



(43) International Publication Date
7 February 2013 (07.02.2013)

- (51) **International Patent Classification:**
H04N 5/74 (2006.01) *G03B 21/20* (2006.01)
G03B 21/14 (2006.01)
- (21) **International Application Number:**
PCT/US2011/045983
- (22) **International Filing Date:**
29 July 2011 (29.07.2011)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
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- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

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

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

Declarations under Rule 4.17:

- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

- with international search report (Art. 21(3))

(54) **Title:** SYSTEM AND METHOD OF VISUAL LAYERING

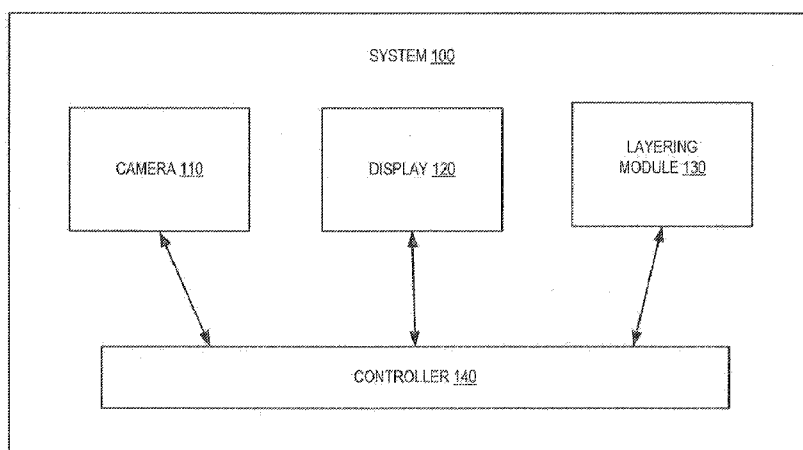


FIG. 1

(57) **Abstract:** A camera identifies a physical object positioned in a workspace. A display displays first digital information into the workspace. A layering module treats the physical object as a first layer in the workspace and treats the first digital information as a second layer in the workspace. A controller controls the visual adjacency of the first and second layers via display of the first digital information.

SYSTEM AND METHOD OF VISUAL LAYERING

BACKGROUND

[0001] Sharing digital information and collaborating based on that digital information is becoming increasingly common. Input devices capture digital information (e.g., user input on a computing device, digital cameras, scanning devices, etc.). Output devices output digital information for consumption by a user or group of users. Output devices may include digital displays or digital projectors that display digital information onto a display screen or into a workspace.

BRIEF DESCRIPTION OF DRAWINGS

[0002] The following description includes discussion of figures having illustrations given by way of example of implementations of embodiments of the invention. The drawings should be understood by way of example, not by way of limitation. As used herein, references to one or more "embodiments" are to be understood as describing a particular feature, structure, or characteristic included in at least one implementation of the invention. Thus, phrases such as "in one embodiment" or "in an alternate embodiment" appearing herein describe various embodiments and implementations of the invention, and do not necessarily all refer to the same embodiment. However, they are also not necessarily mutually exclusive.

[0003] Figure 1 is a block diagram illustrating a system according to various embodiments.

[0004] Figure 2 is a perspective, exterior view illustrating a system according to various embodiments.

[0005] Figure 3 is a perspective view illustrating logical layers in a system according to various embodiments.

[0006] Figure 4 is a block diagram illustrating layer states in a system according to various embodiments.

[0007] Figure 5 is a flow diagram of operation in a system according to various embodiments.

[0008] Figure 6 is a flow diagram of operation in a system according to various embodiments.

DETAILED DESCRIPTION

[0009] Embodiments described herein relate to a projection-capture system. The combination of projection, capture and user input control in the same workspace at the same time facilitates mixed reality (i.e., physical and virtual) collaboration. For example, virtual objects could be files on a user's computer (e.g., electronic presentation slides, electronic documents, digital photos, etc.). Physical objects could be two-dimensional objects (e.g., photos, documents, etc.) or three-dimensional objects (e.g., models, widgets, etc.). As described herein, physical and virtual objects are treated as visually interchangeable "layers." As described herein, these layers represent logical layers and allow systems and devices

described herein to control the workspace environment such that one layer (e.g., physical object or set of digital information) has the appearance of being on top of another layer. In a collaborative environment where users in different locations collaborate via separate projection-capture systems, each user is able to see and interact with both the local and remote objects (physical and virtual) because the camera on each system sends a live (e.g., video) feed to the other location for projection.

