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(54) **TRANSPARENT DISPLAY DEVICE**

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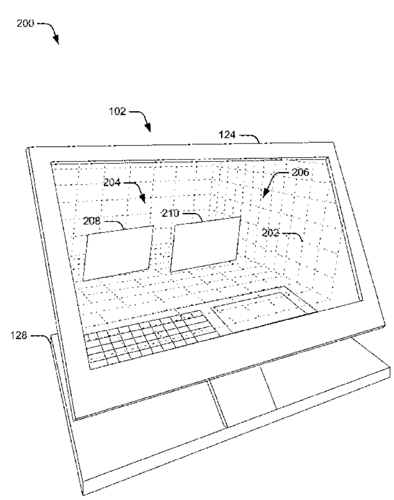
(57) **ABSTRACT**

This document describes techniques and apparatuses for implementing a transparent display device. A transparent display device includes a transparent or translucent screen to render images on the screen, and to render virtual objects that appear to be in a three-dimensional (3D) space behind the screen. The transparent display device also includes a hand tracker to sense movement of a user's hands to interact with one or more of the virtual objects, and to generate 3D-input based on the movement. The transparent or translucent screen enables the user to see the user's hands behind the screen as the user's hands interact with the one or more virtual objects. The transparent display device is controlled to modify the rendering of the images on the screen or the virtual objects behind the screen based on the 3D-input.

15 Claims, 11 Drawing Sheets



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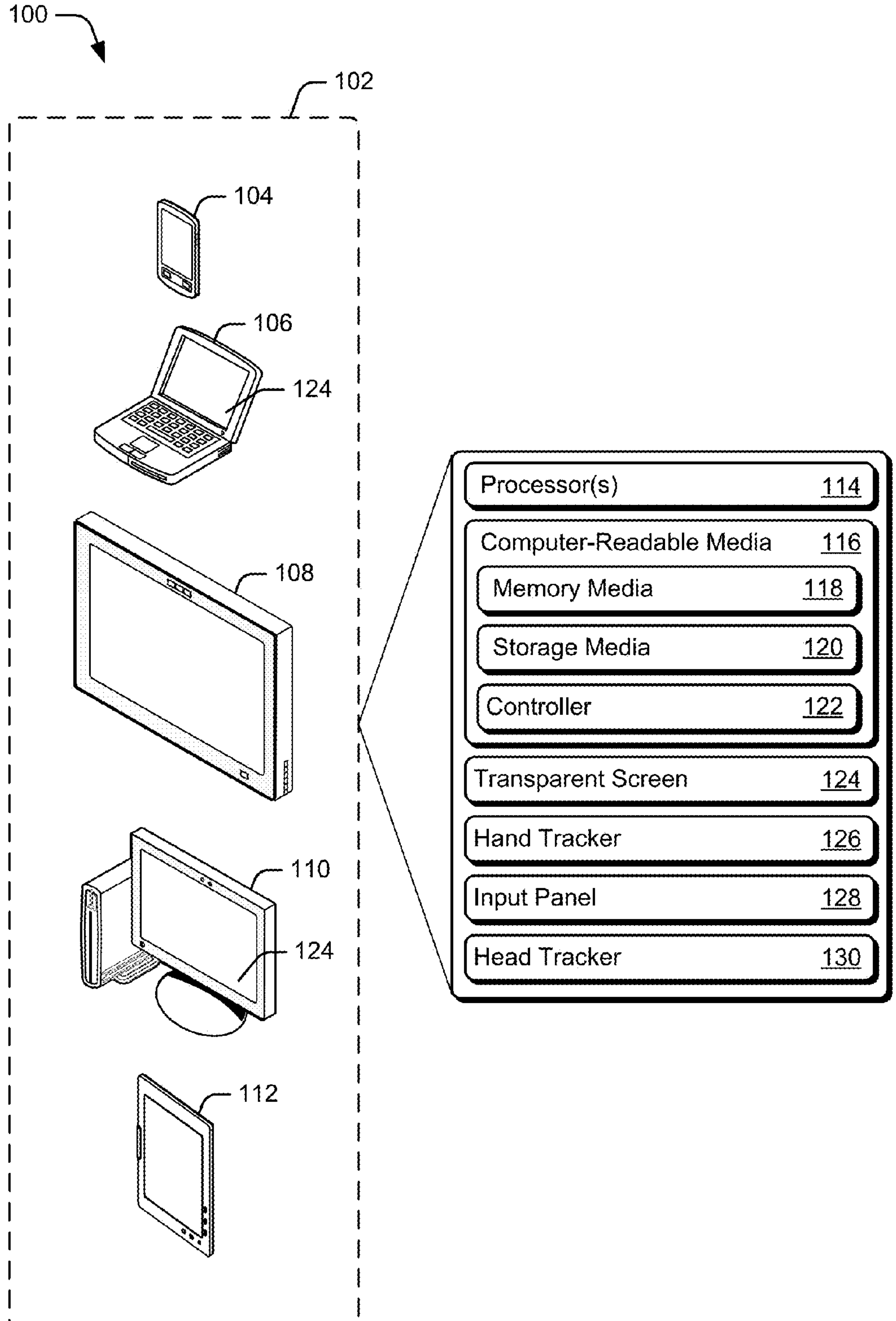
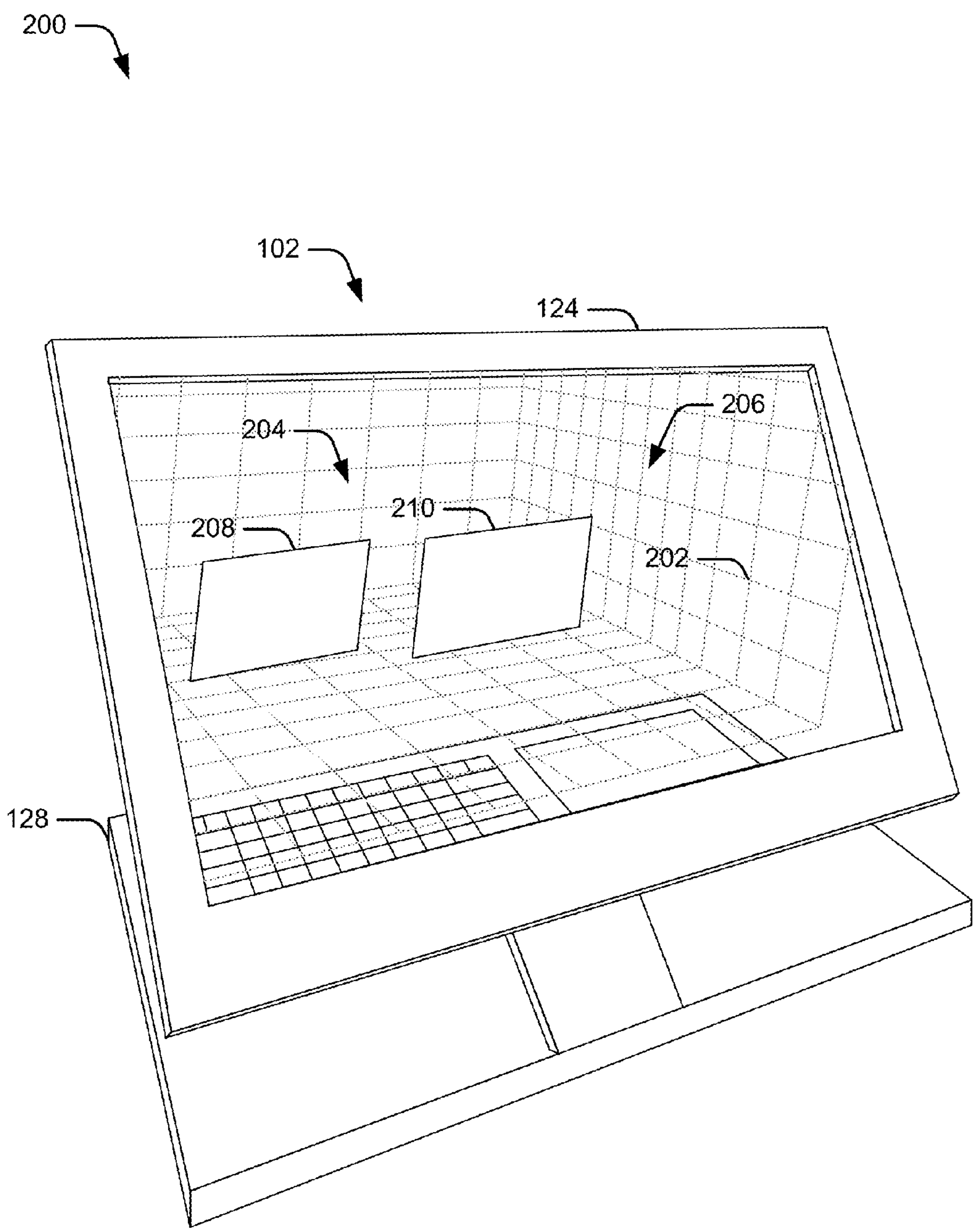

