

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

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
19 January 2012 (19.01.2012)

(10) International Publication Number
WO 2012/009094 A2

(51) International Patent Classification:

G06F 3/01 (2006.01) **G06F 9/44** (2006.01)
G06F 3/14 (2006.01)

(21) International Application Number:

PCT/US2011/040649

(22) International Filing Date:

16 June 2011 (16.06.2011)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

12/824,448 28 June 2010 (28.06.2010) US

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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).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: A SYSTEM FOR PORTABLE TANGIBLE INTERACTION

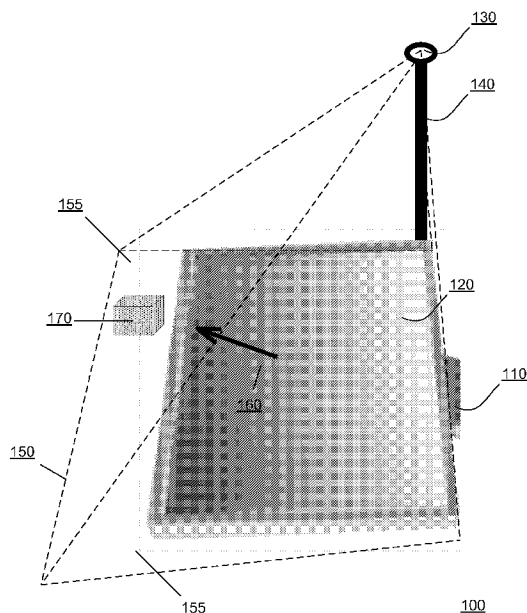


FIG. 1

(57) Abstract: Embodiments of the invention describe a system utilizing at least one camera and a display to create an object and context aware system. Embodiments of the invention may utilize the camera to sense a system's surroundings and use recognition logic or modules to detect and recognize objects on and around the system. System applications may further act on the sensed data and use the display of the system to provide visual feedback and interactive elements as a means to interact with the system user.

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A SYSTEM FOR PORTABLE TANGIBLE INTERACTION

FIELD

Embodiments of the present invention generally pertain to devices and methods to provide enhanced computer device interaction and more specifically to processing object
5 interaction with augmented mobile computer device systems.

BACKGROUND

The increasing processing capabilities of mobile computer systems have created the improved ability to understand and react to physical objects near said systems. System users' contexts may also be used to provide a richer interaction experience.

10 Creating a system with the ability to track objects, act upon them, and provide feedback would significantly increase the value of mobile computers to end users. Tabletop systems have been proposed and developed over the years to provide many of these benefits; however, these systems are typically large and thus not mobile nor personal. One of the reasons for the limitations of prior art solutions such as tabletop
15 systems is the requirement of a large device footprint; such devices utilize additional hardware beneath the tabletop surface in order to process activity on the surface as interactions with the system.

Thus, no current solutions exist for providing enhanced user and object interaction for a mobile computer system that do not require additional display capabilities (e.g., an
20 additional screen, a projector), wherein the mechanisms to enhance user and object interaction do not affect the nomadic characteristics of the mobile computing system.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description includes discussion of figures having illustrations given by way of example of implementations of embodiments of the invention. The drawings
25 should be understood by way of example, and 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
30 do not necessarily all refer to the same embodiment. However, they are also not necessarily mutually exclusive.

FIG. 1 is a block diagram of an embodiment of the invention.

FIG. 2 is a block diagram of an embodiment of the invention.

FIG. 3 is a flow diagram of an embodiment of the invention.

FIG. 4 is an illustration of an application utilizing an embodiment of the invention.

FIG. 5 is an illustration of an application utilizing an embodiment of the invention.

5 **FIG. 6** is an illustration of an application utilizing an embodiment of the invention.

Descriptions of certain details and implementations follow, including a description of the figures, which may depict some or all of the embodiments described below, as well as a discussion of other potential embodiments or implementations of the inventive concepts presented herein. An overview of embodiments of the invention is provided
10 below, followed by a more detailed description with reference to the drawings.

DETAILED DESCRIPTION

Embodiments of the invention describe a system utilizing at least one camera and a display screen to create an object and context aware system. More specifically, embodiments of the invention utilize cameras and sensors to sense the system's
15 surroundings and use recognition logic or modules to detect and recognize objects on and around the system. Said recognition logic or modules may further infer the state of system user(s) and their immediate environment based on the sensed data and any historical context or information it may have about the user. Applications may further act on the sensed data and use the display screen of the system to provide visual feedback and
20 interactive elements (such as buttons, dials, sliders) as a means to interact with the system user(s).

Embodiments of the invention thus provide an object-aware mobile table-top system. Embodiments of the invention may utilize a ubiquitous stable-surface-based platform (e.g., a tablet computer or a convertible tablet) to get nomadic (as opposed to
25 fixed) functionality. Embodiments of the invention may utilize cameras/sensors operatively coupled to the tablet computer to avoid environmental instrumentation (as opposed to cameras and projectors mounted on the ceiling). Integration of these cameras/sensors provides a self-sufficient highly portable, but immersive and inexpensive functionality. Embodiments of the invention utilize a camera positioned above the display
30 surface of a mobile computer (e.g., a tablet computer), thus enabling the detection of objects off the screen (this detection is not be possible with a camera or sensor positioned underneath the display surface). Said camera may be integrated with the mobile device, or

fastened to the mobile device using any means that may position the camera to view the display surface of the device.

Processing related to object awareness may be executed via logic or modules. Software modules may run on the system alone or alternately run on a combination of a
5 networked systems and a back-end server. The functionality of said logic/modules is to parse object, user, and environmental states from the sensor data, and decide how to interact with the user (using the display/actuators of the system itself). The above processing functionality will include: basic frame capture, rectification and lighting correction; image segmentation and feature extraction; perception code to recognize object
10 locations/state and user hands/location; gestures made by users with their hands; and optical character recognition (OCR), handwriting, and barcode recognition to extract text from objects and documents.