[0010] Figure 1 is a block diagram illustrating a system according to various embodiments. Figure 1 includes particular components, modules, etc. according to various embodiments. However, in different embodiments, more, fewer, and/or other components, modules, arrangements of components/modules, etc. may be used according to the teachings described herein. In addition, various components, modules, etc. described herein may be implemented as one or more software modules, hardware modules, special-purpose hardware (e.g., application specific hardware, application specific integrated circuits (ASICs), embedded controllers, hardwired circuitry, etc.), or some combination of these. Various modules and/or components illustrated in Figure 1 may be implemented as a computer-readable storage medium containing instructions executed by a processor and stored in a memory for performing the operations and functions discussed herein.

[0011] System 100 includes a camera 110, a display 120, a layering module 130 and a controller 140. Camera 110, display 120 and layering module 130 are operatively connected to controller 140 to facilitate altering visual adjacency

between layers in a workspace. In an example, display 120 displays a map onto a work-surface. Display 120 could be a display screen placed onto a work-surface or it could be a digital projector that displays information on the work-surface via digital projection. Additionally, camera 110 detects a physical object (e.g., a model of a house or building) placed on the work-surface. Camera 110 could be a visible-light camera (e.g., digital image camera, a digital video camera, etc.) or an infrared (IR) camera.

[0012] Layering module 130 associates the physical object with one visual layer and associates the projected map with another visual layer. By maintaining state information for the various layers, controller 140 is able to control the visual adjacency of the layers. In other words, one layer may initially appear to be "on top of" the other layer, but controller 140 may alter the visual adjacency such that the "bottom" layer visually becomes the "top" layer.

[0013] Figures 2-3 are perspective, exterior views illustrating a system according to various embodiments. Figures 2-3 include particular components, modules, etc. according to various embodiments. However, in different embodiments, more, fewer, and/or other components, modules, arrangements of components/modules, etc. may be used according to the teachings described herein. In addition, various components, modules, etc. described herein may be implemented as one or more software modules, hardware modules, special-purpose hardware (e.g., application specific hardware, application specific integrated circuits (ASICs), embedded controllers, hardwired circuitry, etc.), or some combination of these.

[0014] System 200 includes a top 210 and a base 220. Base 220 includes an infrared (IR) camera 224 and a projector 222, along with housing other components (e.g., processor, memory, layering module, controller, etc.). Projector 222 may be any suitable light projector including, but not limited to, LED (laser emitting diode) and DLP (digital light processing) projection. In various embodiments, projector 222 projects digital information toward top 210 where a mirror reflects the projection onto work-surface 230. IR camera 224 detects the position of physical objects positioned on work-surface 230.

[0015] Projector 222 projects a projection 250 of digital information (e.g., lines) onto work-surface 230. Object 260 is a physical object placed in workspace 230. IR camera 224 detects the position of the object 260. A layering module (e.g., layering module 130) associates projection 250 with one logical layer and object 260 with another logical layer. As shown in Figure 2, object 260 appears to be "on top of" projection 250. In other words, object 260 appears to be a foreground layer while projection 250 appears to be a background layer.

[0016] Figure 3 illustrates the logical layers described above. Layer 310 represents work-surface 230. Layer 320 represents projection 250 and is, in this example, "on top of" layer 310. Layer 330 represents object 260 and is, in this example, "on top of" layer 320. Once objects and digitally projected information have been associated with logical layers, the layering module maintains state information about the visual order of the layers.

[0017] System 200 also includes a user input device 240 that allows the user to interact with system 200. In various embodiments, user input (UI) device 240

includes an infrared digital stylus and/or infrared camera to detect the position of UI device 240 in workspace 230. Although any suitable UI device may be used, a digital stylus has the advantage of allowing input in three dimensions, including along the surface of workspace 230, without a sensing pad or other special surface. Thus, system 200 can be used on a variety of work-surfaces.

[0018] User input received from UI device 240 or other input mechanism may indicate a request to alter the visual adjacency of layers in workspace 230. For example, touching object 260 with UI device 240 may indicate a request to have object 260 be the foreground layer, with projection 250 as the background layer. Touching the surface of workspace 230 might indicate a request to have projection 250 be the foreground layer, with object 260 as the background layer. System 200 can use this input and state information from the layering module to alter the projection from projector 222 such that the visual order of the layers is altered (e.g., foreground and background layers are swapped).

[0019] Figure 4 is block diagram illustrating state changes for layers (real and virtual) in a projection-capture system. For illustrative purposes, the surface of the workspace on which objects are positioned and digital information is projected is considered layer L0. Thus, a layer L1 would be visually adjacent (e.g., "on top of") layer L0 and a layer L2 would be visually adjacent (e.g., "on top of") layer L1. As shown, state 410 includes a physical object (e.g., a map, document, other two-dimensional or three-dimensional object, etc.) associated with layer L1. In other words, the physical object is visually adjacent L0. A projection of digital information (e.g., image, document, etc.) is initially associated

with layer L2 and is visually adjacent layer L1. Thus, in state 410, the projection of digital information visually appears to the system user as being "on top of" the physical object.