100
102
104
106
124
108
110
124
112
Processor(s) 114
Computer-Readable Media 116
Memory Media 118
Storage Media 120
Controller 122
Transparent Screen 124
Hand Tracker 126
Input Panel 128
Head Tracker 130

Fig. 1



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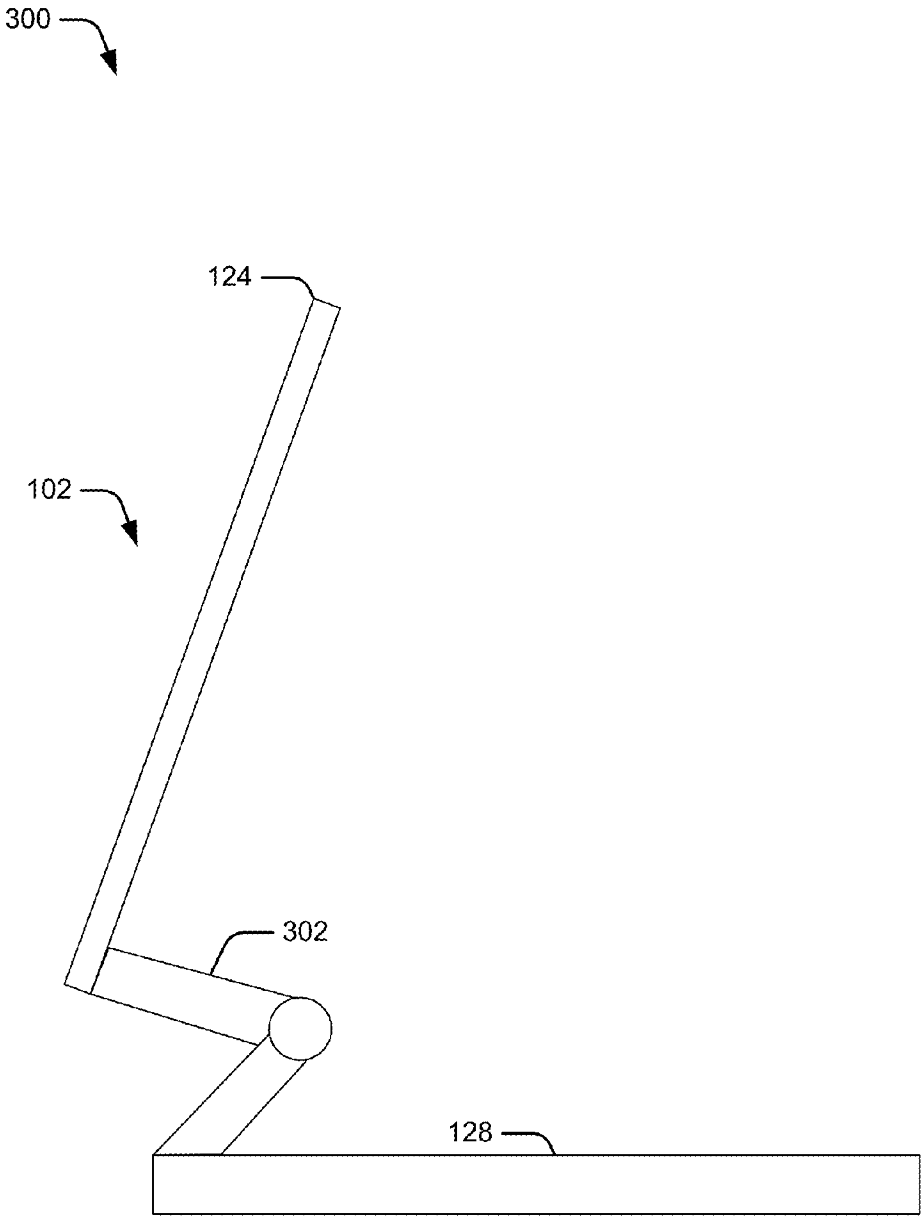
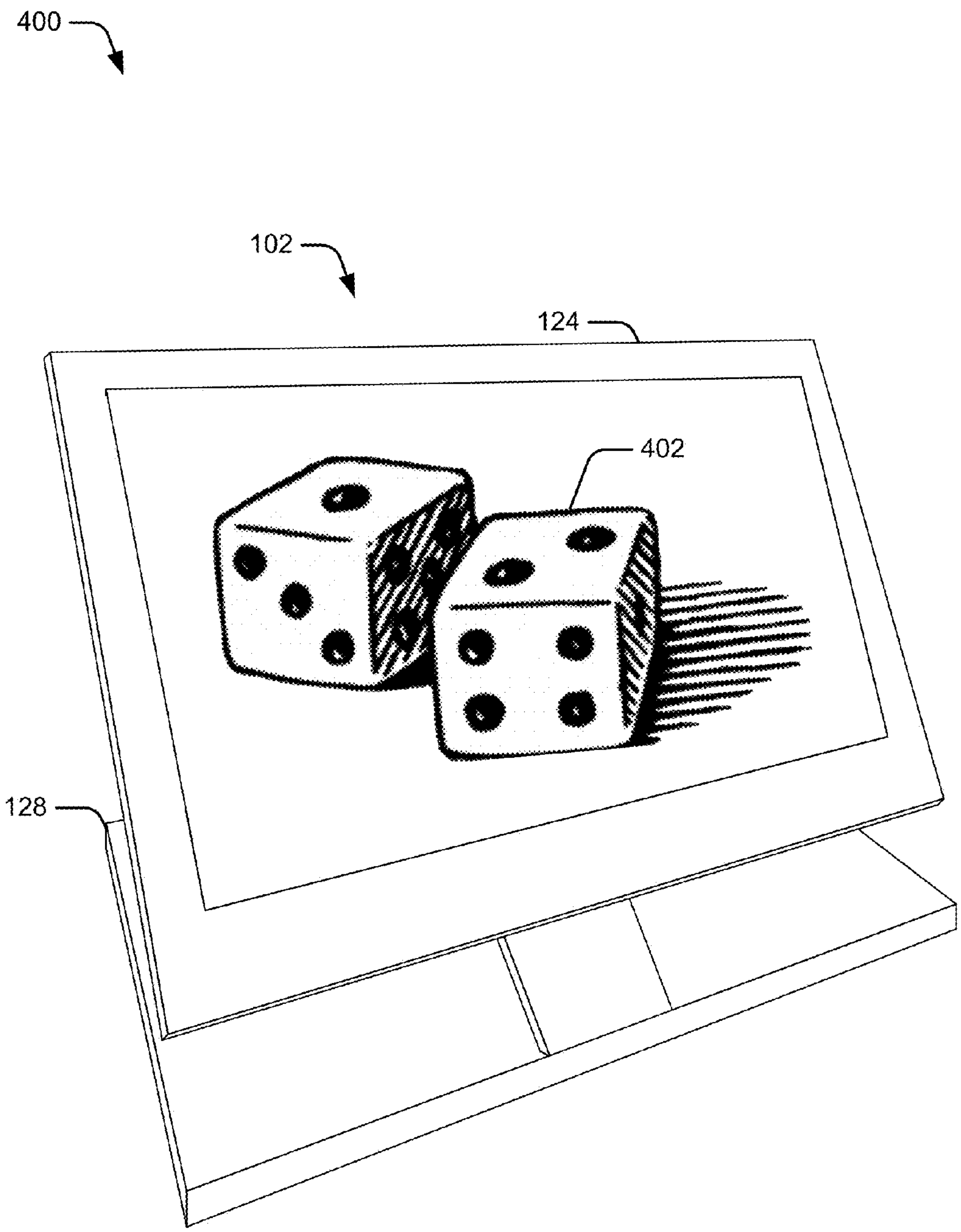