FIG. 1 is a block diagram of an embodiment of the invention. System 100 includes tablet computer 110. Tablet computer 110 is used as an example of a mobile computer
15 system including display surface 120 that may be laid flat with respect to a supporting surface (e.g., a tabletop). It is to be understood that tablet computer 110 is one example of a device utilizing an embodiment of the invention, and it will be further understood some functions of tablet computers (e.g., a touchscreen display) are not necessarily required by embodiments of the invention.

20 System 100 may further include camera 130 positioned above display surface 120. In this embodiment, camera 130 is operatively coupled to tablet computer 110 via arm 140 rotationally extendable from tablet computer 110.

In one embodiment, camera 130 is positioned to capture visual data within target area 150. As illustrated in FIG. 1, target area 150 includes display surface 120 and areas
25 155 outside the display surface.

Tablet computer 110 may further execute an application that generates graphical image 160 to be displayed. Said application may also, via camera 130, identify object 170 within target area 150 via any perception algorithm known in the art. Said object may appear anywhere within target area 150 (i.e., on display surface 120 and area 155). Said
30 application may process an interaction of object 170 with graphical image 160 produced by an application.

In this example, object 170 appears off of display surface 120, but within sub-area 155 of target area 150. The application executing on tablet computer 110 may orientate graphical image (arrow) 160 to identify the position of object 170 within target area 150. In this embodiment, graphical image 160 is generated based on the angle between object
5 170 and the center of screen 120.

Thus, embodiments of the invention may utilize a screen of a computing device to convey a perception of an object and user state, provide feedback to user on actions, and offer choices to the user to either manipulate physical objects or interact with digital on-screen elements.

10 **FIG. 2** is a block diagram of an embodiment of the invention utilizing two cameras. System 200 includes tablet computer 210, including display surface 220. System 200 further includes cameras 230 and 240 positioned upright with respect to display surface 220. With mobile and ultra-mobile devices, screen real-estate often makes it impossible to accommodate a user's hands or fingers without obstructing the digital
15 content on the screen. The use of multiple cameras provides a large interaction space despite the limited screen area provided by tablet computer 210. The physical design of system 200 to include cameras 230 and 240 enables it to view and respond to users' interactions with objects on the surface surrounding the tablet (i.e., the combination of target areas 235 and 245). Thus, the input space of system 200 (i.e., what the system sees)
20 is significantly larger than its output space (limited to the bounds of screen 220).

To avoid cameras 230 and 240 accidentally recognizing virtual elements shown on tablet screen 220, linear polarizing filters may be applied to screen 220 and the cameras (most LCD screens are linearly polarized; however in many tablets, the touch-sensitive element diffuses the light). In one embodiment, the polarizing filters for cameras 230 and
25 240 are rotatable to avoid the need to pre-compute the filter rotation needed to block the view of screen 220 (rotating the filter to the correct alignment needs to be done only once).

Prior to use, the system 200 may be calibrated in order to generate different camera views from cameras 230 and 240 and to deliver correct object positions. In one embodiment, system calibration consists of three operations each of which need to be
30 performed once. In the first operation, the four corners of screen 220 are manually selected by the user, once for each camera. Using the selected corners, a homography is computed for each camera that is later used for translating from camera view to the plane of screen

220. Alternatively, visual markers at the screen corners can be automatically deleted by the system. The homography may be stored on file and loaded automatically whenever system 200 starts up.

After the first calibration operation, an object placed on screen 220 may receive the same coordinates from both cameras 230 and 240; however, an object placed on table surface 260 (i.e., within either target area 235 and 245) will receive different coordinates from the two cameras because the plane of the tablet screen is *raised up* from the plane of surface 260. Thus, in the second calibration operation, a single physical calibration marker is placed on surface 260 within overlapping area 265 between cameras 230 and 240 (at this point, system 200 will observe two markers on the table). Because system 200 is told that there is only one marker on surface 260, it computes a correction offset that should be applied to the two objects it is seeing for their centers to align. The offset is stored and is consequently applied to the coordinates of objects that are outside the bezel of tablet 210. After the second calibration operation, a single object in the cameras' overlap (i.e., area 265) will have overlapping coordinates and will be correctly reported by the vision system only once.

In a third operation, a mapping between the vision system coordinates and the application space coordinates is established. The calibration marker from the previous operation is placed at the four corners of the user application space. Using the coordinates returned by the vision system for the marker at each corner, a coordinate transformation is computed, stored, and is later used by applications of the system.

FIG. 3 is a flow diagram of an embodiment of the invention. Flow diagrams as illustrated herein provide examples of sequences of various process actions. Although shown in a particular sequence or order, unless otherwise specified, the order of the actions can be modified. Thus, the illustrated implementations should be understood only as examples, and the illustrated processes can be performed in a different order, and some actions may be performed in parallel. Additionally, one or more actions can be omitted in various embodiments of the invention; thus, not all actions are required in every implementation. Other process flows are possible.

A frame is retrieved from at least one camera device, 300. In one embodiment, at least two cameras are utilized to provide a larger target input area. A background subtraction is executed of the retrieved frame, 310. In one embodiment, a Gaussian

Mixture Models approach is utilized for background subtraction, with a dedicated model for each camera. When background subtraction is applied, a background/foreground mask associated with the raw camera frame is produced, 320.

Using calibration points identified at system setup, a set of simulated views to be
5 used for object detection is produced, 330. In one embodiment, three simulated views are produced. The first comprises a Screen and Bezel View including a rectified view of the tablet screen and bezel and useful for performing more precise detection of objects placed on the tablet. The second view comprises a Table view including a rectified view of the tablet screen and surrounding surface and is computed such that the tablet screen occupies
10 one of the top quadrants of the rectified view (depending on whether a left or right camera is used). The third view comprises a screen view, including a rectified view of the tablet screen only. If background subtraction is used, a View Module will distort the background/foreground mask received with the raw camera frame such that it matches the simulated view.

