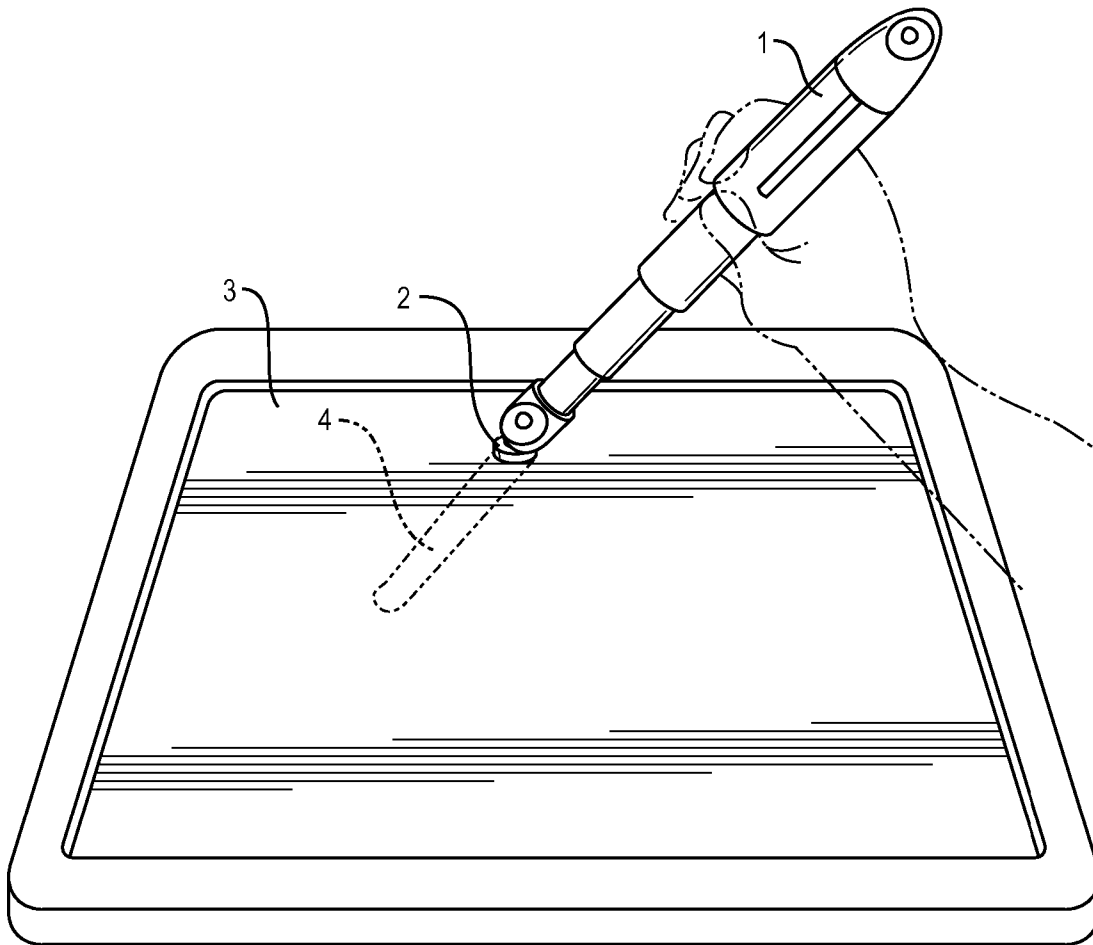




US 20120206419A1

(19) **United States**(12) **Patent Application Publication****Lee et al.**(10) **Pub. No.: US 2012/0206419 A1**(43) **Pub. Date: Aug. 16, 2012**(54) **COLLAPSIBLE INPUT DEVICE**(75) Inventors: **Jinha Lee**, Cambridge, MA (US);
Hiroshi Ishii, Cambridge, MA (US)(73) Assignee: **MASSACHUSETTS INSTITUTE
OF TECHNOLOGY**, Cambridge,
MA (US)(21) Appl. No.: **13/026,156**(22) Filed: **Feb. 11, 2011****Publication Classification**(51) **Int. Cl.**
G06F 3/033 (2006.01)(52) **U.S. Cl.** **345/179**(57) **ABSTRACT**

In exemplary implementations of this invention, a handheld, collapsible input device (CID) may be employed by a user to input and manipulate 3D information. The CID telescopes in length. As a user presses the CID against a display screen, the physical length of the CID shortens, and the display screen displays a virtual end of the CID that appears to project through the screen into the virtual 3D space behind the screen. The total apparent length of the CID, comprised of a physical portion and a virtual portion, remains the same (after taking into account foreshortening). Thus, the user experience is that, as the user holds the physical CID and pushes it against the display screen, the end of the CID appears to be pushed through the display screen into the virtual 3D space beyond it. The CID housing may include a push button for user input.