Fig. 3



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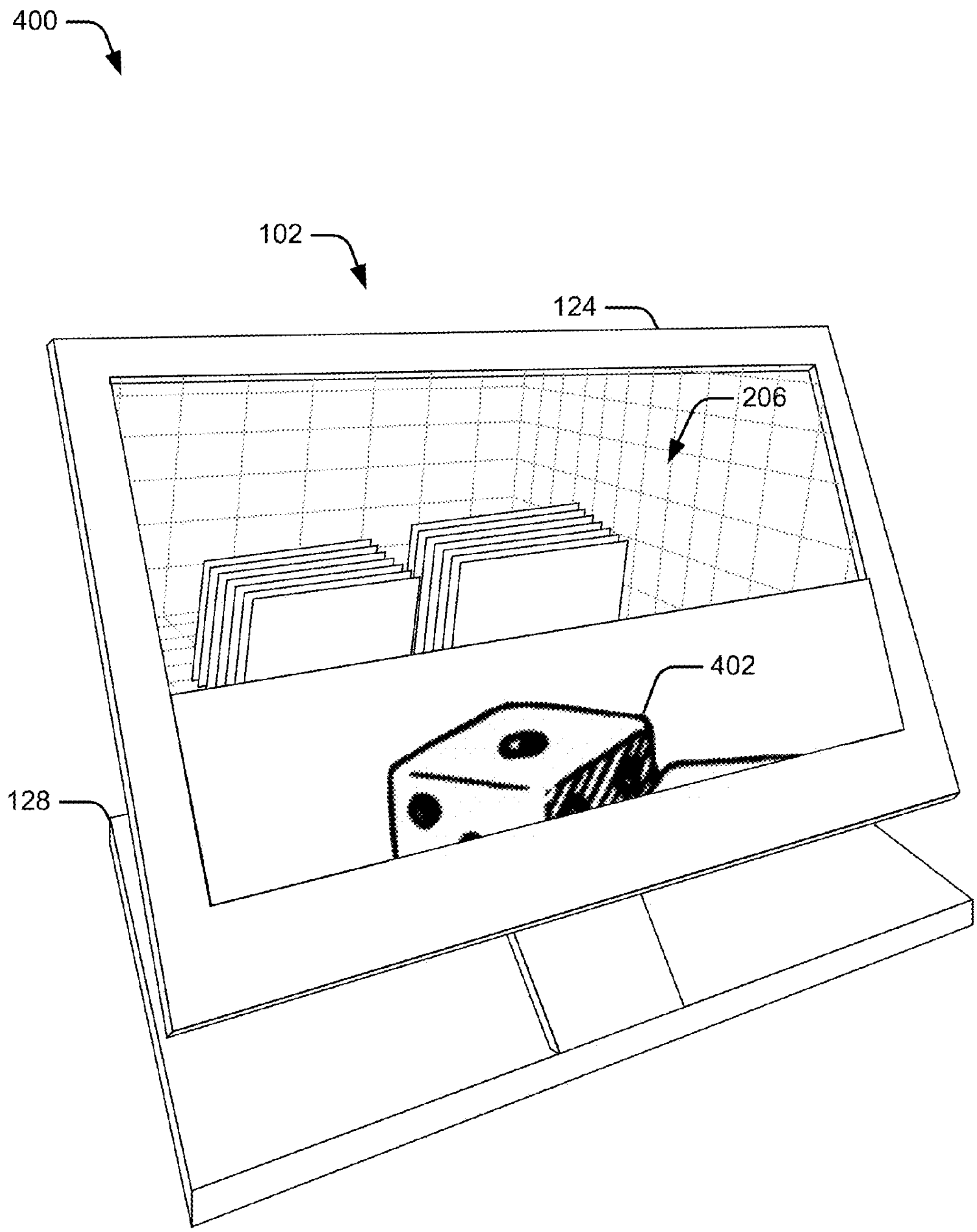