15 In one embodiment, the resolution of each of the above views (Raw, Screen and Bezel, and Table) is independent and may be changed depending primarily on the details of objects that need to be detected.

In one embodiment, a system includes a list of machine-learning classifiers corresponding to one of the above produced views and responsible for vision-based object
20 recognition. Each of these views is passed to their respective classifier, 340. These views may be passed with or without background subtraction. Each classifier then returns a list of detected objects (if any), 350.

It is to be understood that because different views may have different resolutions and coordinate systems in relation to the tablet screen, the coordinates of each object must
25 be transformed into a uniform coordinate system prior to passing the objects to the Camera Module, 360. In one embodiment, the coordinates of each detected object conform to the tablets' coordinate system, such that an object placed at the top-left of the tablet screen will have a coordinate of, for example, (0,0), and an object placed at the bottom right corner of the tablet screen will have a coordinate of, for example, (1280,800). In this
30 example, at the end of this operation objects to the left of the tablet will have negative horizontal coordinates, objects in front of the tablet will have vertical coordinates greater than 800, and objects to the right of the tablet will have horizontal coordinates greater than

1280. Converging on this single coordinate system allows for a straightforward determination as to whether an object is on or off the screen, and one or more visualizations may be chosen appropriately. A list of objects may then be each updated with their associated coordinates, 370.

5 The system may process more than one set of objects classified on different views with potential redundancies; however, each object must be reported at most once to the output system. Thus, the lists from the different views are analyzed and duplicates of objects that occur in multiple lists are removed, 380. Duplicates are determined as objects that have the same template name and for which the bounding boxes overlap by more
10 than, for example, 75%. In one embodiment, when duplicates are found, the system gives preference to objects classified on the higher resolution Screen and Bezel view over those classified on the Table view. The single list of objects is then passed for perception processing, 385.

 Similar to the above operation, objects returned from the two cameras are merged,
15 390. It is to be understood that, unlike merging objects from different views of the same camera, a single object detected by both cameras may not have perfect overlap between the views. In fact, for any 3D object, it will likely not be the case. In one embodiment of the invention, the overlapping area for an object seen by both cameras is used as the possible base of the object. For overlapping objects, only the intersecting area may be
20 reported to an output subsystem to approximate an object's touch point with the surface and provide feedback at the appropriate position.

 Objects within the view of the system cameras are identified and passed to an application for subsequent processing, 395. Thus, the system's input space (what can be seen by the cameras) is much larger than its output space (the extent of the tablet screen).

25 Applications utilizing the above described increased input space may convey the presence of an off-screen object and manipulators may be applied to any representation for conveying the distance of the object from the tablet.

 In one embodiment, an arrow is drawn from the center of the tablet screen in the direction of the object that is on the table. The thickness of the arrow may be used to
30 indicate and update an object's distance from the tablet. For example, arrow thickness may decrease as an object's distance increases. An alpha blend value may also be used to indicate an object's distance from the tablet. This visualization technique changes the

alpha value of representation based on the object's distance from the screen. When the object is touching the screen, the alpha value is 100%. As a default, the alpha value for an object at the edge of the vision system has an alpha value of 20%.

5 In another embodiment, an icon representing the object may be displayed on the screen. The position of the icon may be computed such that the icon is placed at the edge of the screen on the imaginary line connecting the object's center and the center of the screen. Icons may be alpha-blended and resized to indicate an object's distance from the screen.

10 In another embodiment and similar to the above described icon, an arrow may be drawn at the edge of the screen pointing in the direction of the object. For example, thinner, longer arrows may indicate objects are further from the tablet screen. Other portions of the arrow may indicate object distance (e.g., the stem of an arrow becomes longer the farther away an object is).

15 In another embodiment, a callout (similar to a cartoon bubble) may indicate an object within the target area, including a tail pointing towards the off-screen object. The callout may further include a label and an icon. The callout may be further sized and alpha-blended to indicate an object's distance from the screen.

FIG. 4 is a diagram of an application utilizing an embodiment of the invention. The application of FIG. 4 demonstrates the ability to detect objects on tablet computer 400 and around it, and to make use of tablet screen 410. In this application, physical tokens 20 401-409 may be used by to play a game of tic-tac-toe on grid 420. The system recognizes tokens' 401-409 positions on screen 410 via a camera positioned above the screen to determine the state of the game-board and highlight tokens from underneath via images 411-418 (token 409 has not been placed on screen 410, and thus does not have a 25 corresponding image on screen 410). In one embodiment, tokens that are off the screen may be identified and highlighted with icons at the periphery of screen 410 as described above.

In this embodiment, the application (i.e., the tic-tac-toe game) receives a command from the user to monitor the target area. For example, after placing game piece on grid 30 420, a user may hit NEXT button 425 displayed on screen 410 to indicate that they are finished with their turn. At this point, the application may observe the target area to check the state of the game board to ensure that objects on screen 410 are in compliance with the

game (possible violations, such as moving an already-placed piece, removing an opponent's piece, playing two or more pieces on a turn, failing to play on a turn, covering an opponent's piece, and so on). Users may be notified of violations via sound and symbol displayed on screen 410 (e.g., buzzer sounds and red dashes marking an illegal move on grid 420).

FIG. 5 is a diagram of an application utilizing an embodiment of the invention. The application of FIG. 5 illustrates the capability of detecting objects off screen 510 of tablet computer 500 as an input for the application. In this example, the application displays soccer goal 525 with goalie 530. A user may physically roll (or kick) small soccer-ball-shaped object 540 toward virtual on-screen goal 525. When object 540 hits the chassis of tablet 500, virtual ball 545 appears and flies toward goal 525 along the same trajectory as the incoming physical object. Goalie 530 tries to block the shot, favoring the side from which the shooter strikes.