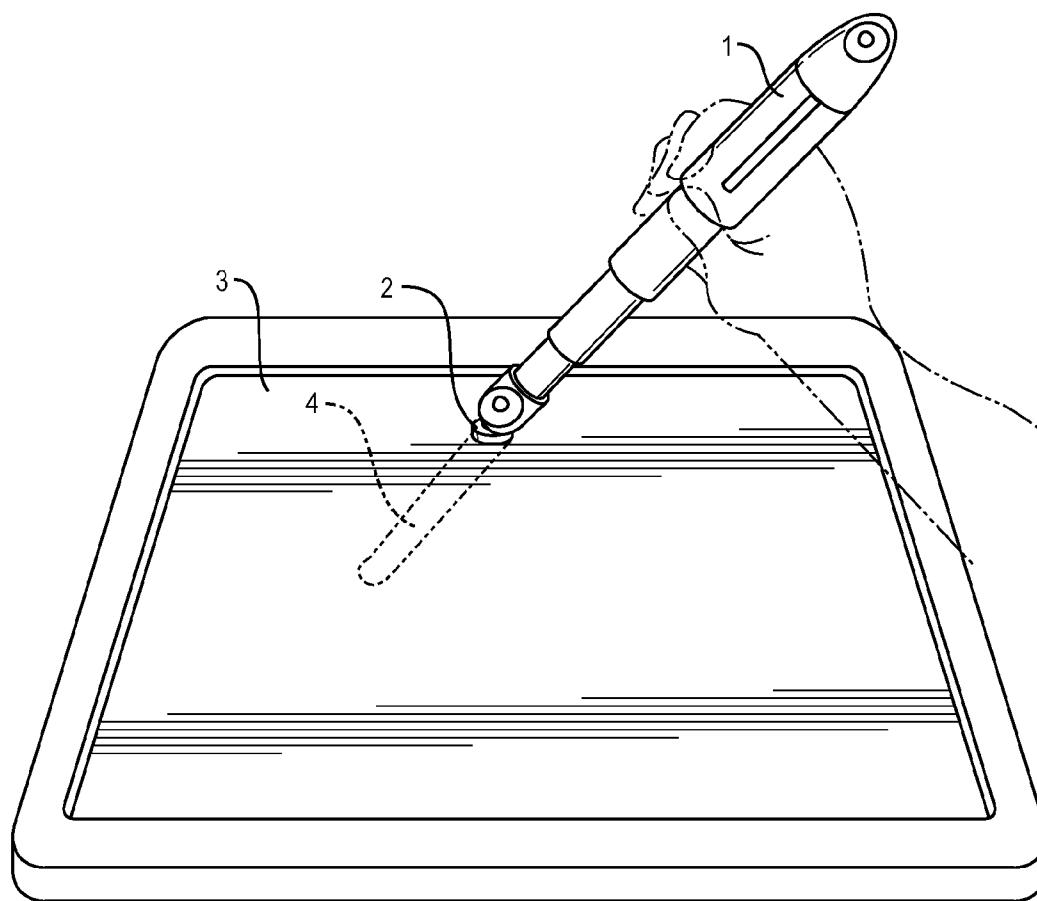


FIG. 1

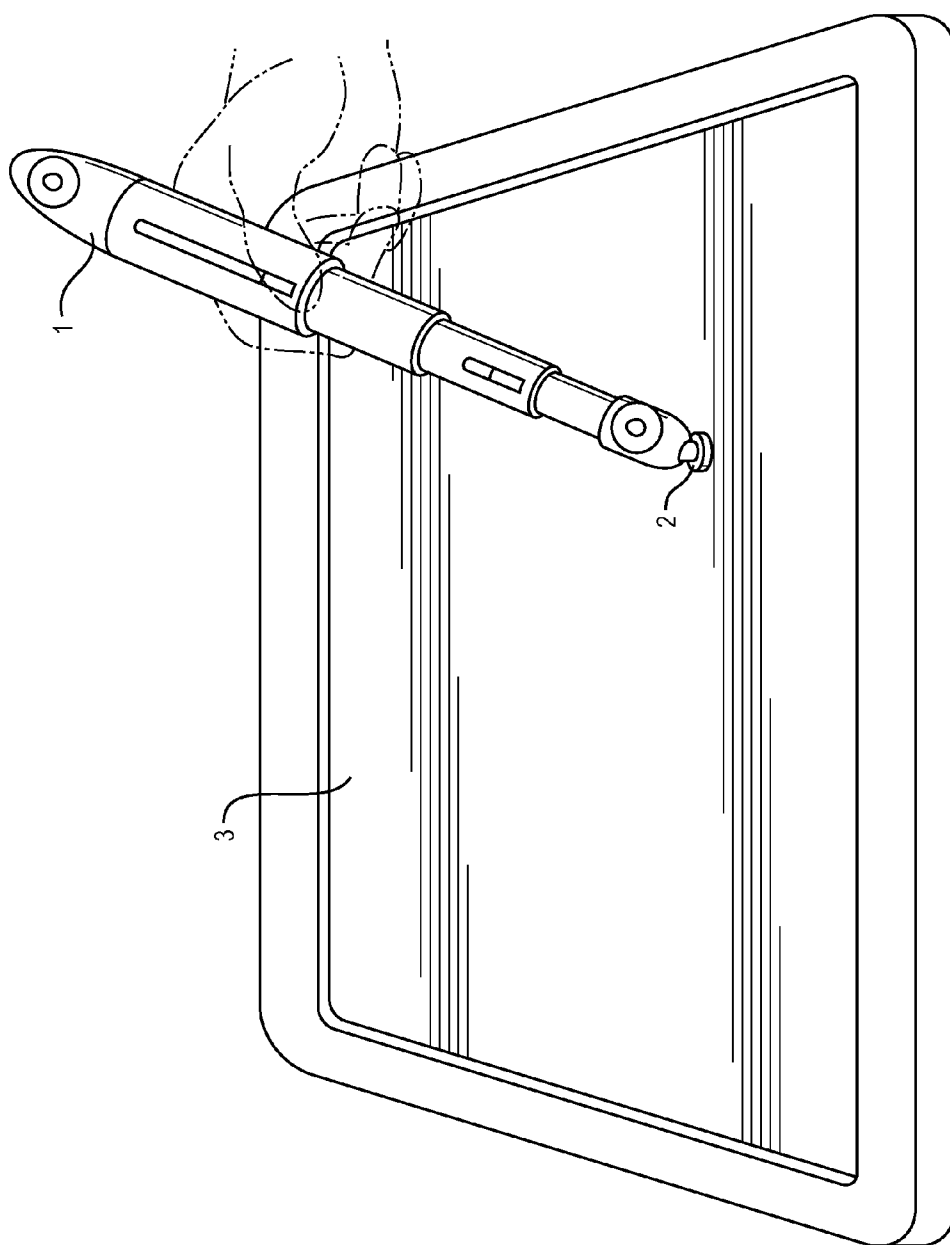


FIG. 2A

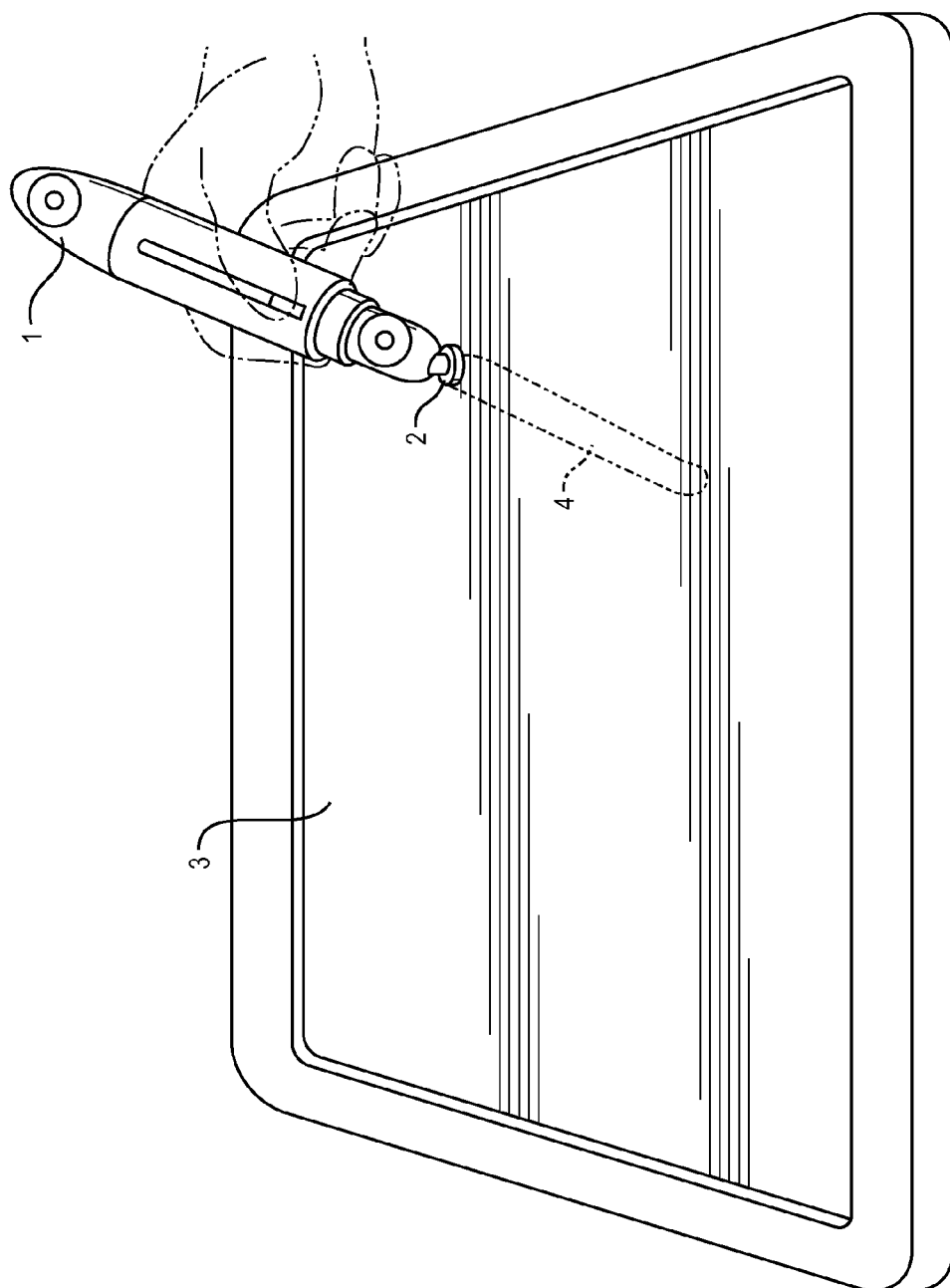