Fig. 4b

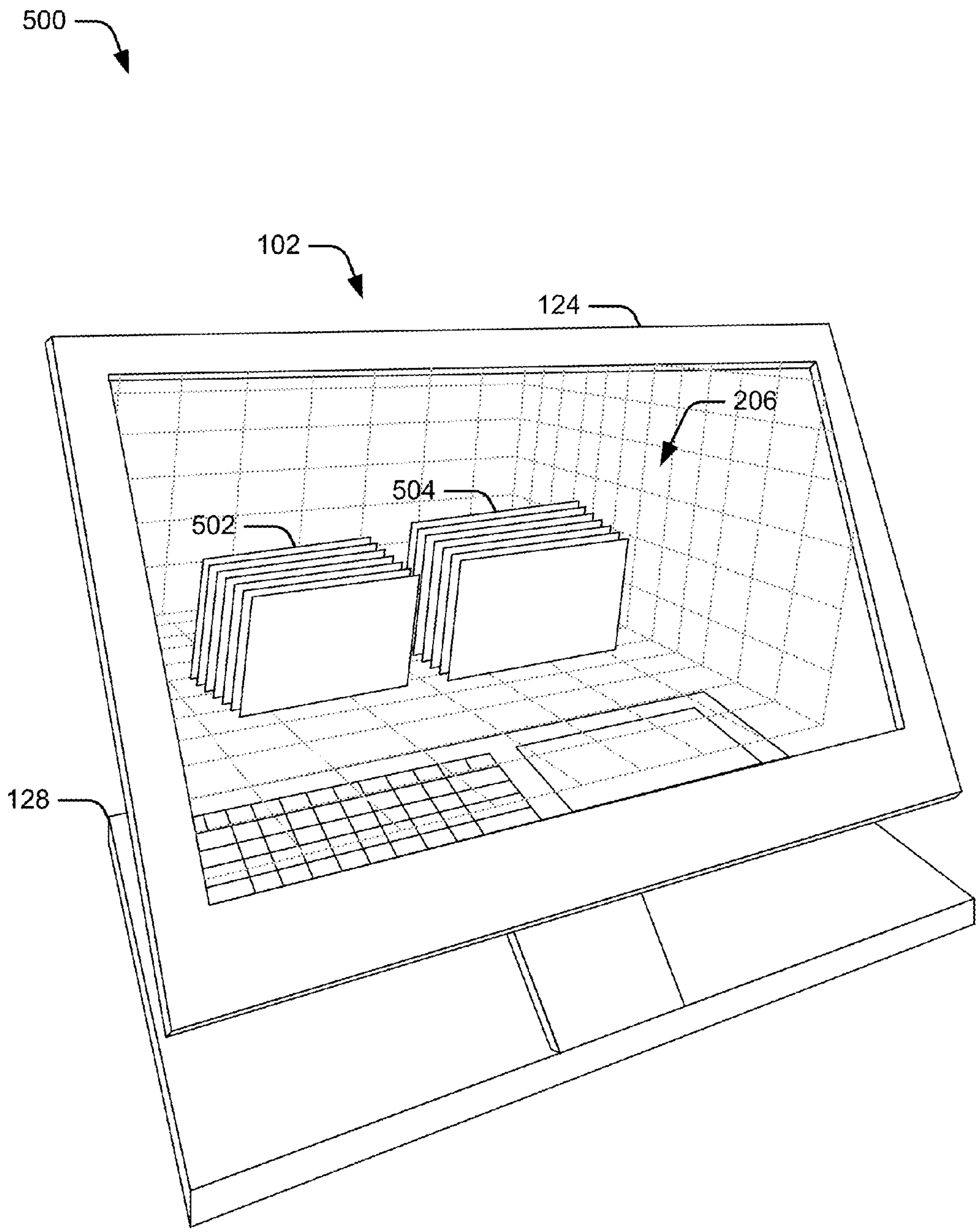


Fig. 5a

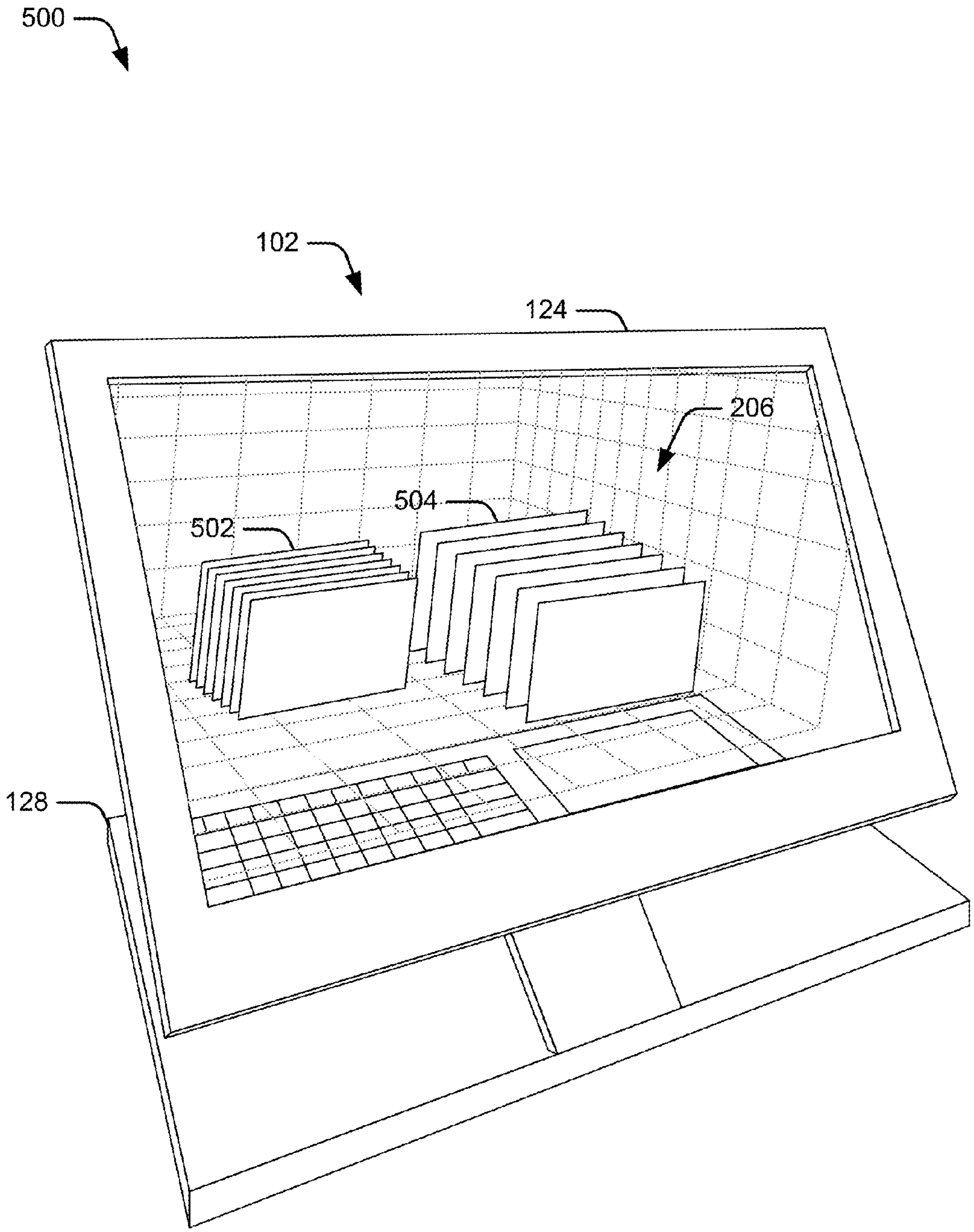


Fig. 5b

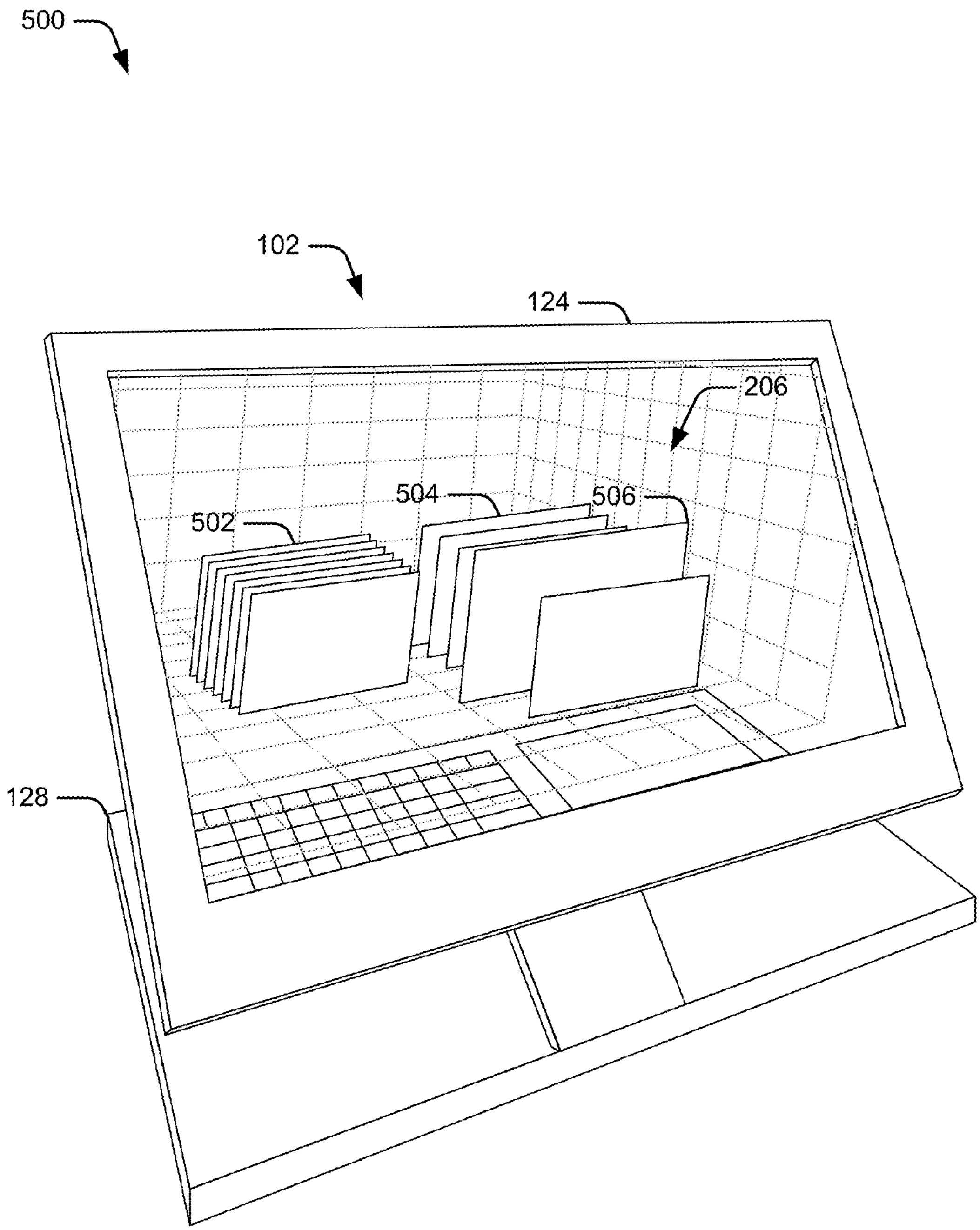


Fig. 5c

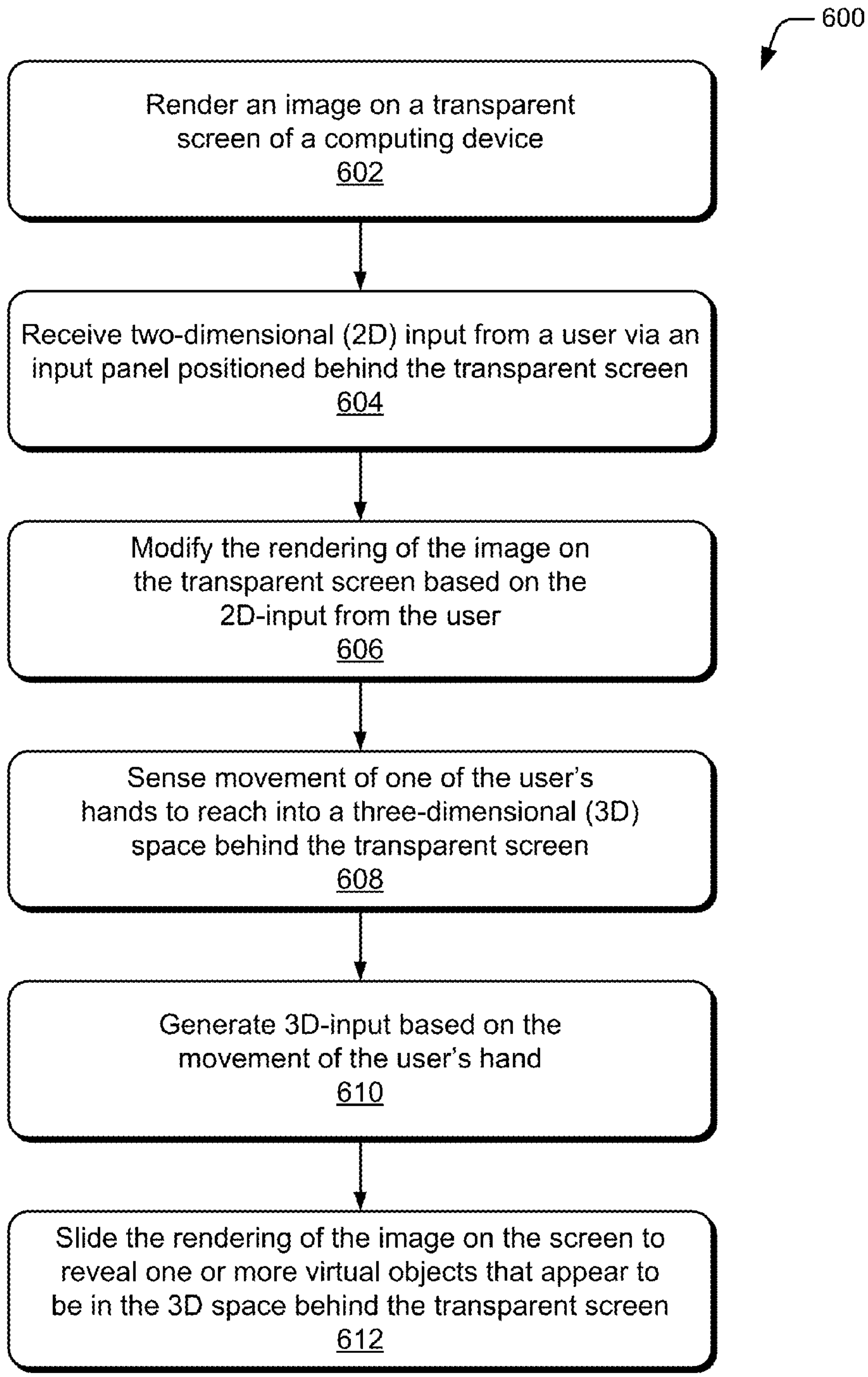

600
Render an image on a transparent screen of a computing device 602
Receive two-dimensional (2D) input from a user via an input panel positioned behind the transparent screen 604
Modify the rendering of the image on the transparent screen based on the 2D-input from the user 606
Sense movement of one of the user's hands to reach into a three-dimensional (3D) space behind the transparent screen 608
Generate 3D-input based on the movement of the user's hand 610
Slide the rendering of the image on the screen to reveal one or more virtual objects that appear to be in the 3D space behind the transparent screen 612