This example application takes advantage of tablet 500 being raised from the ground so that physical object 540 may impact the tablet and then return, more or less, to the user. Velocity and acceleration in the physical world are used directly in physics equations to convert physical motion to virtual motion of virtual ball 545 on screen 510. In one embodiment, shots travel not just in two dimensions, but in a third dimension —above screen 510 whereby the size object 540 with respect to the camera above tablet 500 communicates its height from the ground. Thus, it would be possible to shoot over the goal as well as to the left or right of it.

The embodiment of the invention illustrated in FIG. 5 highlights the ability of embodiments of the invention to detect objects off tablet computer 500, track their velocity and trajectory, and react to them on screen 510.

FIG. 6 is a diagram of an application utilizing an embodiment of the invention. The application of FIG. 6 allows a user to play with a physical object, in this example toy zebra 650, and have the application react to the state of the toy on, or around, tablet 600.

In this embodiment, toy zebra 650 may eat food 615 displayed on the screen 610, or drink from virtual pool of water 620 displayed on screen 610 (a timer may periodically replenish the pool of water) by placing the “head” of the toy on the displayed objects. Sand area 625 provides a place for toy zebra 650 to use the bathroom by placing the toy entirely on screen 610 within the sand area.

The physical orientation of zebra toy 650 also may be utilized by the application. Specifically, zebra toy 650 may go to sleep, as the application will distinguish between a standing zebra and a zebra lying down. For example, laying zebra toy 650 on its side in front of tablet 500 triggers a “dream” wherein a nature video of zebras in the wild plays above the zebra’s head within cartoon bubble 630 on tablet screen 610. If zebra toy 650 is stood-up mid-dream, the dream immediately stops. Gesture tracking within the target area may also be tracked to enable actions such as petting to be recognized and rewarded. This application highlights the ability of embodiments of the invention to detect objects within the target area and process interactions with objects on screen 610 either off or on tablet computer 600.

Various components referred to above as processes, servers, or tools described herein may be a means for performing the functions described. Each component described herein includes software or hardware, or a combination of these. The components can be implemented as software modules, hardware modules, special-purpose hardware (e.g., Application Specific Integrated Circuits (ASICs), Digital Signal Processors (DSPs), etc.), embedded controllers, hardwired circuitry, etc. Software content (e.g., data, instructions, and configuration) may be provided via an article of manufacture including a computer storage readable medium, which provides content that represents instructions that can be executed. The content may result in a computer performing various functions/operations described herein. A computer readable storage medium includes any mechanism that provides (i.e., stores and/or transmits) information in a form accessible by a computer (e.g., computing device, electronic system, etc.), such as recordable/non-recordable media (e.g., read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, etc.). The content may be directly executable (“object” or “executable” form), source code, or difference code (“delta” or “patch” code). A computer readable storage medium may also include a storage or database from which content can be downloaded. A computer readable medium may also include a device or product having content stored thereon at a time of sale or delivery. Thus, delivering a device with stored content, or offering content for download over a communication medium may be understood as providing an article of manufacture with such content described herein.

CLAIMS

1. An apparatus comprising:
a display surface;
a camera positioned to capture visual data within a target area, the target area to
5 include at least a portion of the display surface and an area outside the display surface;
a processor; and
software to be executed via the processor to
generate a graphical image to be displayed on the display surface,
identify an object separate from the display surface within the target area,
10 and
process an interaction of the object with the graphical image.
2. The apparatus of claim 1, further comprising a second camera positioned to capture
visual data within a second target area, the second target area to include at least a portion
of the display surface and a second area outside the display surface.
- 15 3. The apparatus of claim 2, wherein the display surface and the processor are
included in a tablet computer, and further wherein the cameras are each coupled to the
tablet computer via a fastener extended upright relative to the display surface.
4. The apparatus of claim 1, the software to further continuously monitor the target
area to identify the object within the target area.
- 20 5. The apparatus of claim 1, the software to further receive a command to monitor the
target area.
6. The apparatus of claim 1, wherein the interaction of the object with the graphical
image comprises a movement of the object with respect to the graphical image.
7. The apparatus of claim 1, wherein the interaction of the object with the graphical
25 image comprises a position of the object within the target area with respect to the
graphical image.
8. The apparatus of claim 1, the software to further generate a second graphical image
representing the object and to be displayed on the display surface in response to
identifying the object within the target area and outside the display surface.
- 30 9. The apparatus of claim 8, the software to generate the second graphical image
based, at least in part, on at least one of a distance, an angle, and an orientation between
the object and the display surface.

10. An article of manufacture comprising a machine-readable storage medium that provides instructions that, if executed by the machine, will cause the machine to perform operations comprising:

- capturing visual data within a target area via a camera, the target area to include at least a portion of the display surface and an area outside the display surface;
- generating a graphical image;
- displaying the graphical image on the display surface;
- identifying an object separate from the display surface within the target area; and
- processing an interaction of the object with the graphical image.

11. The article of manufacture of claim 10, the operations further comprising capturing visual data within a second target area via a second camera, the second target area to include at least a portion of the display surface and a second area outside the display surface.

12. The article of manufacture of claim 10, wherein the display surface is included in a tablet computer, and further wherein the cameras are each coupled to the tablet computer via a fastener extended upright relative to the display surface.

13. The article of manufacture of claim 10, the operations further comprising continuously monitoring the target area to identify the object within the target area.

14. The article of manufacture of claim 13, the operations further comprising receiving a command to monitor the target area.

15. The article of manufacture of claim 10, wherein the interaction of the object with the graphical image comprises a movement of the object with respect to the graphical image.

16. The article of manufacture of claim 10, wherein the interaction of the object with the graphical image comprises a position of the object within the target area with respect to the graphical image.

