989.
60. H. Fuchs, M. Levoy, S. Pizer, J. Rosenman. "Interactive Visualization of 3D Medical Image Data," National Computer Graphics Association Annual Conference, 1989.
59. H. Fuchs, J. Poulton, J. Eyles, T. Greer. "Coarse-Grain and Fine-Grain Parallelism in the Next Generation Pixel-Planes Graphics System," International Conference on Parallel Processing for Computer Vision and Display, University of Leeds, UK, 1989.
58. H. Fuchs, J. Poulton, J. Eyles, T. Greer, J. Goldfeather, D. Ellsworth, S. Molnar, G. Turk, B. Tebbs, L. Israel. "Pixel-planes 5: A Heterogeneous Multiprocessor Graphics System Using Processor-Enhanced Memories," SIGGRAPH '89, 1989.
57. J. Goldfeather, S. Molnar, G. Turk, H. Fuchs. "Near Real-Time CSG Rendering Using Tree Normalization and Geometric Pruning," IEEE Computer Graphics and Applications, vol. 9, pp. 20-28, 1989.
56. P. Mills, H. Fuchs, S. Pizer, and J. Rosenman. "IMEX: A Tool for Image Display and Contour Management in a Windowing Environment," SPIE: Medical Imaging III - Image Capture and Display, 1989.
55. S. Pizer, H. Fuchs, M. Levoy, J. Rosenman, R. Davis, and J. Renner. "3D Display with Minimal Predefinition," International Symposium on Computer Assisted Radiology, Berlin, Germany, 1989.
54. J. Rosenman, G. Sherouse, H. Fuchs, S. M. Pizer, A. L. Skinner, C. Mosher, K. Novins, and J. Tepper. "Three-Dimensional Display Techniques in Radiation Therapy Treatment Planning," International Journal of Radiation Oncology Biology Physics, vol. 16, 1989.
53. S. Pizer, M. Levoy, H. Fuchs, and J. Rosenman. "Volume Rendering for Display of Multiple Organs, Treatment Objects, and Image Intensities," SPIE: Science and Engineering of Medical Imaging, 1989.
52. H. Fuchs, S. Pizer, J. Creasy, J. Renner, and J. Rosenman. "Interactive, Richly Cued Shaded Display of Multiple 3-D Objects in Medical Images," SPIE Conference: Medical Imaging II, 1988.
51. D. Gilland, B. Tsui, V. Interrante, J. Perry, S. Pizer, H. Fuchs, W. McCartney. "Simultaneous Three-Dimensional Display of Emission and Transmission Data in SPECT," 35th Annual Meeting of the Society of Nuclear Medicine, 1988.
50. J. Eyles, J. Austin, H. Fuchs, T. Greer, and J. Poulton. "Pixel-Planes 4: A Summary," Advances in Graphics Hardware II: Eurographics '87 Second Workshop on Graphics Hardware, 1987.