[0020] In response to user input or other control signal to alter the visual adjacency of the layers, the system layering module changes the layer associations from those of state 410 to those of state 420. In state 420, the physical object becomes layer L2 and the projection of digital information becomes layer L1. To create the visual appearance of the physical object being "on top of" the projection, the system may simply stop projecting the digital information into the workspace.

[0021] State 412 includes a projection of digital information (e.g., a map, document, image, etc.) initially associated with layer L1. In other words, the projection is visually adjacent L0. A physical object (e.g., two-dimensional or three-dimensional) is initially associated with layer L2 and is visually adjacent layer L1. To achieve the visual appearance of physical object being "on top of" the projection, the system may remove the digital information (e.g., map or image data, etc.) corresponding to the coordinates of the physical object from the projection. For example, at the position where the physical object is located, the system may project a blank space (e.g., white or other suitable-colored light) while still projecting the original digital information (e.g., map or image data, etc.) at all other positions in the workspace. Alternatively, the system may capture a digital image of the physical object (e.g., from directly above the physical object) and project that image at the position where the physical object is located (in lieu

of projecting a blank space). In either example, the effect is the appearance of the physical object being "on top of" of the projected digital information.

[0022] In response to user input or other control signal to alter the visual adjacency of the layers, the system layering module changes the layer associations from those of state 412 to those of state 422. In state 422, the physical object becomes layer L1 and the projection of digital information becomes layer L2. To create the visual appearance of the projected digital information being "on top of" the physical object, the system may simply project all of the digital information into the workspace including at the position where the physical object is located.

[0023] It should be noted that multiple projection-capture systems may be used in remote locations for virtual collaboration. The states depicted in Figure 4 illustrate an example of such collaboration. The user in the first location might have a physical object and a projection according to state 410. At the same time, the user in the second location might have a physical object and a projection according to state 412. In other words, system represented by state 410 may capture a digital image of the physical object and send it to the collaborating system, where the digital image is projected according to state 412. Likewise, the user in the second location has a physical object according to state 412. This physical object is also captured digitally and sent to the other system, shown as the projection in state 410. In this way, system users in different locations may collaborate using both real and virtual objects.

[0024] Figure 5 is a flow diagram of operation in a system according to various embodiments. Figure 5 includes particular operations and execution order according to certain embodiments. However, in different embodiments, other operations, omitting one or more of the depicted operations, and/or proceeding in other orders of execution may also be used according to teachings described herein.

[0025] A system identifies 510 a physical object in a workspace. The physical object can be two-dimensional or three-dimensional. Objects may be identified by a camera (e.g., infrared, digital image capture, digital video, etc.). In various embodiments, identification includes determining a position (e.g., coordinates) of the object within the workspace. A layering module associates 520 the physical object with a first layer. The system also displays (e.g., projects) 530 digital information (e.g., an image) as a second layer into the workspace. Again, the layering module maintains the association between the projected information and the second layer.

[0026] The system, perhaps in response to user input, alters 540 the visual adjacency between the first and second layers. For example, the first layer might initially be visually adjacent (e.g., appears to be "on top of") the surface of the workspace. The second layer might initially be visually adjacent (e.g., appears to be "on top of") the first layer. In response to a user request or other control signal, the system switches the visual order of the layers. Thus, the second layer becomes visually adjacent the surface of the workspace while the first layer becomes visually adjacent the second layer.

[0027] Figure 6 is a flow diagram of operation in a system according to various embodiments. Figure 6 includes particular operations and execution order according to certain embodiments. However, in different embodiments, other operations, omitting one or more of the depicted operations, and/or proceeding in other orders of execution may also be used according to teachings described herein.

[0028] A projection-capture system identifies 610 a physical object in a workspace. Again, the physical object can be two-dimensional or three-dimensional. Objects may be identified by a camera (e.g., infrared, digital image capture, digital video, etc.). A system layering module associates 620 the physical object with a first layer. The system also displays (e.g., projects) 630 digital information (e.g., an image) as a second layer into the workspace. Again, the layering module maintains the association between the projected information and the second layer.

[0029] The system detects 640 a change in the position of the physical object. For example, the system may include an infrared camera or a visible-light camera (e.g., digital still-image camera or a digital video camera) for detecting the position of the physical object. In response to detecting the change in position of the physical object, the system maintains 650 the visual adjacency between the first and second layers. For example, if a workspace is logically divided into four quadrants, a physical object might initially be detected as occupying the first quadrant. If the physical object (associated with one layer) is initially visually "on top of" projected digital information (associated with a

different layer), then the system may abstain from projecting the digital information that would otherwise be located in the first quadrant, consistent with the visual order of the layers. However, in response to detecting movement of the physical object from the first quadrant to the second quadrant, the system may then project the digital information associated with the first quadrant while removing from the projection the digital information associated with the second quadrant, thereby maintaining the appearance that the physical object is "on top of" the projected digital information.