17. The article of manufacture of claim 10, the operations further comprising identifying the object within the target area and outside the display surface; and in response to identifying the object within the target area and outside the display surface

- generating a second graphical image representing the object, and
- displaying the second graphical image on the display surface.

18. The article of manufacture of claim 17, wherein generating the second graphical image is based, at least in part, on at least one of a distance, an angle, and an orientation between the object and the display surface.

19. A method comprising:

5 capturing visual data within a target area via a camera, the target area to include at least a portion of the display surface and an area outside the display surface;

generating a graphical image;

displaying the graphical image on the display surface;

identifying an object separate from the monitor within the target area; and

10 processing an interaction of the object with the graphical image.

20. The method of claim 19, further comprising capturing visual data within a second target area via a second camera, the second target area to include at least a portion of the display surface and a second area outside the display surface.

21. The method of claim 20, wherein the display surface is included in a tablet

15 computer, and further wherein the cameras are each coupled to the tablet computer via a fastener extended upright relative to the display surface.

22. The method of claim 19, further comprising

identifying the object within the target area and outside the display surface; and

in response to identifying the object within the target area and outside the display

20 surface

generating a second graphical image representing the object, and

displaying the second graphical image on the display surface,

wherein generating the second graphical image is based, at least in part, on at least one of a distance, an angle, and an orientation between the object and the display surface.

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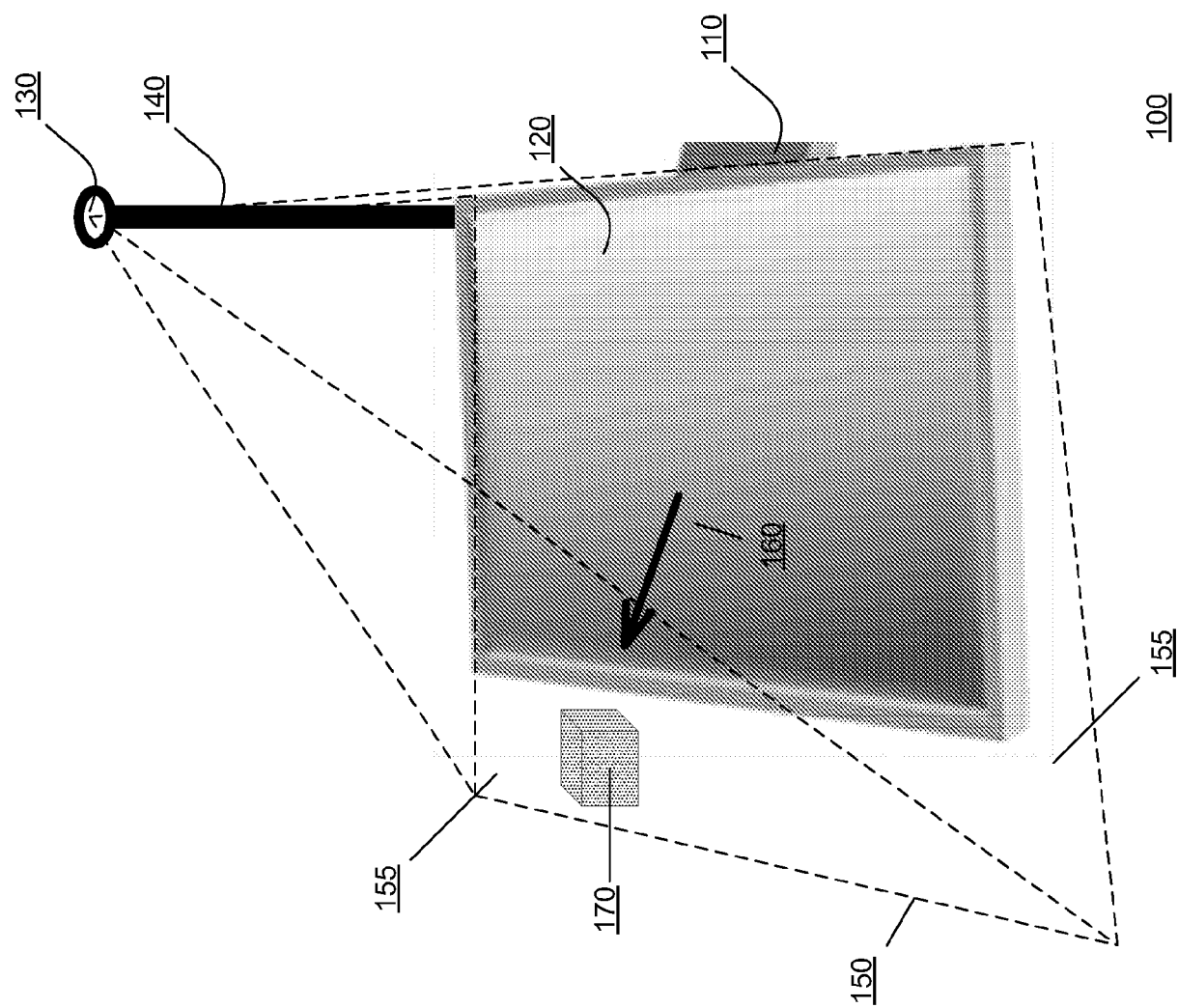