49. H. Fuchs. "An Introduction to Pixel-Planes and other VLSI-Intensive Graphics Systems," NATO International Advanced Study Institute, Il Ciocco, Italy, 1987.
48. S. Pizer and H. Fuchs. "Three-Dimensional Image Presentation Techniques in Medical Imaging," International Symposium on Computer Assisted Radiology, Berlin, Germany, 1987.
47. J. Poulton, H. Fuchs, J. Austin, J. Eyles, T. Greer. "Building a 512 x 512 Pixel-Planes System," 1987 Stanford Conference: Advanced Research in VLSI, 1987.
46. J. Rosenman, E. Chaney, S. Pizer, G. Sherouse, H. Fuchs, "The Value of Three-Dimensional Display Techniques in Radiation Therapy Treatment Planning," International Journal of Radiation Oncology and Biomedical Physics, vol. 13, pp. 198, 1987.
45. L. Bergman, H. Fuchs, E. Grant, S. Spach, "Image Rendering by Adaptive Refinement," Computer Graphics, vol. 20 (Proceedings, SIGGRAPH 1986) pp. 29-37, 1986.
44. E. Chaney, J. Rosenman, G. Sherouse, D. Bourland, S. Pizer, H. Fuchs, E. Staab, M. Varia, S. Mahaley. "Three-Dimensional Display of Brain and Prostate Implants," Endocurietherapy / Hyperthermia Oncology, vol. 2, pp. 93-99, 1986.
43. H. Fuchs. "VLSI for Graphics," British Computer Society's International Summer Institute on The State of the Art in Computer Graphics, University of Stirling, Stirling, Scotland, 1986.
42. H. Fuchs. "VLSI-intensive Graphics Systems," NATO Advanced Study Institute: Mathematics and Computer Science in Medical Imaging, Il Ciocco, Italy, 1986.
41. J. Goldfeather and H. Fuchs. "Quadratic Surface Rendering on a Logic-Enhanced Frame Buffer Memory System," IEEE Computer Graphics and Applications, vol. 6, pp. 48-59, 1986.
40. J. Goldfeather, J. Hultquist, H. Fuchs. "Fast Constructive-Solid Geometry Display in the Pixel-Powers Graphics System," Computer Graphics, vol. 20, (Proceedings, SIGGRAPH 1986), pp. 107-116, 1986.
39. S. Pizer, H. Fuchs, C. Mosher, L. Lifshitz, G. Abram, S. Ramanathan, B. Whitney, J. Rosenman, E. Staab, E. Chaney, G. Sherouse. "3D Shaded Graphics in Radiotherapy and Diagnostic Imaging," Computer Graphics '86, National Computer Graphics Association annual conference, 1986.
38. D. Bourland, E. Chaney, H. Fuchs, S. Mahaley, J. Naves, S. Pizer, J. Rosenman, G. Sherouse, E. Staab, M. Varia, R. Whaley. "Planning Stereotactic I-125 Implants of the Brain Using Interactive 2D and 3D Graphics," Twenty-Seventh Annual Meeting of the American Association of Physicists in Medicine, 1985.
37. E. Chaney, H. Fuchs, S. Pizer, J. Rosenman, G. Sherouse, E. Staab, M. Varia. "A Three-Dimensional Imaging System for Radiotherapy Treatment Planning," XIV International Conference on Medical and Biological Engineering and the VII International Conference on Medical Physics, Medical Biological Engineering and Computing, Espoo, Finland, 1985.
36. H. Fuchs, editor. "Proceedings of the 1985 Chapel Hill Conference on Very Large Scale Integration." Rockville, MD: Computer Science Press, 1985, pp. 476.
35. H. Fuchs and G. Abram. "Specialized Computer Organization for Raster-Graphics Display," in Algorithmically-Specialized Parallel Computers, L. Snyder, L. H. Jamieson, D. B. Gannon, and H. J. Siegel, Eds. Academic Press, 1985, pp. 79-88.
34. J. Poulton, H. Fuchs, A. Paeth (1985). "Pixel-planes Graphic Engine: A Case Study." In Principles of CMOS VLSI Design by N. Weste and K. Eshraghian, Addison-Wesley, 1985, pp. 448-480.