[0030] In examples described herein, methods and systems manage the visual adjacency of first and second layers. The methods and systems described herein are readily extendible to more than two layers. For example, additional layers of projected digital information could be managed by a projection capture system. Also, additional physical objects could each be associated with a distinct layer. The visual adjacency between these multiple physical and projected layers may be managed according to the embodiments described herein.

[0031] Various modifications may be made to the disclosed embodiments and implementations of the invention without departing from their scope. Therefore, the illustrations and examples herein should be construed in an illustrative, and not a restrictive sense.

CLAIMS

What is claimed is:

1. A system, comprising:
 - a camera to identify a physical object positioned in a workspace;
 - a display to display first digital information in the workspace;
 - a layering module to treat the physical object as a first layer in the workspace and to treat the first digital information as a second layer in the workspace; and
 - a controller to control the visual order of the first and second layers via display of the first digital information.
2. The system of claim 1, wherein the camera is at least one of an infrared camera or a visible-light camera.
3. The system of claim 1, further comprising:
 - the controller to alter the display of the first digital information to maintain an existing visual order between the first and second layers in response to a change in position of the physical object relative to the first digital information.
4. The system of claim 1, further comprising:
 - a user input module to receive user input; and
 - the controller to alter the display of the first digital information to alter the visual order of the first and second layers.

5. The system of claim 1, further comprising:
 - the display to display second digital information in the workspace; and
 - the layering module to treat the second digital information as a third layer in the workspace; and
 - the controller to control display of the first and second digital information to alter the visual order between the first, second, and third layers.
6. The system of claim 1, wherein the display is a digital projector.
7. A computer-readable storage medium containing instructions that, when executed, cause a computer to:
 - identify a physical object positioned in a workspace;
 - associate the physical object with a first layer;
 - display digital information as a second layer in the workspace; and
 - alter the visual adjacency between the first and second layers.
8. The computer-readable storage medium of claim 7, comprising further instructions that cause the computer to:
 - maintain an existing visual adjacency between the first and second layers in response to a change in position of the physical object relative to the displayed digital information.

9. The computer-readable storage medium of claim 7, comprising further instructions that cause the computer to:
 - display additional digital information as a third layer in the workspace; and
 - alter the visual adjacency between the first, second, and third layers.
10. A method for a projector-camera system, comprising:
 - identifying a physical object positioned in a workspace;
 - associating the physical object with a first layer;
 - projecting digital information as a second layer into the workspace; and
 - altering the visual adjacency between the first and second layers.
11. The method of claim 10, wherein the physical object is identified via infrared sensing.
12. The method of claim 10, wherein the digital information comprises a digital image or digital video feed.
13. The method of claim 10, further comprising:
 - maintaining an existing visual adjacency between the first and second layers in response to a change in position of the physical object relative to the projected digital information.
14. The method of claim 10, wherein altering the visual adjacency comprises:

receiving user input;

altering the visual adjacency of the first and second layers in response to the user input.

15. The method of claim 10, further comprising:

projecting additional digital information as a third layer into the workspace; and
altering the visual adjacency between the first, second, and third layers.