Fig. 6

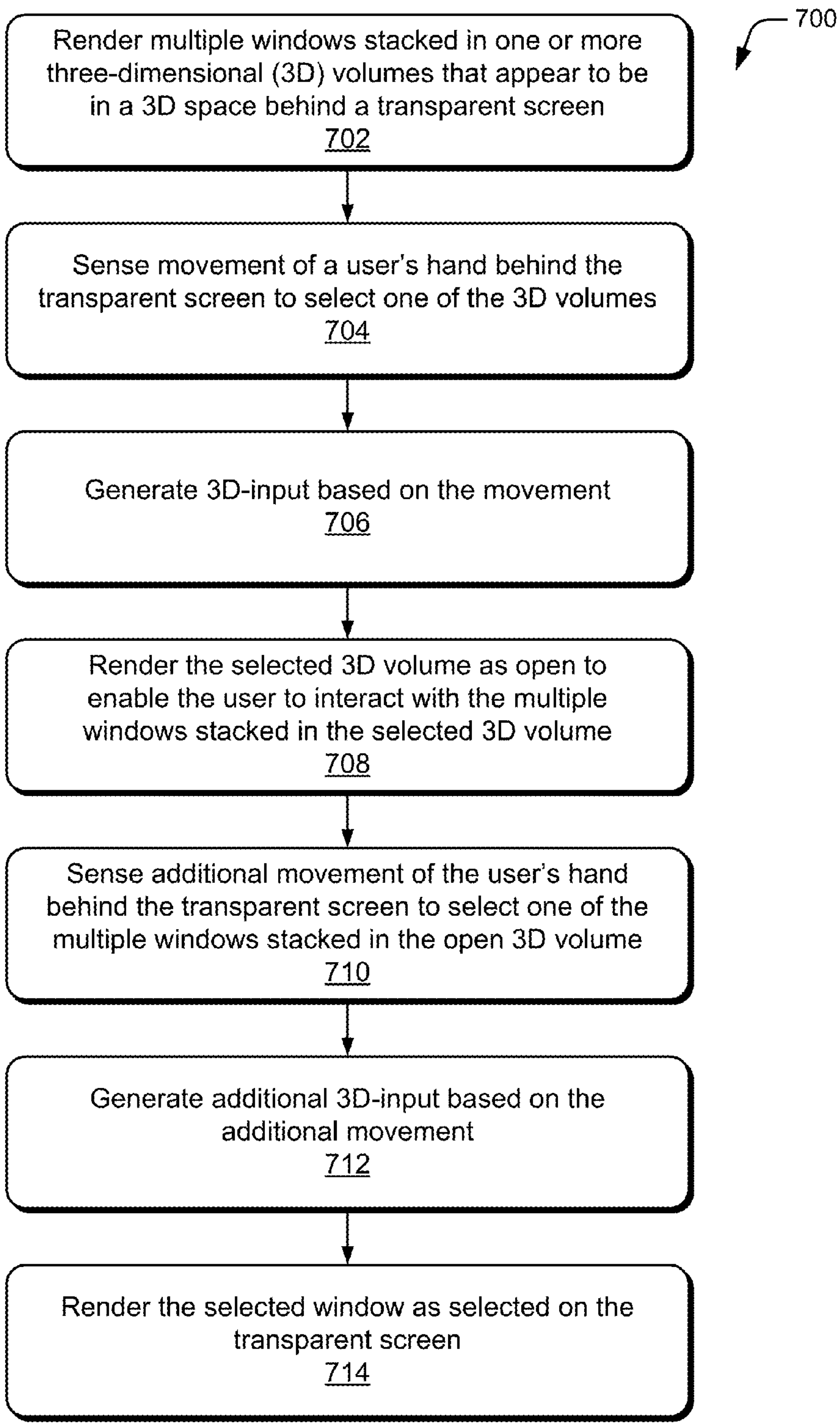
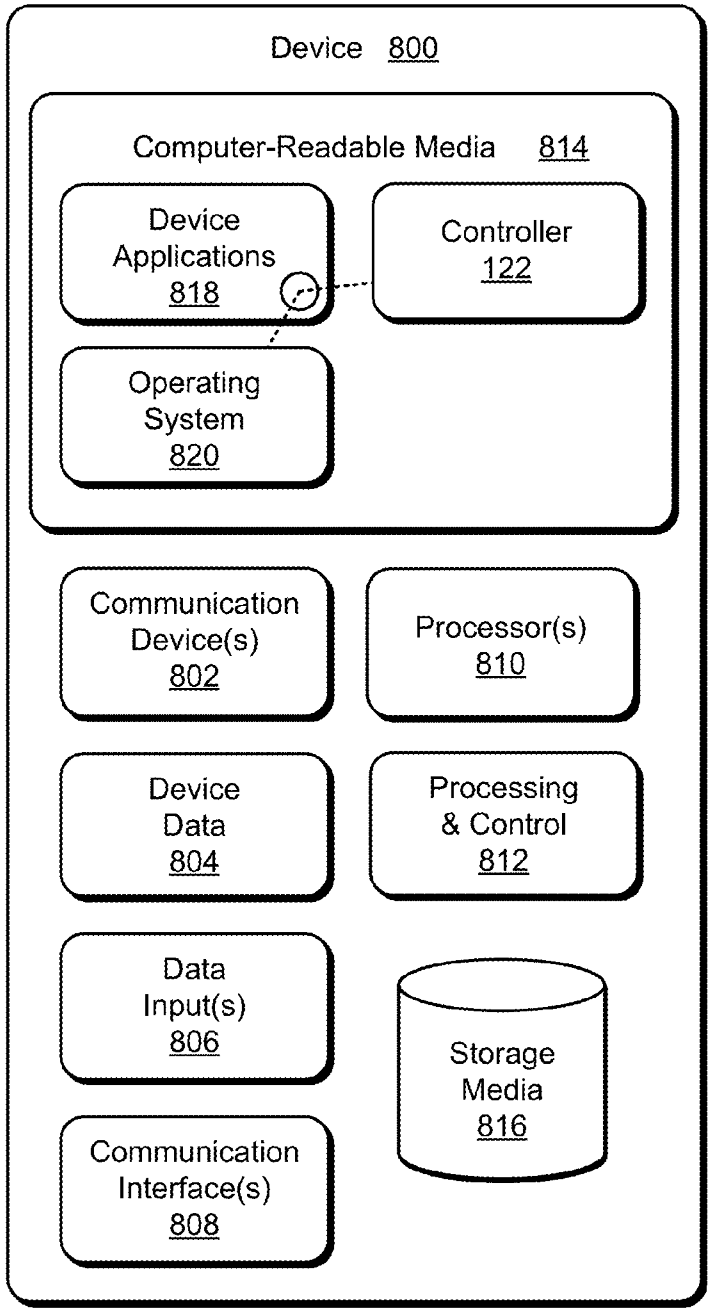

700
Render multiple windows stacked in one or more three-dimensional (3D) volumes that appear to be in a 3D space behind a transparent screen
702
Sense movement of a user's hand behind the transparent screen to select one of the 3D volumes
704
Generate 3D-input based on the movement
706
Render the selected 3D volume as open to enable the user to interact with the multiple windows stacked in the selected 3D volume
708
Sense additional movement of the user's hand behind the transparent screen to select one of the multiple windows stacked in the open 3D volume
710
Generate additional 3D-input based on the additional movement
712
Render the selected window as selected on the transparent screen
714

Fig. 7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Computer-Readable Media 814
Device Applications 818
Controller 122
Operating System 820
Communication Device(s) 802
Processor(s) 810
Device Data 804
Processing & Control 812
Data Input(s) 806
Storage Media 816
Communication Interface(s) 808

Fig. 8

TRANSPARENT DISPLAY DEVICE

BACKGROUND

In typical user interactions with windows management and content retrieval, windows of information (e.g., a web page, a word-processing document, and a picture) are concurrently projected on a two-dimensional (2D) screen. These windows of information can be visualized and navigated via a "multiple layers" view, but even in the multiple layers view some of the windows are hidden by a top layer of windows. Unlike on a physical desk where documents and objects can be scattered around, in a conventional computer desktop user interface there is no fixed position given to inactive windows behind a top active window. Thus, the user cannot cognitively register background windows to a specific position in the physical space, making it difficult and inefficient for the user to choose among different windows.

SUMMARY

This document describes techniques and apparatuses for implementing a transparent display device. A transparent display device includes a transparent or translucent screen to render images on the screen, and to render virtual objects that appear to be in a three-dimensional (3D) space behind the screen. The transparent display device also includes a hand tracker to sense movement of a user's hands to interact with one or more of the virtual objects, and to generate 3D-input based on the movement. The transparent or translucent screen enables the user to see the user's hands behind the screen as the user's hands interact with the one or more virtual objects. The transparent display device is controlled to modify the rendering of the images on the screen or the virtual objects behind the screen based on the 3D-input.