33. H. Fuchs, J. Goldfeather, J. Hultquist, S. Spach, J. Austin, F. Brooks, J. Eyles, J. Poulton. "Fast Spheres, Shadows, Textures, Transparencies, and Image Enhancements in Pixel-Planes," SIGGRAPH '85, San Francisco, CA, 1985.
32. H. Fuchs and J. Poulton. "Parallel Processing In Pixel-Planes, a VLSI Logic-Enhanced Memory for Raster Graphics," ICCD'85, The IEEE International Conference on Computer Design, Port Chester, New York, 1985.
31. A. Glassner and H. Fuchs. "Hardware Enhancements for Raster Graphics," in Fundamental Algorithms for Computer Graphics, R. A. Earnshaw, Ed.: Springer-Verlag, Heidelberg, 1985, pp. 631-658.
30. J. Poulton, H. Fuchs, J. Austin, J. Eyles, J. Heinecke, C.-H. Hsieh, J. Goldfeather, J. Hultquist, S. Spach. "Pixel-Planes: Building a VLSI-Based Raster Graphics System," 1985 Chapel Hill Conference on Very Large Scale Integration, 1985.
29. G. Abram and H. Fuchs. "VLSI Architectures for Computer Graphics," NATO Advanced Study Institute on Microarchitecture of VLSI Computers, Sogesta-Urbino, Italy, 1984.
28. G. Bishop and H. Fuchs. "The Self-Tracker: A Smart Optical Sensor on Silicon," 1984 MIT Conference on Advanced Research in VLSI, Artech House, Dedham, MA, 1984.
27. H. Fuchs and S. Pizer. "Systems for Three-Dimensional Display of Medical Images," 1984 International Joint Alpine Symposium on Medical Computer Graphics and Image Communications and Clinical Advances in Neuro CT/NMR, 1984.
26. E. Heinz, D. Osborne, B. Drayer, A. Yeates, H. Fuchs, S. Pizer. "Examination of the Extracranial Carotid Bifurcation by Thin-Section Dynamic CT: Direct Visualization of Intimal Atheroma in Man (Part 2)," American Journal of Neuroradiology, American Roentgen Ray Society, vol. 0195-6108/84/0504-0361, pp. 361-366, 1984.
25. E. Heinz, S. Pizer, H. Fuchs, E. Fram, P. Burger, B. Drayer, D. Osborne. "Examination of the Extracranial Carotid Bifurcation by Thin-Section Dynamic CT: Direct Visualization of Intimal Atheroma in Man (Part 1)," American Journal of Neuroradiology, American Roentgen Ray Society, vol. 0195-6108/84/0504-0355, pp. 355-359, 1984.
24. P. Mills, H. Fuchs, S. Pizer. "High-speed Interaction on a Vibrating Mirror 3D Display," SPIE Proc. Conf., Processing and Display of Three-Dimensional Data II, SPIE 507: 1984.
23. H. Fuchs, G. Abram, E. Grant. "Near Real-Time Shaded Display of Rigid Objects," Proceedings of ACM SIGGRAPH, vol. 17, pp. 65-72, 1983.
22. H. Fuchs (compiler). "Selected Reprints on VLSI Technologies and Computer Graphics," vol. EH0204-8: IEEE Computer Society Press, 1983, pp.1-490.
21. S. Pizer, H. Fuchs, E. Heinz, E. Staab, E. Chaney, J. Rosenman, J. Austin, S. Bloomberg, E. MacHardy, P. Mills, D. Strickland. "Interactive 3D Display of Medical Images," VIIIth IPMI Conference, Brussels, Belgium, 1983.
20. H. Fuchs, Guest Editor. ACM Transactions on Graphics, Vol. 1, No. 1 (premier issue), 1982.
19. H. Fuchs, S. Pizer, E. Heinz, S. Bloomberg, L. Tsai, D. Strickland. "Design of and Image Editing with a Space-Filling 3-D Display Based on a Standard Raster Graphics System," SPIE Conference on Processing and Display of Three-Dimensional Data, Bellingham, WA, 1982.