FIG. 1

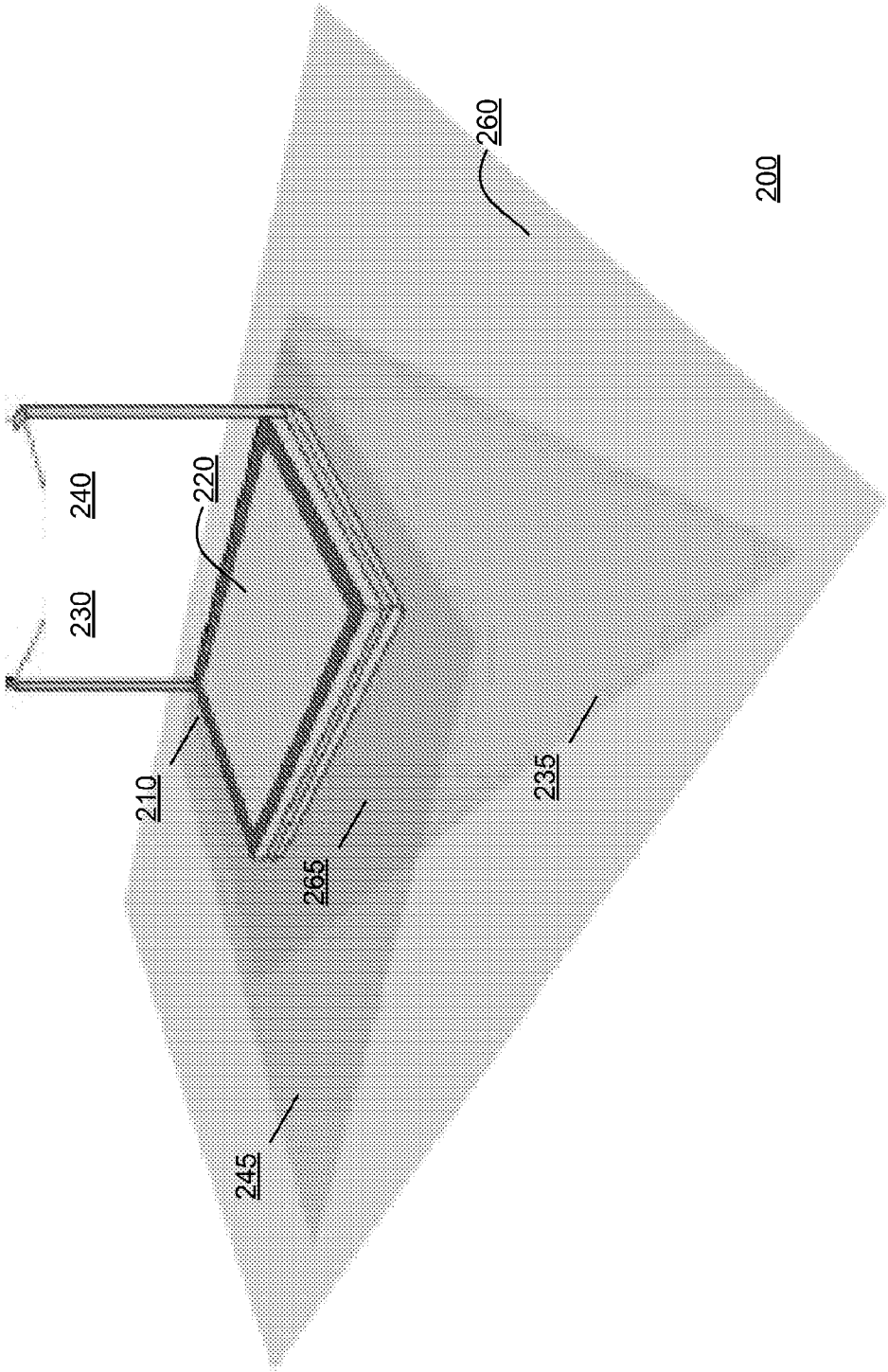


FIG. 2