FIG. 2B

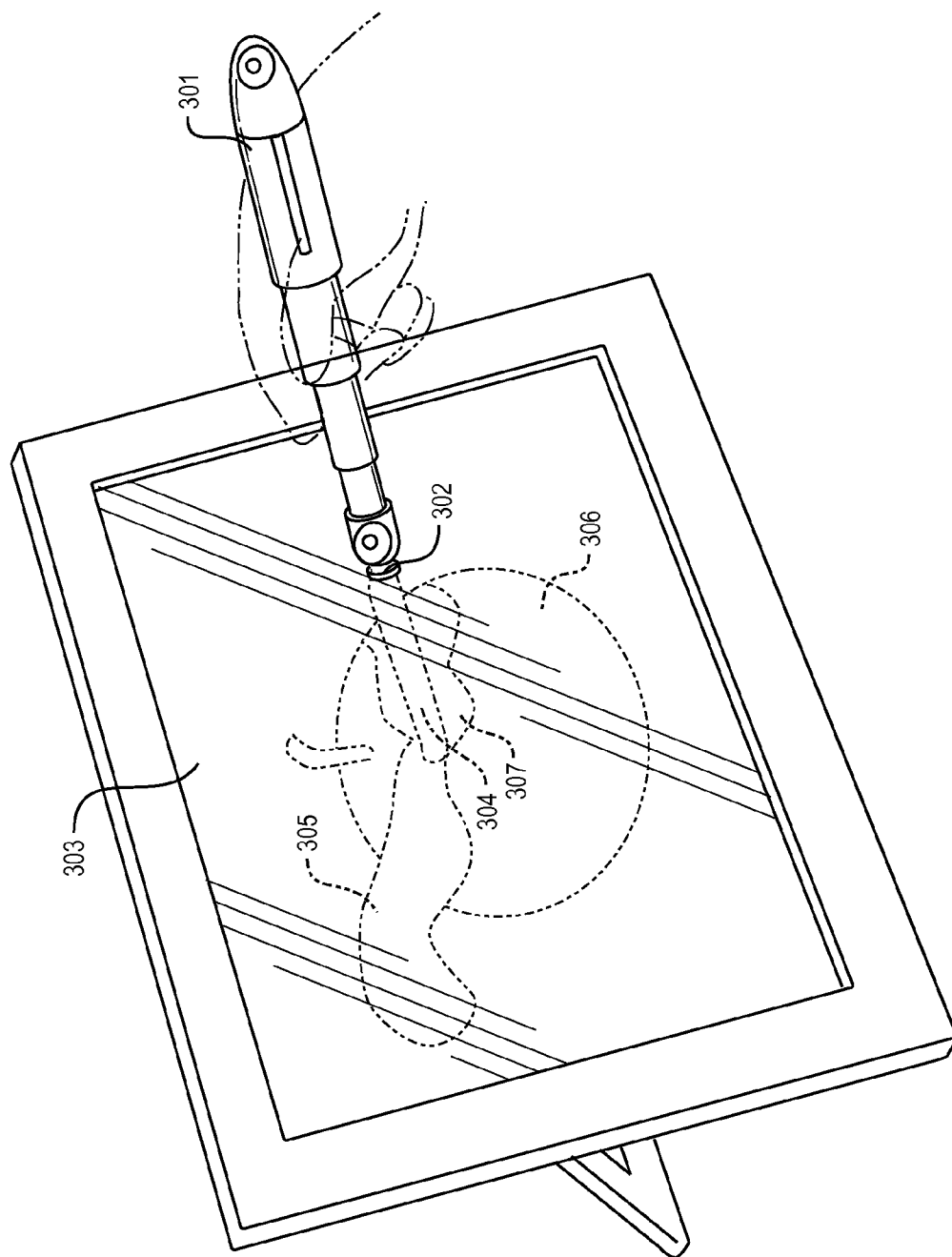


FIG. 3

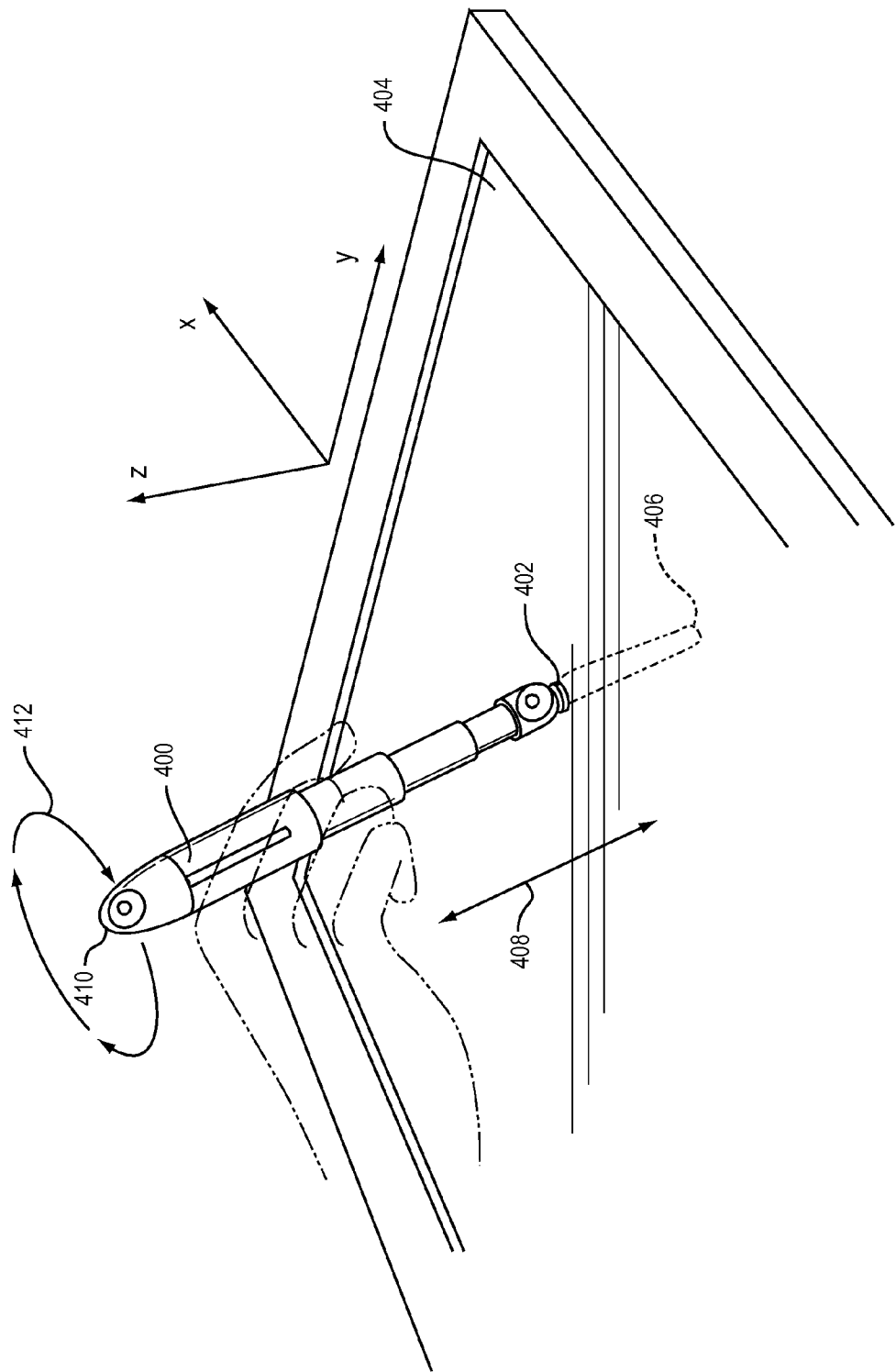


FIG. 4A