18. H. Fuchs, S. Pizer, E. Heinz, L. Tsai, S. Bloomberg. "Adding a True 3-D Display to a Raster Graphic System," IEEE Computer Graphics and Applications, vol. 2, pp. 73-78, 1982.
17. H. Fuchs, J. Poulton, A. Paeth, A. Bell. "Developing Pixel-Planes, a Smart Memory-Based Raster Graphics System," MIT Conference on Advanced Research in VLSI, Artech House, Dedham, MA, 1982.
16. S. Pizer, H. Fuchs, E. Heinz, S. Bloomberg, L. Tsai. "Varifocal Mirror Display of Organ Surfaces from CT Scans," World Congress of Nuclear Medicine and Biology, Paris, France, 1982.
15. H. Fuchs and J. Poulton. "Pixel-Planes: A VLSI-Oriented Design for a Raster Graphics Engine," VLSI Design (formerly called Lambda), vol. 2, pp. 20-28, 1981.
14. J. Rosenberg and H. Fuchs. "Survey and Evaluation of Color-Display Terminals for VLSI," VLSI Design (formerly called Lambda), vol. 2, pp. 58-60, 1981.
13. H. Fuchs and J. Poulton. "Pixel-Planes: A VLSI-Oriented Design for 3-D Raster Graphics," Proceedings of the Canadian Man-Computer Communications Society 7th Conference (Waterloo, Ontario, 10-12 June 1981), pp. 343-347.
12. H. Fuchs, Z. Kedem, B. Naylor. "On Visible Surface Generation by a Priori Tree Structures," Proceedings of ACM SIGGRAPH '80, Seattle, Washington, 1980.
11. Z. Kedem and H. Fuchs. "On Finding Several Shortest Paths in Certain Graphs," Eighteenth Annual Allerton Conference on Communication, Control, and Computing, Champaign-Urbana, IL, 1980.
10. J. Barros and H. Fuchs. "Generating Smooth 2-D Monocolor Line Drawings on Video Displays," Proceedings of ACM SIGGRAPH '79, Chicago, IL, 1979.
9. H. Fuchs and B. Johnson. "An Expandable Multiprocessor Architecture for Video Graphics (Preliminary Report)," 6th Annual ACM-IEEE Symposium on Computer Architecture, 1979.
8. H. Fuchs, Z. Kedem, B. Naylor. "Predetermining Visibility Priority in 3-D Scenes (Preliminary Report)," Proceedings of ACM SIGGRAPH '79, Chicago, IL, 1979.
7. H. Fuchs, S. Pizer, J. Cohen, J. Brooks. "A Three-Dimensional Display of Medical Images from Slices," Vth International Conference on Information Processing in Medical Imaging (Traitement Des Informations en Imagerie Medicale), Paris, France, 1979.
6. H. Fuchs, J. Duran, B. Johnson, Z. Kedem. "Acquisition and Modeling of Human Body Form Data," 1978 NATO Symposium on Applications of Human Biostereometrics, Paris, France, 1978.
5. H. Fuchs and Z. Kedem. "The 'Highly Intelligent' Tablet as an Efficient Pointing Device for Interactive Graphics (Preliminary Report)," 1978 Annual ACM Conference, 1978.
4. H. Fuchs. "Distributing a Visible Surface Algorithm over Multiple Processors," Proc. 1977 ACM Annual Conference.
3. H. Fuchs, J. Duran, B. Johnson. "A System for Automatic Acquisition of Three-Dimensional Data," 1977 National Computer Conference, 1977.
2. H. Fuchs, Z. Kedem, S. Uselton. "Optimal Surface Reconstruction from Planar Contours," Communications of the ACM, vol. 20, pp. 693-702, 1977. (One of only two papers from SIGGRAPH'77 Conference selected to be published in Communications of the ACM.)

1. H. Fuchs, "The Automatic Sensing and Analysis of Three-Dimensional Surface Points from Visual Scenes," Ph.D. Dissertation, Department of Computer Science, University of Utah, Salt Lake City, 1975.

Technical Reports (Selected)

D. Cotting, I. Nebel, M. Gross, H. Fuchs, "Towards a Continuous, Unified Calibration of Projectors and Cameras," Computer Graphics Laboratory, ETH Zurich, Switzerland, and University of North Carolina at Chapel Hill, Department of Computer Science, Chapel Hill, NC, 2011.

T. Johnson, H. Towles, A. State, F. Wu, G. Welch, A. Lastra, H. Fuchs. "A Projector- based Physical Sand Table for Tactical Planning and Reviewing," UNC Department of Computer Science, Chapel Hill, NC, 2009.

D. Bandyopadhyay, R. Raskar, A. State, and H. Fuchs, "Dynamic Spatially Augmented 3D Painting," UNC Department of Computer Science, Chapel Hill, NC, 2001.