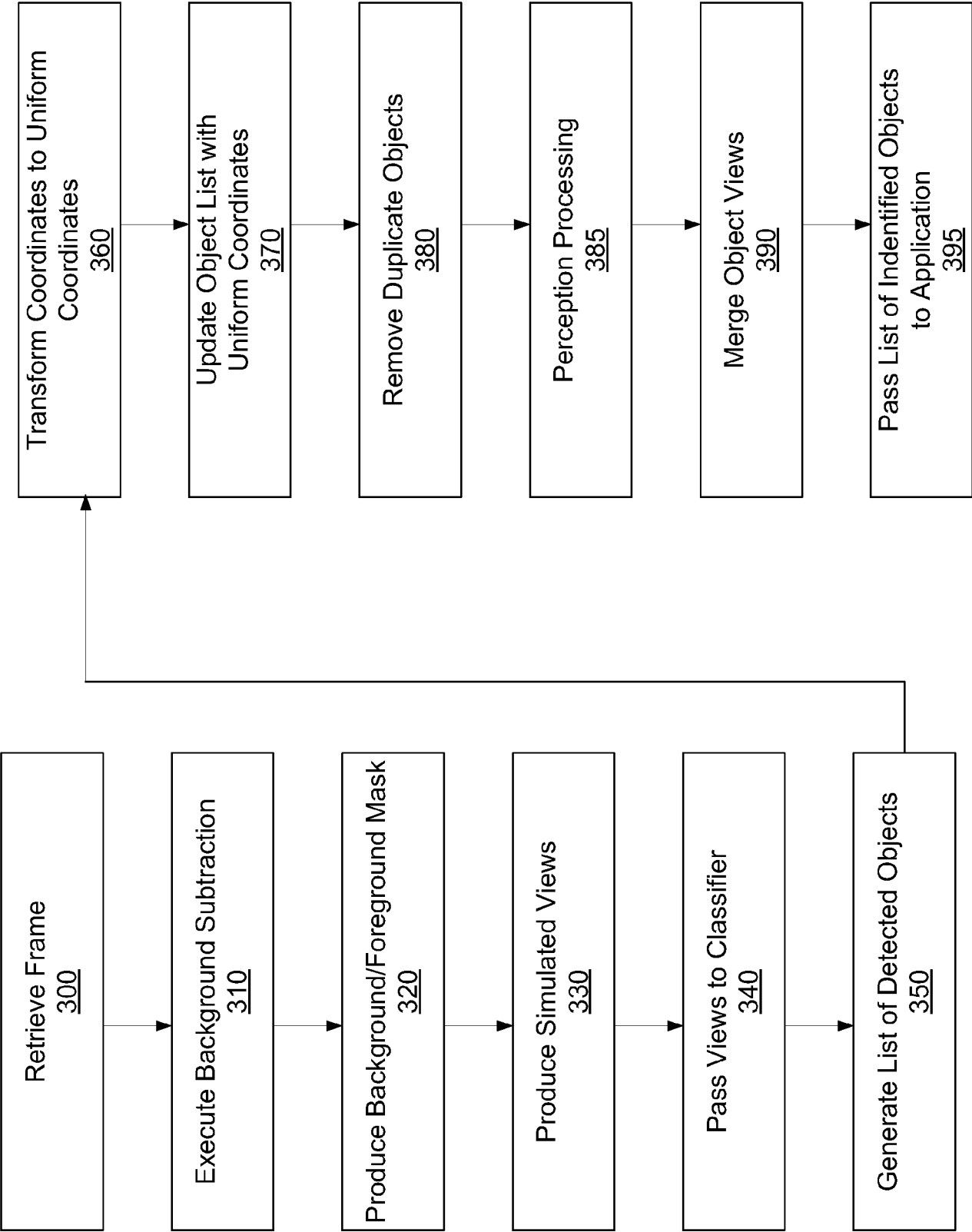
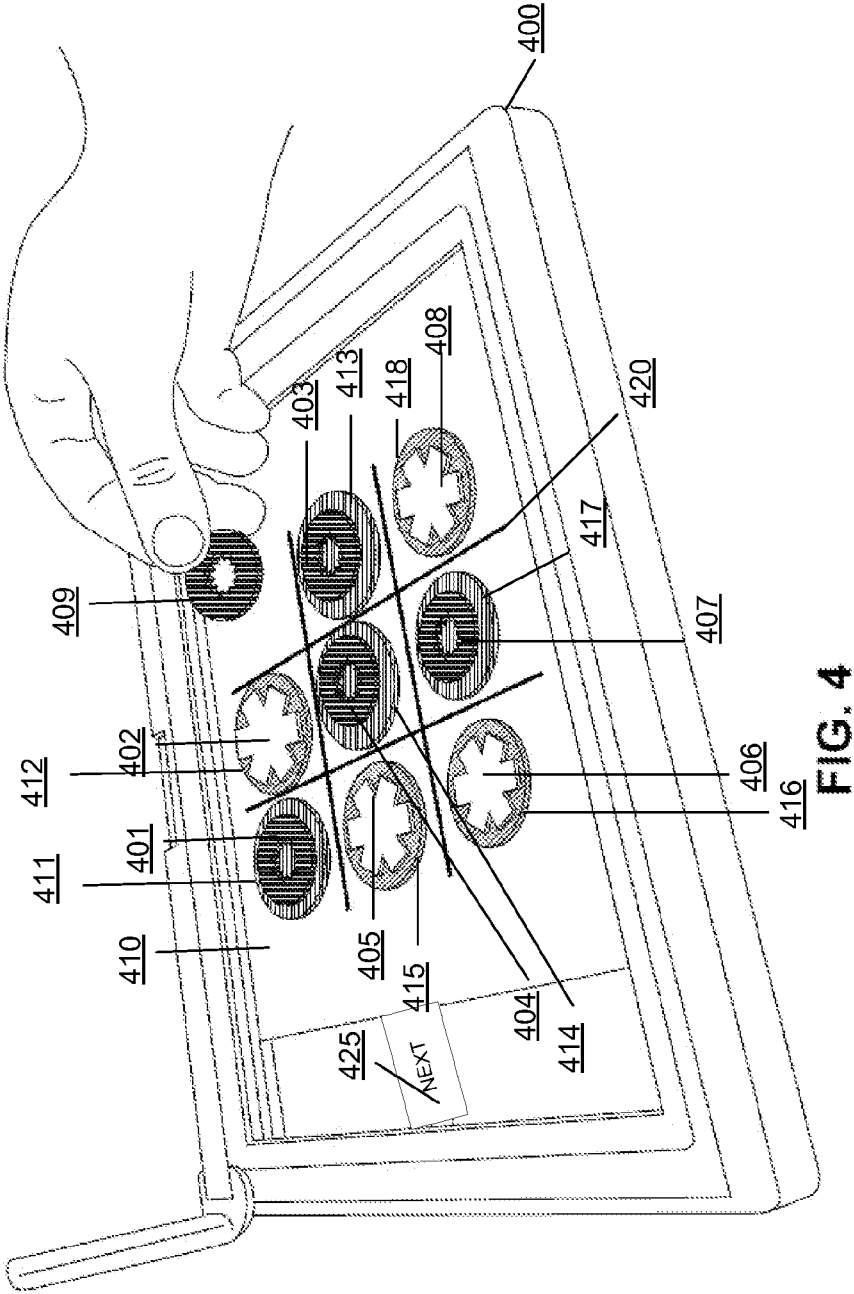