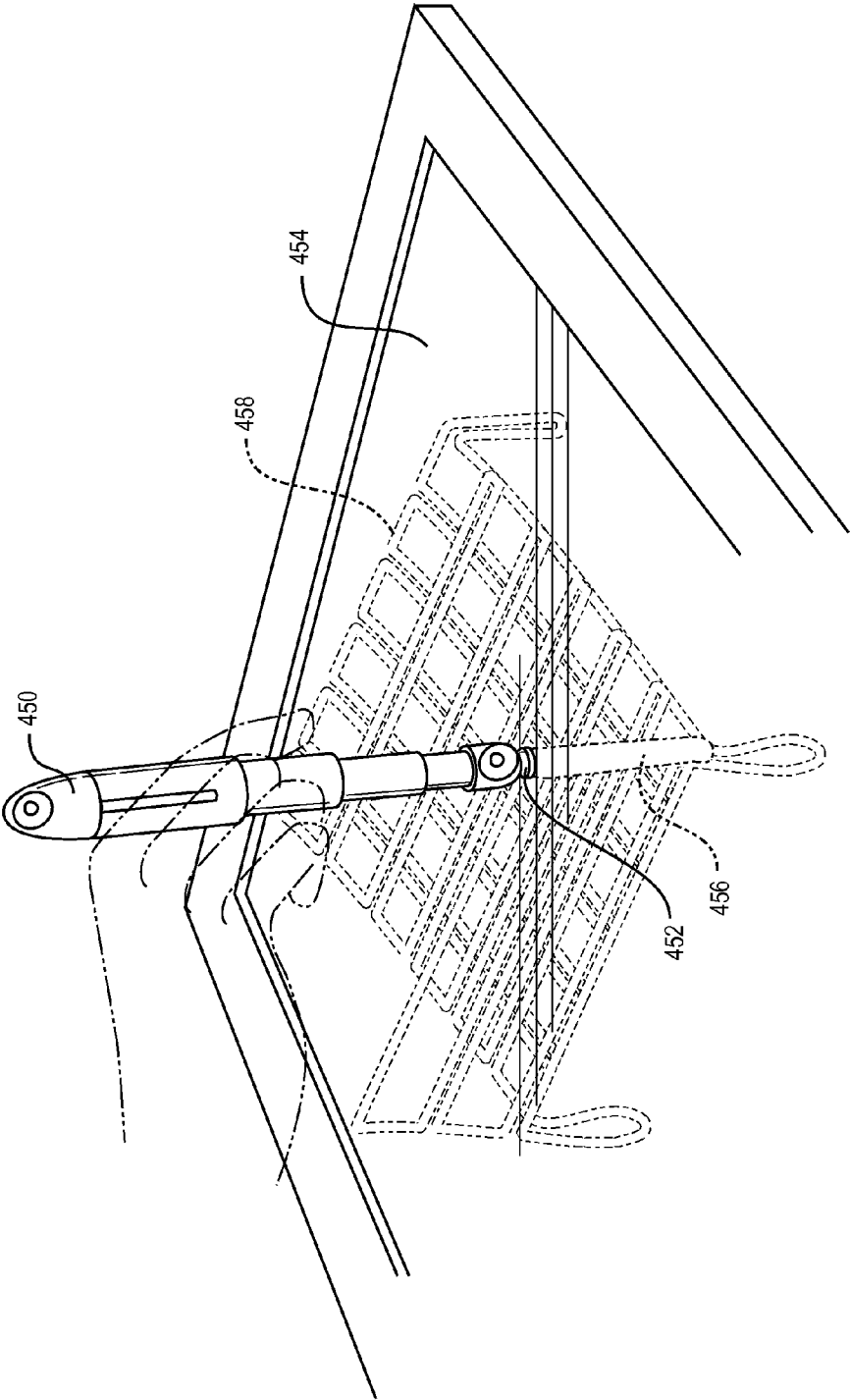


FIG. 4B

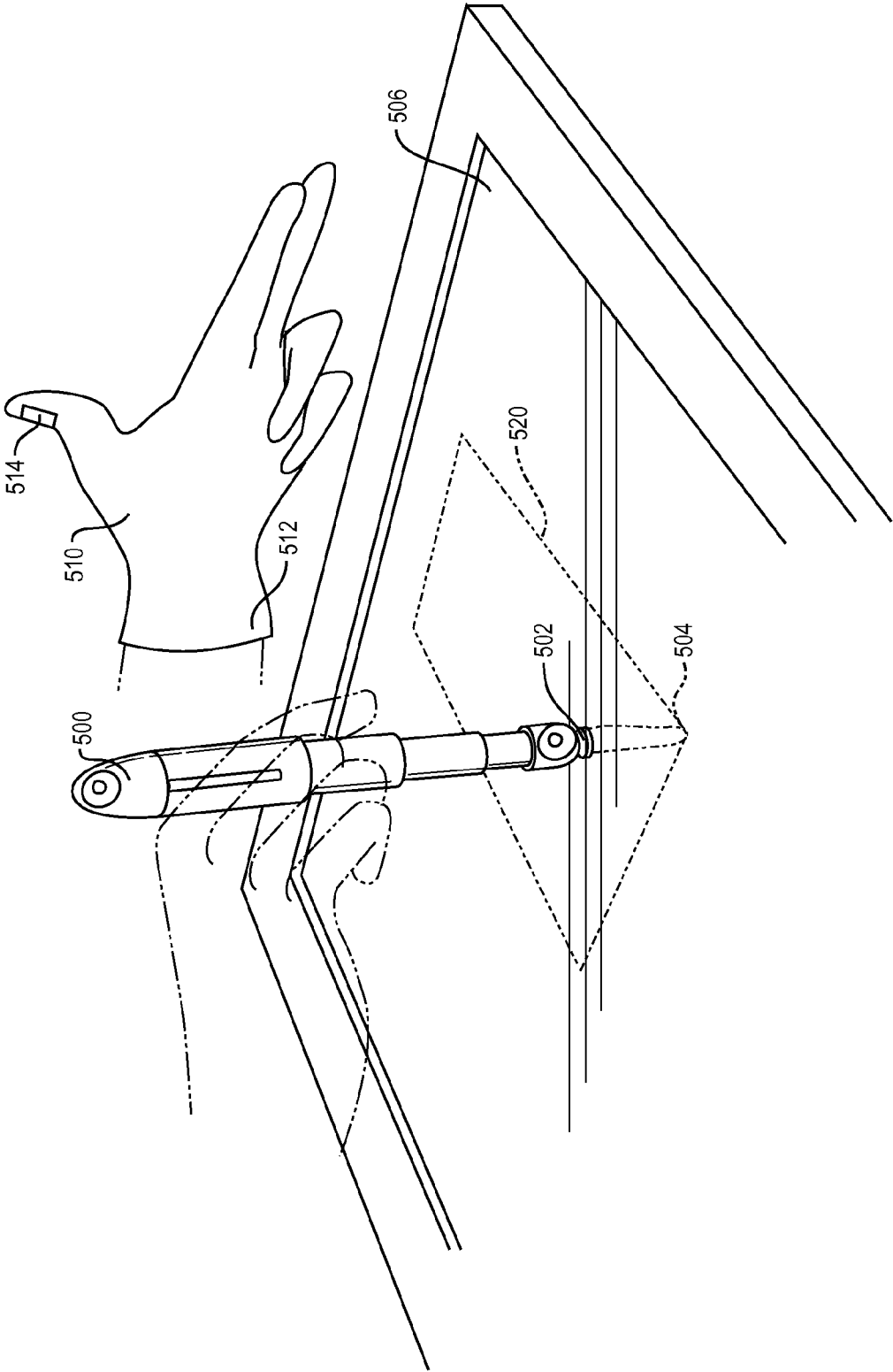


FIG. 5A

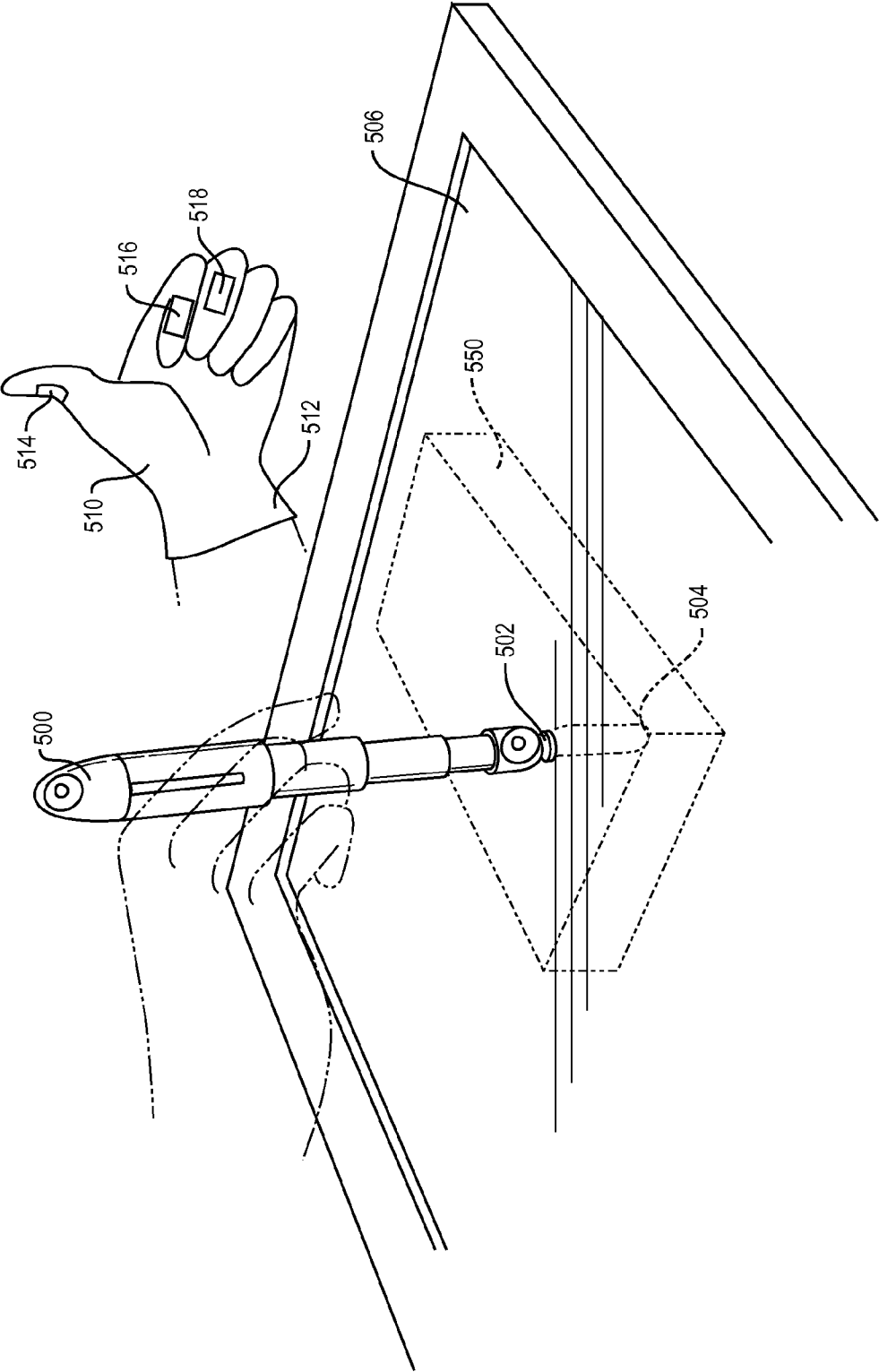