This summary is provided to introduce simplified concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of techniques and apparatuses for implementing a transparent display device are described with reference to the following drawings. The same numbers are used throughout the drawings to reference like features and components:

FIG. **1** illustrates an example environment in which a transparent display device can be implemented.

FIG. **2** illustrates a detailed example of a transparent display device.

FIG. **3** illustrates a detailed example of a side-view of a transparent display device.

FIG. **4***a* illustrates a detailed example of a transparent display device rendering a 2D image.

FIG. **4***b* illustrates a detailed example of a transparent display device implementing a sliding door technique.

FIG. **5***a* illustrates a detailed example of a transparent display device rendering multiple windows stacked in 3D volumes.

FIG. **5***b* illustrates another detailed example of a transparent display device rendering multiple windows stacked in 3D volumes.

FIG. **5***c* illustrates another detailed example of a transparent display device rendering multiple windows stacked in 3D volumes.

FIG. **6** illustrates an example method implemented by a transparent display device.

FIG. **7** illustrates an additional example method implemented by a transparent display device.

FIG. **8** illustrates an example device in which techniques for a transparent display device can be implemented.

DETAILED DESCRIPTION

Overview

This document describes techniques and apparatuses for implementing a transparent display device. A transparent display device includes a transparent or translucent screen to render images on the screen, and to render virtual objects that appear to be in a three-dimensional (3D) space behind the screen. The transparent display device also includes a hand tracker to sense movement of a user's hands to interact with one or more of the virtual objects, and to generate 3D-input based on the movement. The transparent or translucent screen enables the user to see the user's hands behind the screen as the user's hands interact with the one or more virtual objects. The transparent display device is controlled to modify the rendering of the images on the screen or the virtual objects behind the screen based on the 3D-input.

Example Environment

FIG. **1** is an illustration of an example environment **100** in which a transparent display device can be implemented. Environment **100** includes a transparent display device **102**, which is illustrated, by way of example and not limitation, as one of a smart phone **104**, a laptop computer **106**, a television device **108**, a desktop computer **110**, or a tablet computer **112**.

Transparent display device **102** includes processor(s) **114** and computer-readable media **116**, which includes memory media **118** and storage media **120**. Applications and/or an operating system (not shown) embodied as computer-readable instructions on computer-readable media **116** can be executed by processor(s) **114** to provide some or all of the functionalities described herein. Computer-readable media also includes a controller **122**. How controller **122** is implemented and used varies, and is described in further detail below.

Transparent display device **102** also includes a transparent screen **124** that is configured to render images on the screen, and to render virtual objects that appear to be in a three-dimensional (3D) space behind the screen. While referred to as a transparent screen herein, transparent screen **124** can be implemented as either a transparent screen or as a semi-transparent or translucent screen. Transparent screen **124** can be implemented to render two-dimensional (2D) images and/or 3D images. For example, in some embodiments transparent screen **124** can render 2D images that are typically displayed on a 2D screen, such as a word-processing document, a PDF document, 2D pictures, or 2D video, to name just a few. Alternately or additionally, transparent screen **124** can render 3D images that can be viewed with or without eye glasses. For example, in some cases transparent screen **124** can be implemented to render 3D images using an optic such as a wedge that can be viewed by a user without the use of eye glasses. In other cases, transparent screen **124** can render 3D images that can be viewed by a user wearing eye glasses, such as shutter glasses, polarized glasses, or lenticular glassless displays, to name just a few.

As described in more detail below, transparent display device **102** can be controlled to transition between rendering the 2D images and/or 3D images on the transparent screen and rendering the virtual objects that appear to be in the 3D space behind the transparent screen. As discussed in more detail below, the images displayed on the transparent screen may be opaque, or partially opaque, to cover the virtual objects, but can be controlled to slide away to reveal the virtual objects displayed behind transparent screen **124**.

In various embodiments, transparent screen **124** may be configured as a 2D or 3D flat-panel electronic display, such as a high-resolution liquid crystal display (LCD). Transparent screen **124** can be physically coupled to transparent display device **102** or implemented separate from transparent display device **102**. For example, transparent screen **124** is physically coupled to laptop computer **106** but is implemented separate from desktop computer **110**.

FIG. **2** illustrates a detailed example **200** of transparent display device **102** in accordance with one embodiment. In this example, transparent screen **124** uses a grid **202** to render virtual objects **204** that appear to a user as if the virtual objects are rendered in a 3D space **206** behind transparent screen **124**. It is to be appreciated that grid **202** may not be viewable by the user, but is used by transparent display device **102** to render the virtual objects so that they appear to be positioned in the 3D space behind transparent screen **124**. In this example, virtual objects **204** are depicted as windows **208** and **210**. Windows **208** and **210** can each represent a page associated with an application, such a web browser page, a word-processing document, or a PDF file. It is to be noted, however, that transparent screen **124** can render any type of virtual object in 3D space **206**.

By rendering virtual objects **204** that appear to be in 3D space **206**, transparent screen **124** enables the user to manipulate virtual objects **204** using one or both of the user's hands. It is to be noted that transparent screen **124** is transparent and thus enables the user to see the user's actual hands (as opposed to a virtual rendering of the user's hands) as the user manipulates virtual objects **204**. Thus, transparent display device **102** leverages the user's spatial understanding and kinesthetic memory to access and manipulate virtual objects **204** in 3D space **206**.

Transparent display device **102** also includes a hand tracker **126**, which is configured to sense movement of the user's hands, such as gestures, to interact with one or more of virtual objects **204** in 3D space **206** behind transparent screen **124**, and to generate 3D-input based on the movement. In an embodiment, hand tracker **126** is implemented as a depth camera that senses a 3D position, movement, and/or pose of each of the user's hands. As discussed in more detail below, controller **122** is configured to receive the 3D-input from hand tracker **126**, and to modify the rendering of the 2D or 3D images on transparent screen **124** (not illustrated in FIG. **2**) or virtual objects **204** in 3D space **206**, based on the 3D-input.

In some embodiments, transparent display device **102** also includes an input panel **128** that is positioned behind transparent screen **124** and is configured to receive 2D-input, such as touch-input and/or key-input, from the user. In this example, as opposed to the conventional design of a laptop where the laptop screen is attached to the trailing edge (far from the user) of the keyboard panel, transparent screen **124** is coupled to a near-edge (edge closer to the user) of input panel **128**. Input panel **128** may include any combination of a keyboard configured to receive key-input or a mouse, track pad, touch pad, or other 2D sensing device configured to receive touch-input. By being positioned behind transparent screen **124**, input panel **128** enables the user to reach behind the transparent screen to use the input panel.

It is to be noted that because transparent screen **124** is transparent or translucent, the user may be able to see input panel **128** as the key-input or touch-input is entered. For example, when input panel **128** includes a keyboard, the user may be able to see both the keys of the keyboard and the user's fingers through the transparent screen as the user types on the keyboard. Further, the position of input panel **128** behind transparent screen **124** enables the user to easily transition between using input panel **128** (e.g., for typing) to manipulating virtual objects **204** in 3D space **206**. For example, if the user is typing on the keyboard of input panel **128**, the user can simply raise one or both of the user's hands in order to manipulate or interact with virtual objects **204**.

FIG. **3** illustrates a detailed example **300** of a side view of the transparent display device illustrated in FIG. **2**. In this example, transparent screen **124** is coupled to input panel **128** via a foldable hinge **302**. Foldable hinge **302** enables transparent screen **124** to fold on top of input panel **128** to close transparent display device **102**. Foldable hinge **302**, in this example, is attached to the middle of both transparent screen **124** and input panel **128**, which enables the user to comfortably place the user's hands behind the transparent screen to use input panel **128**.

While examples **200** and **300** illustrate transparent screen **124** as being physically attached to input panel **128**, alternately input panel **128** may be positioned behind transparent screen **124** without being physically connected to the transparent screen. For example, transparent screen **124** may be implemented as a desktop monitor, and input panel **128** may be implemented as a keyboard and/or mouse that can be placed behind the desktop monitor.

In some embodiments, transparent display device **102** also includes a head tracker **130** that is configured to track a position of the user's head or eyes relative to transparent screen **124**. Controller **122** is configured to render, or modify the rendering of, virtual objects **204** based on the position of the user's head or eyes so that the virtual objects appear to be in 3D space **206**. Head tracker **130** can be implemented as a 3D camera or as an array of cameras. In various embodiments, both hand tracker **126** and head tracker **130** may be implemented as short-range depth cameras. In example **200**, hand tracker **126** and head tracker **130** can be mounted to transparent screen **124**, making transparent display device **102** truly a mobile device. Thus, controller **122** controls transparent display device **102** to render virtual objects **204** on transparent screen **124** that are updated in real time based on the user's eye or head position, such that the user perceives that the virtual objects are displayed behind the transparent screen at a programmed set position.