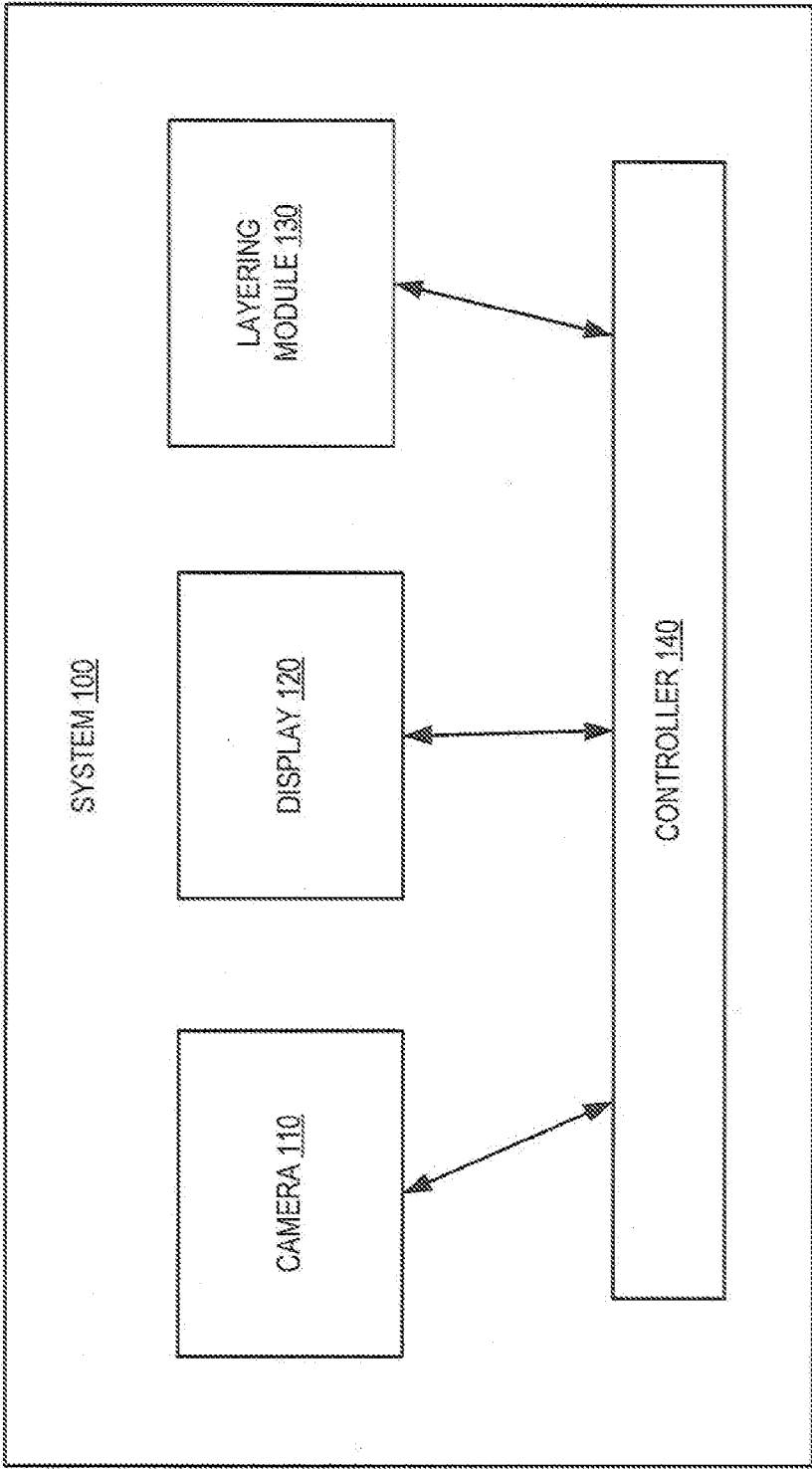


FIG. 1

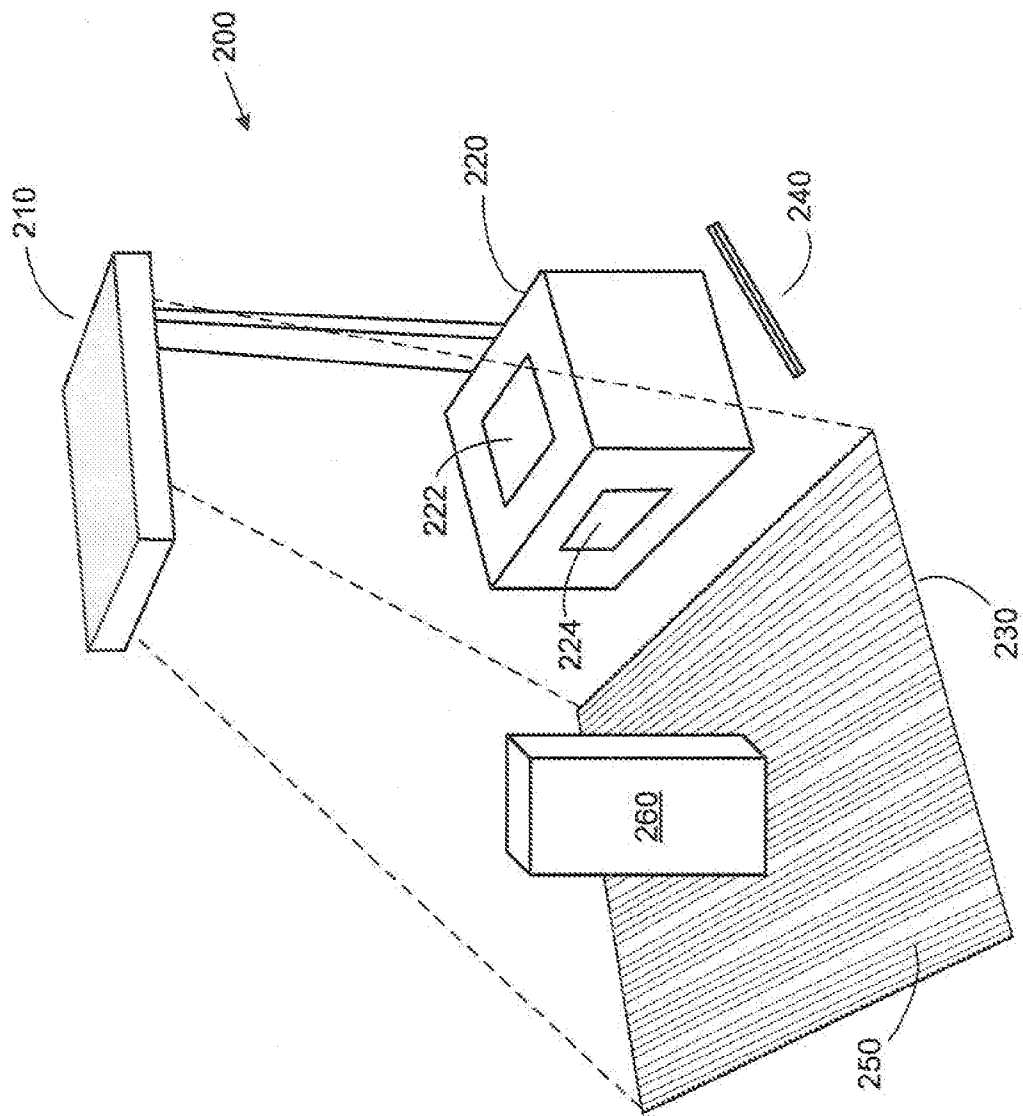


FIG. 2

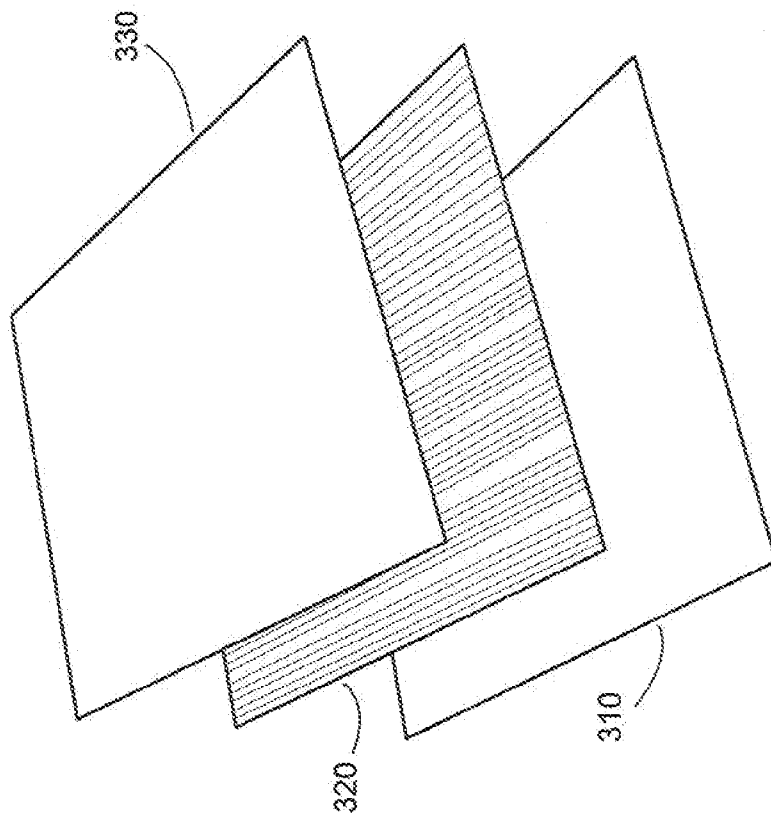


FIG. 3

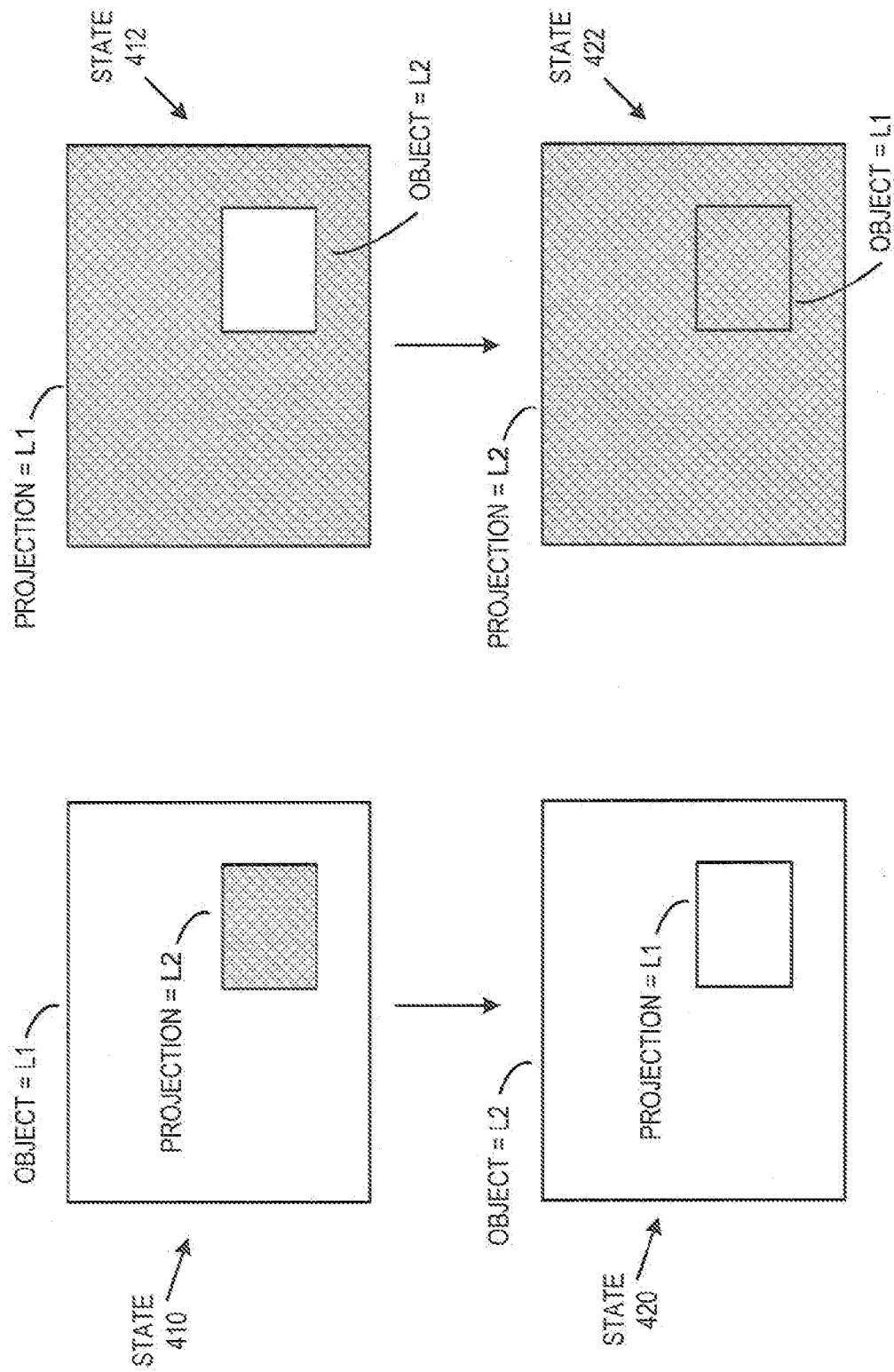


FIG. 4

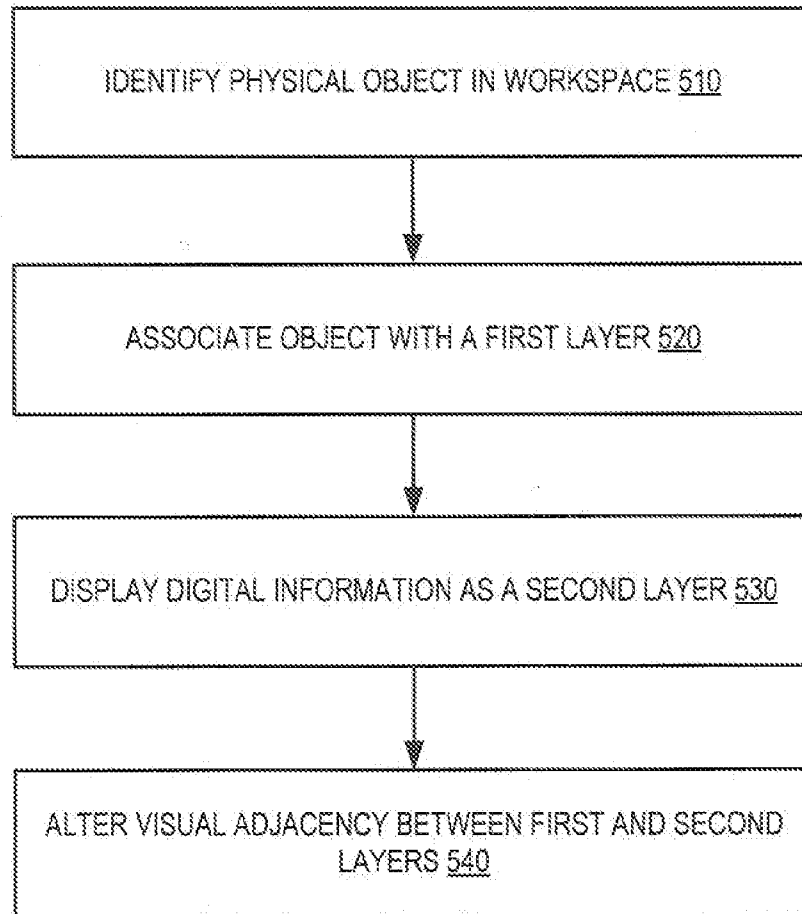


FIG. 5

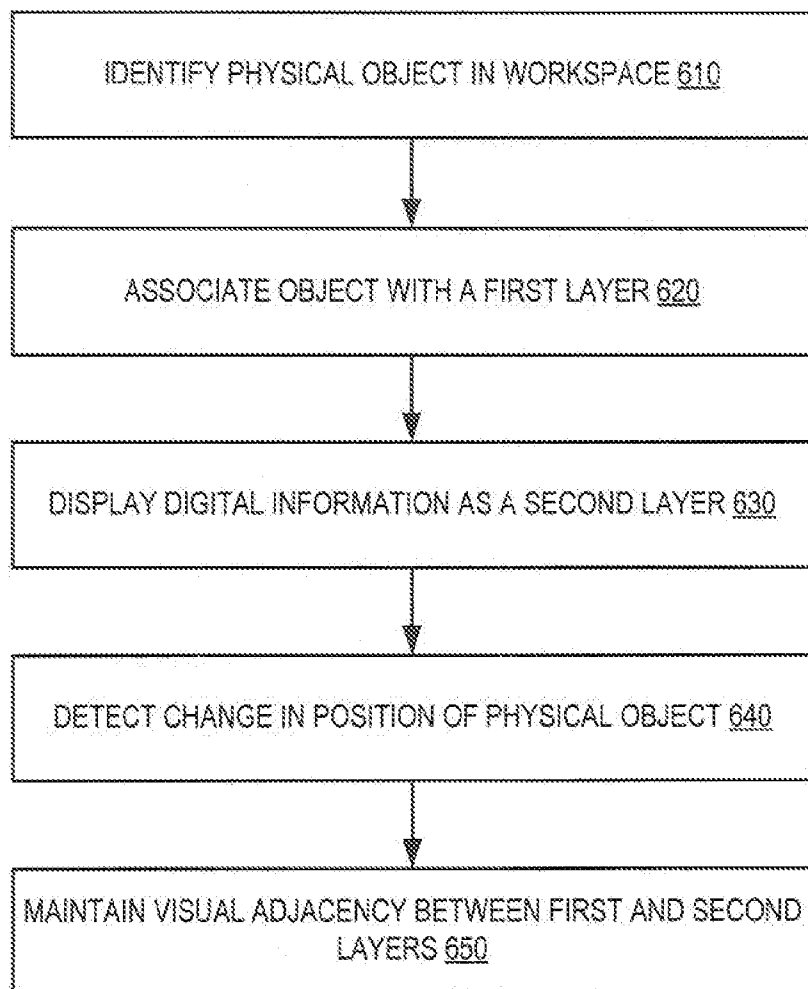


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/045983**A. CLASSIFICATION OF SUBJECT MATTER*****H04N 5/74(2006.01)i, G03B 21/14(2006.01)i, G03B 21/20(2006.01)i***

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04N 5/74; G06F 3/048; H04N 1/00; G06T 7/60; G06F 17/30; G06F 13/00; H04B 1/40; G06T 1/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: object, identify, information, display, order, layer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2011-081556 A (SONY CORP) 21 April 2011 See abstract, claims 1-9, paragraphs [0024]-[0105], figures 1, 11-14.	1-15
Y	JP 10-222436 A (MEIDENSHA CORP) 21 August 1998 See abstract, claims 1, 2, paragraphs [0020]-[0030], figures 6-9.	1-15
Y	JP 2004-192623 A (NIPPON TELEGR & TELEPH CORP <NTT>) 08 July 2004 See abstract, paragraphs [0019], [0312], figure 65.	11
A	KR 10-2011-0003705 A (LG ELECTROICS INC.) 13 January 2011 See abstract, paragraphs [0089]-[0109], figures 4-9b.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

20 FEBRUARY 2012 (20.02.2012)

Date of mailing of the international search report

20 FEBRUARY 2012 (20.02.2012)

Name and mailing address of the ISA/KR

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Facsimile No. 82-42-472-7140

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Telephone No. 82-42-481-5984



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2011/045983

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