FIG. 5B

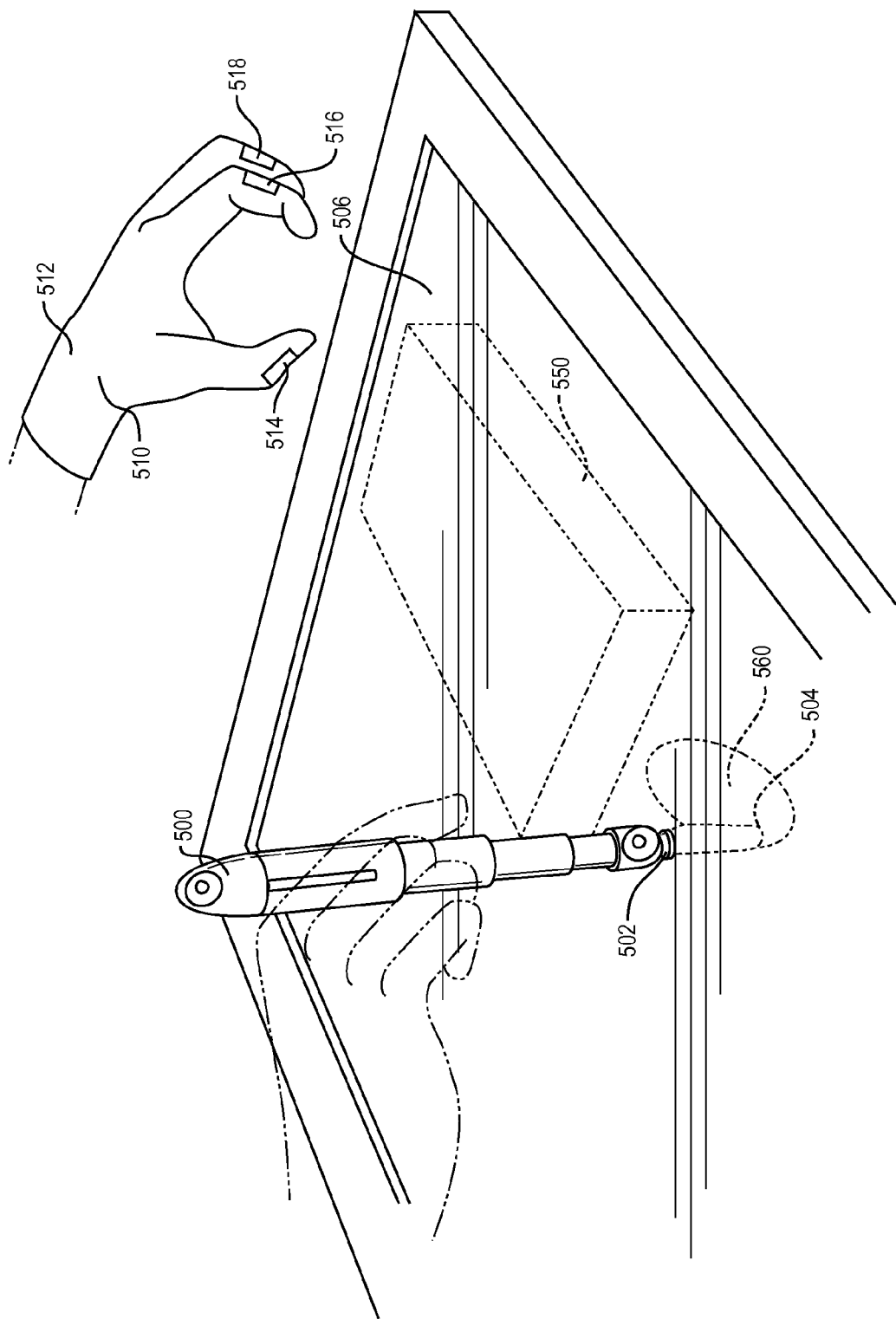


FIG. 5C

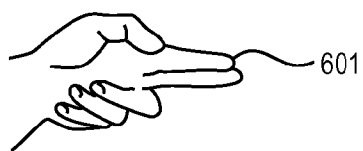


FIG. 6A

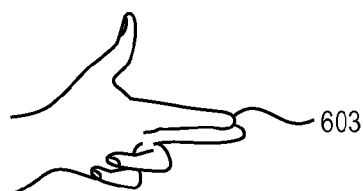