FIG. **4*a*** illustrates a detailed example **400** of transparent display device **102** in accordance with one embodiment. In this example, transparent display device **102** renders a 2D or 3D image **402** on the surface of transparent screen **124**. Image **402** may be any type of 2D image that can be displayed on a conventional 2D screen, or 3D image that can be displayed on a 3D screen. In this example, image **402** is a picture of a pair of dice. Note, however, that transparent screen **124** may display image **402** as a web browser window, a word-processing document, a picture, or a PDF file, to name just a few examples. The user can interact with image **402** using input panel **128**. For example, the user can type on the keyboard of input panel **128** to write an email message, or use a track pad or mouse of the input panel to modify the size of image **402**.

Transparent display device **102** receives the 2D-input from the user via input panel **128**, and controller **122** controls the transparent display device to modify the rendering of image **402** on the transparent screen based on the 2D-input.

In various embodiments, transparent display device **102** employs a "sliding door" technique when the user raises one or both of the user's hands off of input panel **128** to reach into the 3D space behind transparent screen **124**. Consider for example that in FIG. **4***b* the user raises one of the user's hands off of input panel **128** to reach into 3D space **206**. Hand tracker **126** senses this movement, and generates 3D-input that is received by controller **122**. Controller **122** then controls transparent screen **124** to slide the rendering of image **402** to reveal one or more virtual objects that appear to be in 3D space **206** behind transparent screen **124**. In this example, the rendering of image **402** is controlled to slide down transparent screen **124**. Alternately, however, the rendering of image **402** can be controlled to slide up transparent screen **124** or to slide across (e.g., slide left across or slide right across) transparent screen **124**. In some embodiments, image **402** can also or instead be controlled to fade, dissolve, or transition in any other way to reveal the virtual objects in 3D space **206**.

After the rendering of the image on the screen slides to reveal the virtual objects, the user can interact with the virtual objects using one or both of the user's hands. In an embodiment, when the user lowers the user's hand to go back to entering input using input panel **128**, hand tracker **126** senses the movement of the user's hand to reach towards the input panel and generates 3D-input that is received by controller **122**. Controller **122** then controls transparent screen **124** to slide the rendering of image **402** to cover the one or more virtual objects (e.g., slide back up, back down, back left, or back right). It is to be appreciated, therefore, that the sliding door technique enables the user to easily transition between entering 2D-input via input panel **128** and entering 3D-input using the user's hands in 3D space **206**.

Transparent display device **102** enables the user to interact with virtual objects that appear to be in the 3D space behind transparent screen **124** in a variety of different ways. In an embodiment, transparent display device **102** employs a "virtual cabinet" technique to cause transparent screen **124** to render multiple windows stacked in one or more 3D volumes that appear to be in 3D space **206**. For example, FIG. **5***a* illustrates another detailed example **500** of transparent display device **102** in accordance with one embodiment. In this example, transparent screen **124** renders multiple windows stacked in 3D volumes **502** and **504** that appear to be in 3D space **206**. Each of the windows stacked in 3D volumes **502** and **504** can represent a page associated with an application, such a web browser page, a word-processing document, or a PDF file.

Transparent display device **102** enables the user to interact with 3D volumes **502** and **504** in 3D space **206** by positioning one or both of the user's hands near the 3D volumes in 3D space **206**. Hand tracker **126** is configured to sense movement of the user's hand behind the transparent screen to select one of 3D volumes **502** or **504**, and to generate 3D-input based on the movement. Responsive to receiving the 3D-input from hand tracker **126**, controller **122** controls transparent display device **102** to render the selected 3D volume as open on transparent screen **124** to enable the user to interact with the multiple windows stacked in the selected 3D volume.

It is to be noted that rendering the 3D volume as open enables the user to more easily view the multiple windows in the selected 3D volume. For example, in FIG. **5***a*, 3D volumes **502** and **504** are rendered as closed making it difficult for the user to see, or select, each individual window in 3D volumes **502** and **504**. In FIG. **5***b*, if the user moves the user's hand to select 3D volume **504**, the movement of the user's hand is sensed by hand tracker **126** which generates 3D-input that is received by controller **122**. Controller **122** then controls transparent screen **124** to modify the rendering of 3D volume **504** to render 3D volume **504** as open. For example, as illustrated in FIG. **5***b*, the windows in 3D volume **504** are open, or spread out, as compared to the windows in 3D volume **502**. Opening the 3D volume enables the user to more easily see, and thus more easily interact with, each of the windows in 3D volume **504**.

Transparent display device **102** enables the user to interact with the multiple windows in open 3D volume **504** by positioning one or both of the user's hands near the multiple windows in 3D space **206**. For example, in FIG. **5***c* if the user moves the user's hand to one of the multiple windows **506** in 3D volume **504**, the movement of the user's hand is sensed by hand tracker **126** which generates 3D-input. Controller **122** receives the 3D-input and controls transparent screen **124** to render selected window **506** as selected. For example, in FIG. **5***c* controller **122** controls transparent display device **102** to render window **506** as selected by causing window **506** to "pop up" out of 3D volume **504**. Popping window **506** out of 3D volume **504** enables the user to see more information regarding window **506**. The user can then select window **506**, such as by pinching the window, to display the window as a 2D image on transparent screen **124**.

In various embodiments, transparent display device **102** is configured to provide feedback on transparent screen **124** based on the location of the user's hands in 3D space **206**. In one embodiment, for example, controller **122** alters the color of the transparent screen based on the location of the user's hand. In FIG. **5***c*, for example, controller **122** can cause an area around window **506** to glow as the user reaches the user's hand towards window **506**. This feedback helps the user interact with the windows in 3D space **206**. In another embodiment, a 3D cursor can be displayed which is mapped to a position of the user's hand or finger. In another embodiment, controller **122** can cause a part of the screen to not be rendered based on the location of the user's hand to render an illusion of the user's hand being in front of a virtual object.

Example Methods

FIG. **6** is a flow diagram depicting an example method **600** implemented by a transparent display device. Block **602** renders an image on a transparent screen of a computing device. For example, transparent display device **102** (FIG. **1**) renders a 2D or a 3D image on transparent screen **124** of the transparent display device.

Block **604** receives 2D-input from a user via an input panel positioned behind the transparent screen. For example, transparent display device **102** receives 2D-input from a user via input panel **128** that is positioned behind transparent screen **124**. Input panel **128** may include any combination of a keyboard configured to receive key-input, or a mouse, track pad, or touch pad configured to receive touch-input.

Block **606** modifies the rendering of the image based on the 2D-input from the user. For example, controller **122** controls transparent display device **102** to modify the rendering of the 2D or 3D image on transparent screen **124** based on the 2D-input received from the user via input panel **128**.

Block **608** senses movement of one of the user's hands to reach into a 3D space behind the transparent screen, and block **610** generates 3D-input based on the movement of the user's hand. For example, hand tracker **126** senses movement of one or both of the user's hand to reach into 3D space **206** (FIG. **2**) behind transparent screen **124**, and generates 3D-input based on the movement.

Block **612** slides the rendering of the image on the screen to reveal one or more virtual objects that appear to be in the 3D-space behind the transparent screen responsive to receiving the 3D-input. For example, controller **122** controls transparent display device **102** to slide the rendering of the 2D or 3D image displayed on transparent screen **124** to reveal one or more virtual objects that appear to be in 3D space **206** behind the transparent screen responsive to receiving the 3D-input from hand tracker **126**.

FIG. **7** is a flow diagram depicting an additional example method **700** implemented by a transparent display device. Block **702** renders multiple windows stacked in one or more 3D volumes that appear to be in a 3D space behind a transparent screen. For example, transparent display device **102** (FIG. **1**) renders multiple windows stacked in one or more 3D volumes, such as 3D volumes **502** and **504** (FIG. **5***a*), that appear to be in 3D space **206** behind transparent screen **124**.

Block **704** senses movement of a user's hand behind the transparent screen to select one of the 3D volumes, and block **706** generates 3D-input based on the movement. For example, hand tracker **126** senses movement of the user's hand behind transparent screen **124** to select 3D volume **504**, and generates 3D-input based on the movement.

Block **708** renders the selected 3D volume as open to enable the user to interact with the multiple windows stacked in the selected 3D volume. For example, controller **122** controls transparent display device **102** to render selected 3D volume **504** (FIG. **5***b*) as open on transparent screen **124** to enable the user to interact with the multiple windows stacked in selected 3D volume **504**.

Block **710** senses additional movement of the user's hand behind the transparent screen to select one of the multiple windows stacked in the open 3D volume, and block **712** generates additional 3D-input based on the additional movement. For example, hand tracker **126** senses additional movement of the user's hand behind transparent screen **124** to select window **506** (FIG. **5***c*) stacked in open 3D volume **504**, and generates additional 3D-input based on the additional movement.

Block **714** renders the selected window as selected on the transparent screen. For example, controller **122** controls transparent display device **102** to render selected window **506** as selected on transparent screen **124**, such as by causing window **506** to pop out of 3D volume **504**.