R. Raskar, H. Fuchs, G. Welch, A. Lake, and M. Cutts, "3D Talking Heads: Image Base Modeling at Interactive Rates Using Structured Light Projection," UNC Department of Computer Science, Chapel Hill, NC, 1998.

W. Dally, L. McMillan, G. Bishop, and H. Fuchs, "The Delta Tree: An Object-Centered Approach to Image-Based Rendering," MIT Artificial Intelligence Laboratory, Technical Memo 1604, Cambridge, MA, May 1996.

U. Neumann, A. State, H. Chen, H. Fuchs, T. Cullip, Q. Fang, M. Lavoie, and J. Rhoades, "Interactive Multimodal Volume Visualization for a Distributed Radiation-Treatment Planning Simulator," UNC Department of Computer Science, Chapel Hill, NC, 1994.

H. Fuchs, J. Poulton, "Supercomputing Power for Interactive Visualization," Report of Research Progress October 1990 – March 1991, UNC Department of Computer Science, Chapel Hill, NC, 1994.

H. Fuchs, F. Brooks. "Advanced Technology for Portable Personal Visualization," Report of Research Progress, April – December 1991, UNC Department of Computer Science, Chapel Hill, NC, 1991.

H. Fuchs, J. Poulton, A. State, E. Hill, and R. Brusq. "An Architecture for Advanced Avionics Displays," Wright Research and Development Center, Wright Patterson Air Force Base, OH TR90-7006, May 1990. 1990.

Invited Talks (Selected)

60. Keynote, 2019 World Conference on VR Industry, Nanchang, China, October 2019.

59. Keynote, ISMAR 2018, Munich, Germany, October 2018.

58. Google, SF, Aug. 2018.

57. Disney Research, Zurich, Switzerland, May 2018.

56. Snap Research, Venice, CA, Feb. 2018.

55. Vuforia, Vienna, Austria, Jan. 2018.

54. Keynote, ACM Multimedia Systems 2017, Taipei, Taiwan, June 2017.

53. Keynote, Eurographics 2016, Lisbon, Portugal, May 2016.

52. Technical University of Vienna, Symposium of Visual Computing Trends, January 2015
51. Samsung Developer Conference, San Francisco, November 2014
50. University of Maryland, Department of Computer Science, Distinguished Colloquia, October 2014.
49. Keynote (1 of 4), 5th International Conference on Remote Sensing in Archeology, Duke University, October 2014.
48. Keynote, IEEE VR 2014, Minneapolis, MN, March 2014.
47. Keynote, BEAMING Workshop, Barcelona, Spain, June 2011, "Toward Improved Telepresence: BeingThere International Research Center for Telepresence and Telecollaboration...and related work."
46. Keynote, Japan VR, Tokyo, Japan, December 2010.
45. Keynote, ISMAR 2010, Seoul, Korea, October 2010.
44. Keynote, IEEE International Symposium on Multimedia (ISM2010), Taichung, Taiwan, December 2010, "Physical and Digital Media of Telepresence."
43. ISMAR Symposium Workshop, Orlando, Florida, October 2009.
42. AMI-ARCS Workshop, London, England, September 2009.
41. NAIST, Japan, July 2009.
40. Keynote, NOSSDAV, Williamsburg, Virginia, June 2009, "Experiences Building Telepresence Systems."
39. University of Pennsylvania, Franklin Institute Symposium, RoboFest: A Celebration of Robotics at the GRASP Laboratory, April 2009.
38. NASA Langley Research Center, Initiated the Speaker Series on Virtual Worlds, April 2009.
37. 9th Marconi Research Conference, Office Ergonomics Research Committee (OERC), Marconi Center, Marshall, CA, January 2009.
36. Keynote, Graphics Hardware 2008, Sarajevo, Bosnia and Herzegovina June 20, 2008.
35. Keynote, PROCAMS 2008, Los Angeles, CA, August 9, 2008.
34. Keynote (1 of 2), Eurographics 2004, Grenoble, France, September 2004.
33. J. Barkley Rosser Distinguished Lecture, University of Wisconsin, Madison, WI, March 2001.
32. Distinguished Lecture, National Science Foundation (NSF), February 2001.
31. Address, Sesquicentennial Anniversary, University of Rochester, October 2000 (1 of 2 in Computer Science).
30. Distinguished Lecture, Stanford University Department of Computer Science, June 2000.
29. Keynote Address, Virtual Reality Software and Technology (VRST '99), London, England, December 1999.
28. Keynote, 1st International Symposium on Mixed Reality (ISMR'99), Yokohama, Japan. Mar. 9, 1999.