FIG. 3



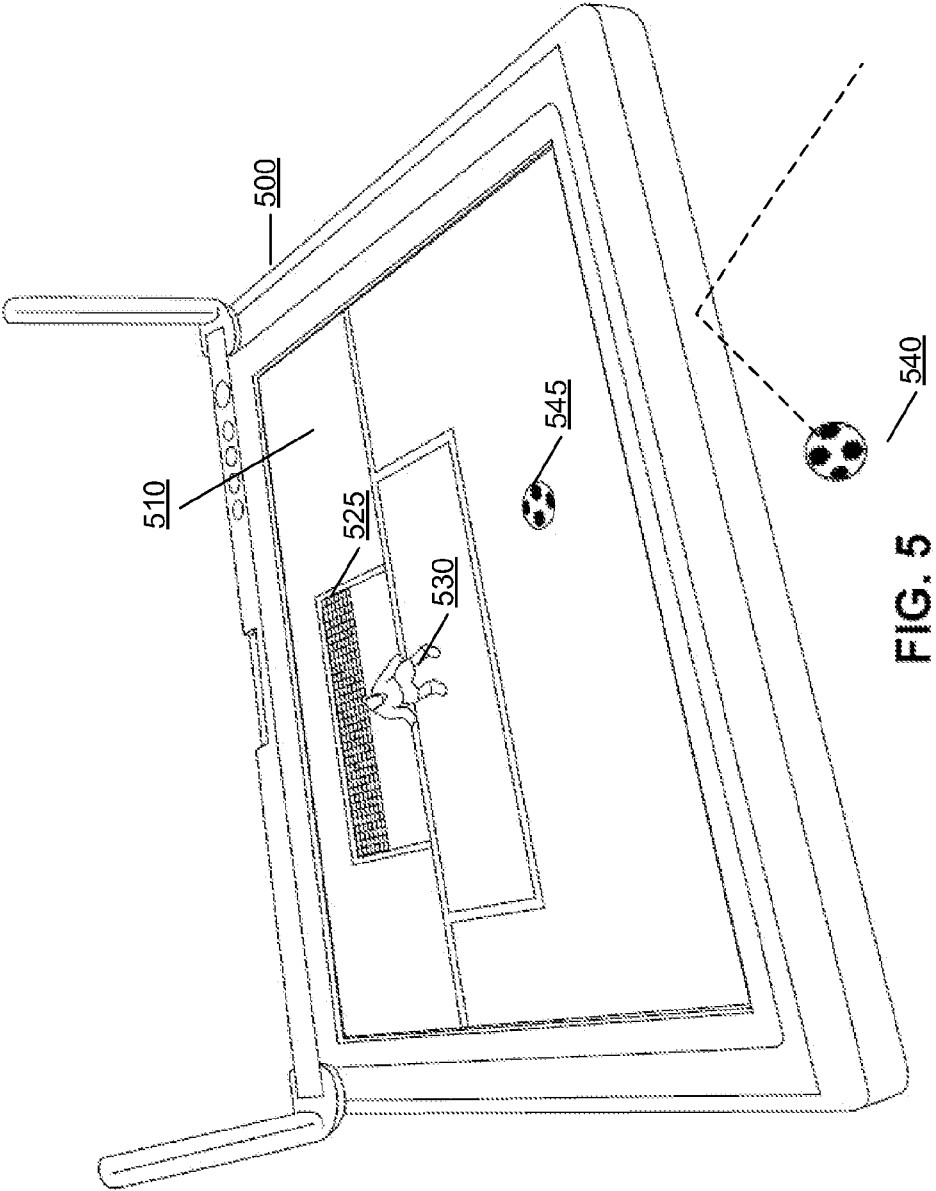


FIG. 5

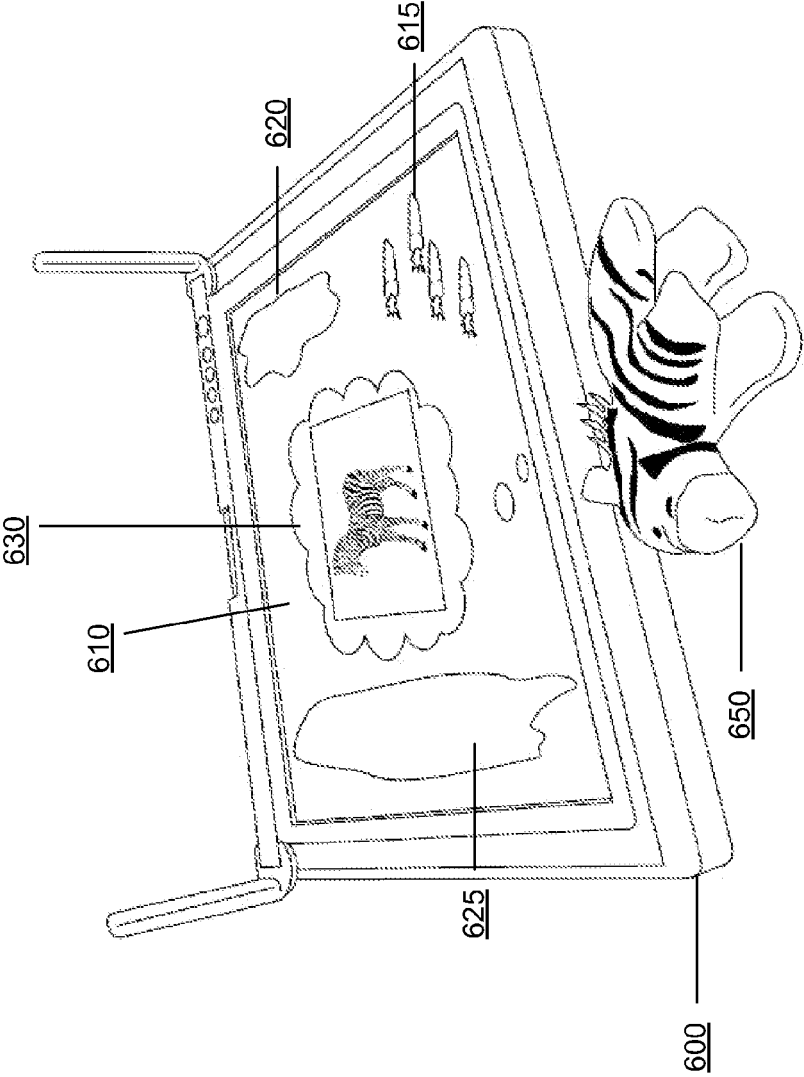


FIG. 6