FIG. 6B

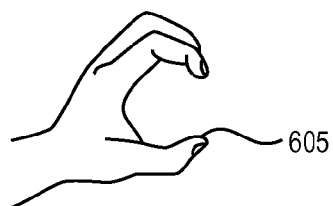


FIG. 6C

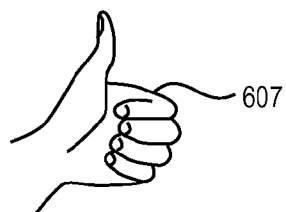


FIG. 6D



FIG. 6E

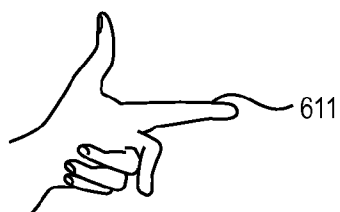


FIG. 6F

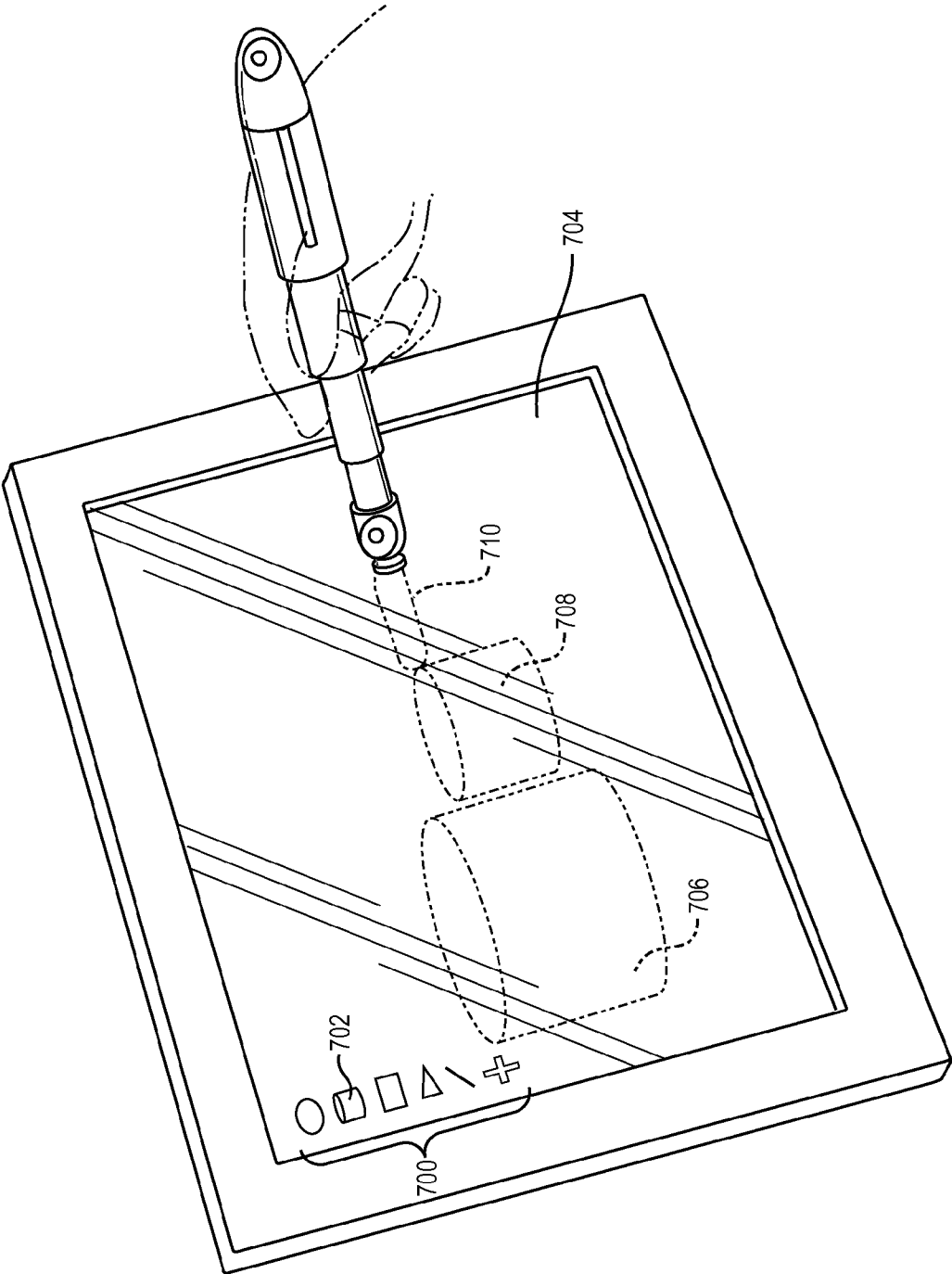


FIG. 7

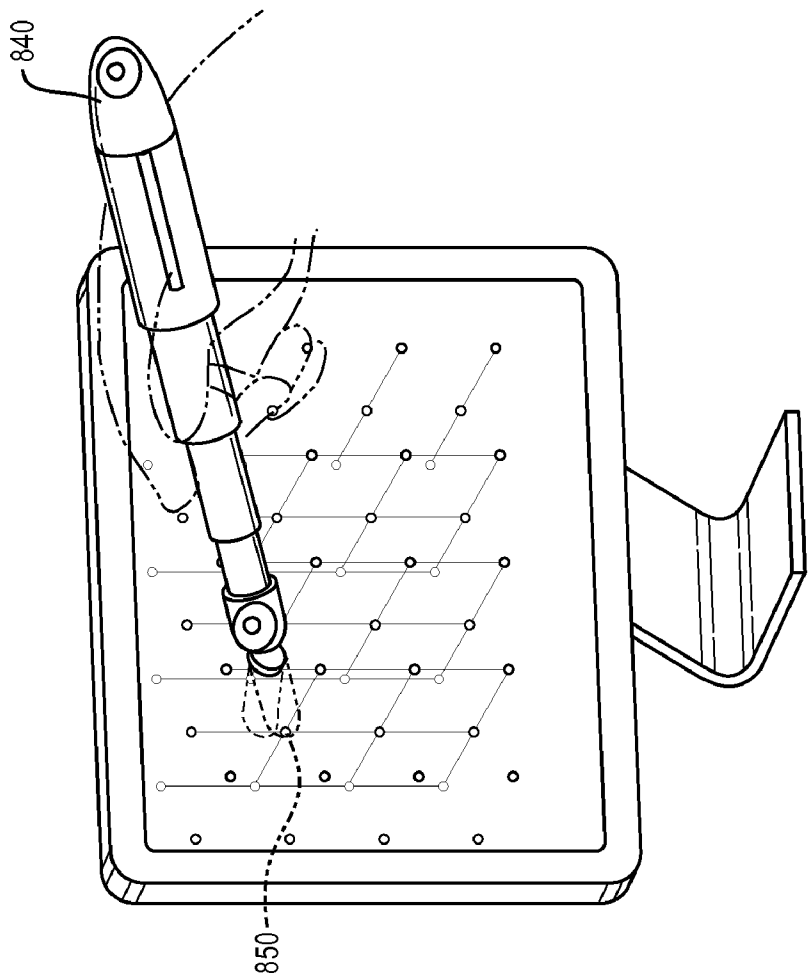