27. University of Utah Department of Computer Science Distinguished Lecture, December 8, 1998.
26. Invited Paper, Advanced Multimedia Content Processing (AMCP'98), Osaka, Japan. Nov. 9, 1998.
25. Keynote, Advanced School for Computing and Imaging (ASCI'98), Lommel, Belgium. June 11, 1998.
24. Fraunhofer Inauguration Symposium, Virtual Environments Panel, Darmstadt, Germany, Oct. 30, 1997.
23. Keynote, Eurographics '97, Budapest, Hungary, September 6, 1997.
22. Keynote, Computer Graphics International'97, Hasselt, Belgium, June 25, 1997.
21. Keynote, 2nd Visualization Conference, Technicon, Haifa, Israel, June 30, 1996.
20. Keynote, 1995 Symposium on Interactive 3D Graphics, Monterey, CA, April 10-12, 1995.
19. University of Southern California Department of Computer Science Distinguished Lecture, Los Angeles, CA, Dec. 2, 1994.
18. Invited talk, The London VR User Show, VR in Medicine Workshop, London, England, September 1994.
17. IEEE EMBS 1994 International Summer School on Three-Dimensional Biomedical Imaging, to teach course on Virtual Reality in Medical Imaging, July 7-8, 1994.
16. Invited talk, ATR Workshop on Virtual Space Teleconferencing Systems, Kyoto, Japan, Dec. 3, 1993.
15. Invited talk, Computer Graphics International '92 (CGI '92), Tokyo, Japan, June 24, 1992.
14. NATO Advanced Research Workshop, Travemünde, Germany, June 26, 1990.
13. Keynote, First Conference on Visualization in Biomedical Computing, Atlanta, Georgia, May 23, 1990.
12. Keynote Address, Computer Graphics International, Leeds, UK, June 1989.
11. World Congress on Medical Physics and Biomedical Engineering, San Antonio, Texas, August 1988.
10. Member of panel on "Parallel Processing for Computer Vision and Display" at SIGGRAPH'88, August 1988.
9. Member of panel on "3D Imaging in Medicine: Pitfalls and Possible Remedies" at the National Computer Graphics Association annual conference, Anaheim, California, March 1988.
8. International Conference and Exhibition on Parallel Processing for Computer Vision and Display (sponsored by IBM - UK Labs, Univ. of Leeds, British Computer Society, Computer Graphics Society, Eurographics), University of Leeds, UK (January 1988).
7. NATO International Advanced Study Institute on Theoretical Foundations of Computer Graphics and CAD, Il Ciocco, Lucca, Italy (July 1987).
6. NATO International Advanced Study Institute on Mathematics and Computer Science in Medical Imaging, Il Ciocco, Lucca, Italy, (September 1986).
5. International Summer Institute (British Computer Society), State of the Art in Computer Graphics, Stirling, Scotland (June 1986).

4. NATO International Advanced Study Institute on Fundamental Algorithms for Computer Graphics, Ilkley, England (April 1985).

3. Qualitative Changes in the Future of Interactive Graphics. [COMPCON 1985](#), San Francisco, California (February 1985).

2. Eurographics'85, Nice, France (September 1985) (1 of 4 keynotes).

1. NATO International Advanced Study Institute on Microarchitecture of VLSI Computers, Urbino, Italy (July 1984).