Example Device

FIG. **8** illustrates various components of example device **800** that can be implemented as any type of client, server, and/or display device as described with reference to the previous FIGS. **1-7** to implement techniques enabling a transparent display device. In embodiments, device **800** can be implemented as one or a combination of a wired and/or wireless device, as a form of flat panel display, television, television client device (e.g., television set-top box, digital video recorder (DVR), etc.), consumer device, computer device, server device, portable computer device, user device, communication device, video processing and/or rendering device, appliance device, gaming device, electronic device, and/or as another type of device. Device **800** may also be associated with a viewer (e.g., a person or user) and/or an entity that operates the device such that a device describes logical devices that include users, software, firmware, and/or a combination of devices.

Device **800** includes communication devices **802** that enable wired and/or wireless communication of device data **804** (e.g., received data, data that is being received, data scheduled for broadcast, data packets of the data, etc.). The device data **804** or other device content can include configuration settings of the device, media content stored on the device, and/or information associated with a user of the device. Media content stored on device **800** can include any type of audio, video, and/or image data. Device **800** includes one or more data inputs **806** via which any type of data, media content, and/or inputs can be received, such as user-selectable inputs, messages, music, television media content, recorded video content, and any other type of audio, video, and/or image data received from any content and/or data source.

Device **800** also includes communication interfaces **808**, which can be implemented as any one or more of a serial and/or parallel interface, a wireless interface, any type of network interface, a modem, and as any other type of communication interface. The communication interfaces **808** provide a connection and/or communication links between device **800** and a communication network by which other electronic, computing, and communication devices communicate data with device **800**.

Device **800** includes one or more processors **810** (e.g., any of microprocessors, controllers, and the like), which process various computer-executable instructions to control the operation of device **800** and to enable techniques for implementing a transparent display device. Alternatively or in addition, device **800** can be implemented with any one or combination of hardware, firmware, a system-on-chip (SoC), or fixed logic circuitry that is implemented in connection with processing and control circuits which are generally identified at **812**. Although not shown, device **800** can include a system bus or data transfer system that couples the various components within the device. A system bus can include any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures.

Device **800** also includes computer-readable storage media **814**, such as one or more memory devices that enable persistent and/or non-transitory data storage (i.e., in contrast to mere signal transmission), examples of which include random access memory (RAM), non-volatile memory (e.g., any one or more of a read-only memory (ROM), non-volatile RAM (NVRAM), flash memory, EPROM, EEPROM, etc.), and a disk storage device. A disk storage device may be implemented as any type of magnetic or optical storage device, such as a hard disk drive, a recordable and/or rewriteable compact disc (CD), any type of a digital versatile disc (DVD), and the like. Device **800** can also include a mass storage media device **816**.

Computer-readable storage media **814** provides data storage mechanisms to store the device data **804**, as well as various device applications **818** and any other types of information and/or data related to operational aspects of device **800**. For example, an operating system **820** can be maintained as a computer application with the computer-readable storage media **814** and executed on processors **810**. The device applications **818** may include a device manager, such as any form of a control application, software application, signal-processing and control module, code that is native to a particular device, a hardware abstraction layer for a particular device, and so on.

The device applications **818** also include any system components or modules to implement techniques using or enabling a transparent display device. In this example, the device applications **818** can include controller **122** for controlling a transparent display device.

CONCLUSION

This document describes various apparatuses and techniques for implementing a transparent display device. Although the invention has been described in language specific to structural features and/or methodological acts, it is to be understood that the invention defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed invention.

What is claimed is:

1. A transparent display device comprising:

a transparent screen configured to render two-dimensional (2D) images on the transparent screen, and to render one or more virtual three-dimensional (3D) volumes comprising stacked windows that appear in a 3D space behind the transparent screen, the transparent screen configured to employ a grid to cause the 3D volumes to appear to be in 3D space, each window of the stacked windows selectable to launch, an associated application, file, or page, each of the one or more virtual 3D volumes initially rendered in a closed state;

a hand tracker configured to sense movement of a user's hands and to enable a user interaction with the one or more virtual 3D volumes in the 3D space behind the transparent screen;

a processor in communication with the transparent screen and the hand tracker, the processor configured to:

first select a virtual 3D volume of the one or more virtual 3D volumes based on the movement; and

second select a window of the selected virtual 3D volume;

a controller configured to:

render, responsive to the first selection, the windows of the selected virtual 3D volume in an open state; and

transition, responsive to the second selection, the transparent screen from a 3D display mode to a 2D display mode by sliding the application, file, or page associated with the selected window in 2D on the transparent screen while simultaneously ceasing to render the one or more virtual 3D volumes to create an appearance of covering the one or more virtual 3D volumes.

2. The transparent display device of claim **1**, wherein the transparent screen is configured to be transparent when rendering the one or more 3D volumes that appear in a 3D space behind the transparent screen and the transparent screen is configured to be at least partially opaque when rendering 2D images.

3. The transparent display device of claim **1**, further comprising a head tracker that is configured to track a position of a user's head or eyes relative to the transparent screen, and wherein the controller is configured to modify the rendering of the one or more virtual 3D volumes that appear to be in the 3D space behind the transparent screen based on the position of the user's head or eyes.

4. The transparent display device of claim **1**, wherein the transparent screen is a liquid crystal display (LCD).

5. A method comprising:

rendering an image on a transparent screen of a computing device;

receiving two-dimensional (2D) input from a user via an input panel positioned behind the transparent screen;

modifying the rendering of the image on the transparent screen based on the 2D-input;

sensing movement of one of the user's hands to reach into a three-dimensional (3D) space behind the transparent screen;

generating 3D-input based on the movement of the user's hand;

responsive to sensing the movement of the one of the user's hands to reach into the 3D space behind the transparent screen and without further user input, transitioning the transparent screen from a 2D display mode to a 3D display mode by simultaneously ceasing to render the image on the transparent screen and revealing one or more virtual 3D volumes comprising stacked windows that appear to be in the 3D space behind the transparent screen, each window of the stacked windows representing, and selectable to launch, an associated application, file, or page, each of the one or more virtual 3D volumes initially rendered in a closed state;

sensing additional movement of the one of the user's hands to reach towards the input panel; and

responsive to sensing the additional movement and without further user input, sliding the rendering of the image onto the transparent screen effective to transition the transparent screen from the 3D display mode to the 2D display mode.

6. A method comprising:

rendering multiple windows stacked in one or more virtual three-dimensional (3D) volumes that appear to be in a 3D space behind a transparent screen, each window of the multiple windows associated with, and selectable to launch, an associated application, file, or page, the virtual 3D volumes being rendered in a closed state;

sensing movement of a user's hand behind the transparent screen to select one of the one or more virtual 3D volumes;

generating 3D-input based on the movement;

rendering the selected virtual 3D volume in an opened state to enable the user to interact with the multiple windows stacked in the selected 3D volume responsive to receiving the 3D-input;

sensing additional movement of the user's hand behind the transparent screen to select a window of the selected virtual 3D volume;

generating additional 3D-input based on the additional movement; and

responsive to sensing the additional movement of the user's hand selecting a window of the selected virtual 3D volume and without further user input, transitioning the transparent screen from a 3D display mode to a two-dimensional (2D) display mode by simultaneously:

presenting a sliding effect comprising sliding an application, file, or page associated with the selected window in 2D onto the transparent screen; and

simultaneously ceasing to present the one or more virtual 3D volumes.

7. The method of claim **6**, further comprising, responsive to sensing movement of the user's hand behind the transparent screen, rendering feedback on the transparent screen based on the location of the user's hand in the 3D space.

8. The method of claim **7**, wherein rendering the feedback further comprises causing the transparent screen to glow based on the location of the user's hand in the 3D space.

9. The method of claim **7**, wherein rendering the feedback further comprises causing display of a cursor on the transparent screen based on the location of the user's hand in the 3D space.

10. The method of claim 6, wherein the transparent screen enables the user to see the user's hand behind the transparent screen.

11. The method of claim 6, further comprising sensing a position of the user's head or eyes relative to the transparent screen, and wherein the rendering the multiple windows comprises rendering the multiple windows as stacked in the one or more virtual 3D volumes that appear to be in the 3D space behind the transparent screen based on the position of the user's head or eyes relative to the transparent screen.

12. The method of claim 6, wherein rendering the open state of the selected virtual 3D volume renders each window of the multiple windows as having an increased distance in the 3D space from each other window of the multiple windows, the increased distance being greater than a distance between each window of the multiple windows as rendered in the closed state, the increased distance effective to:

give the multiple windows an expanded appearance; and

increase exposure of two or more of the multiple windows.

13. The method of claim 12, wherein rendering the open state of the selected virtual 3D volume concurrently renders the open state of the selected virtual 3D volume and a closed state of at least one other virtual 3D volume of the one or more virtual 3D volumes.

14. The method of claim 6, wherein the movement of the user's hand to select one of the multiple windows causes an area around each window of the multiple windows to glow progressively as the user's hand reaches the respective window, only one window glowing at any given time to indicate a current position of the user's hand with respect to the multiple windows.

15. The method of claim 6, wherein simultaneously presenting the sliding effect and ceasing to present the one or more 3D volumes creates an effect of covering the one or more virtual 3D volumes with the application, file, or pages associated with the selected window.

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