FIG. 8B

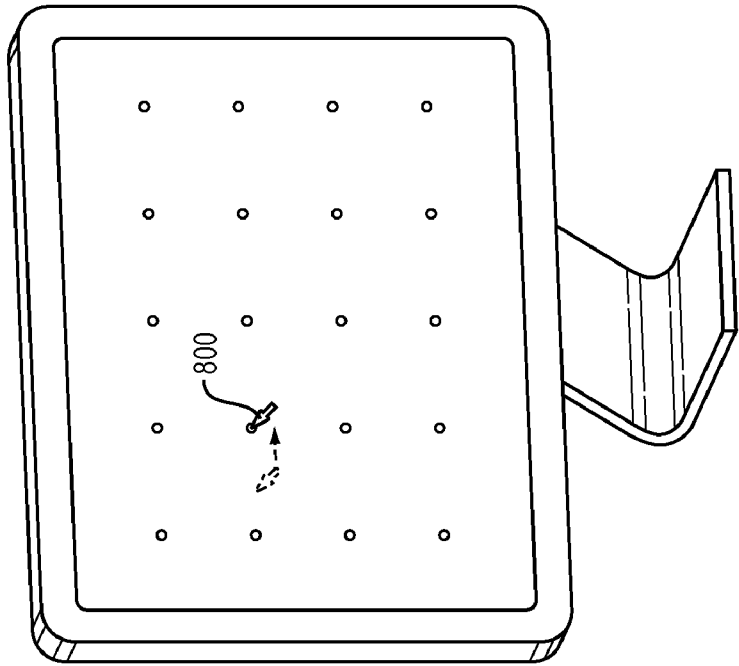


FIG. 8A
(PRIOR ART)

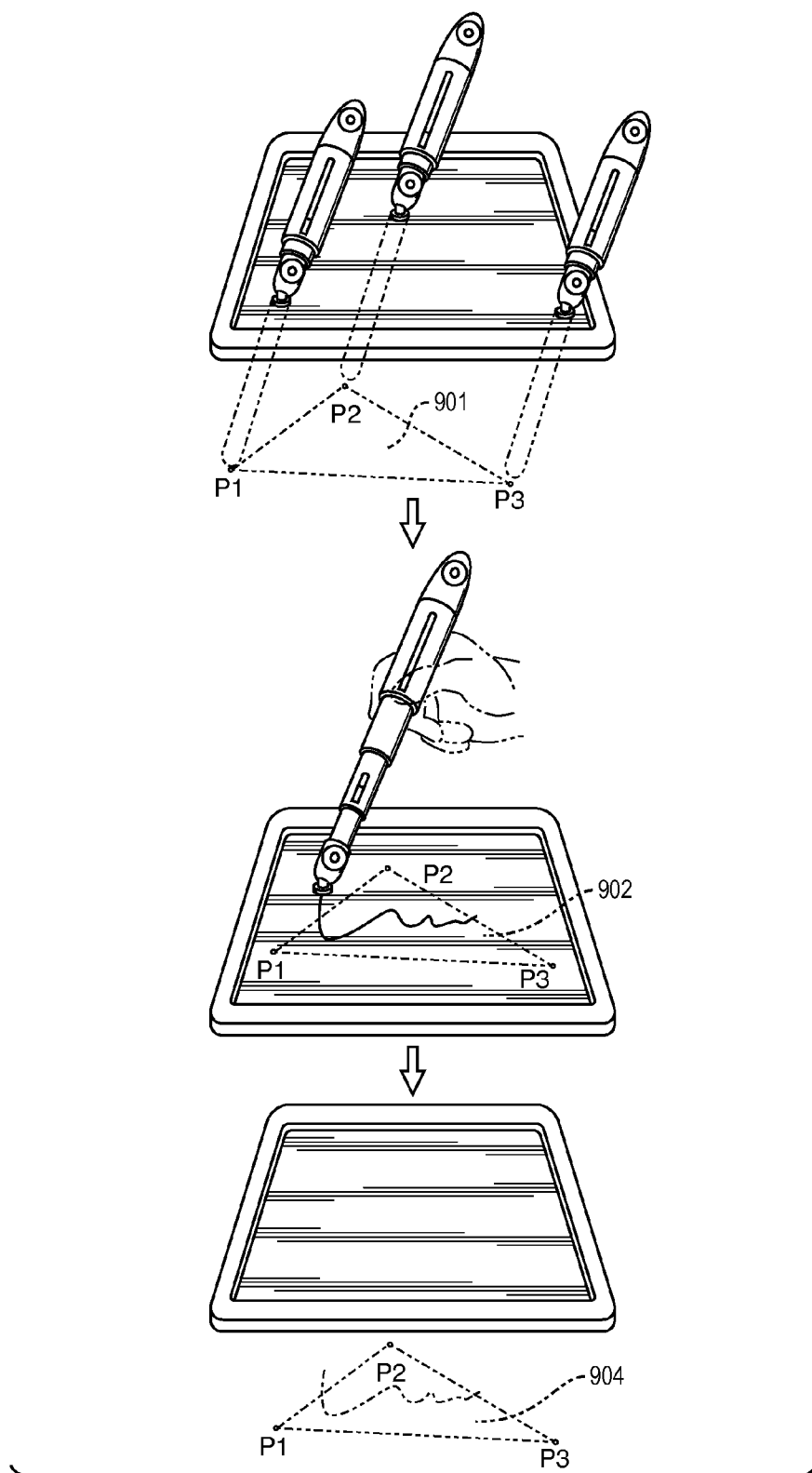


FIG. 9

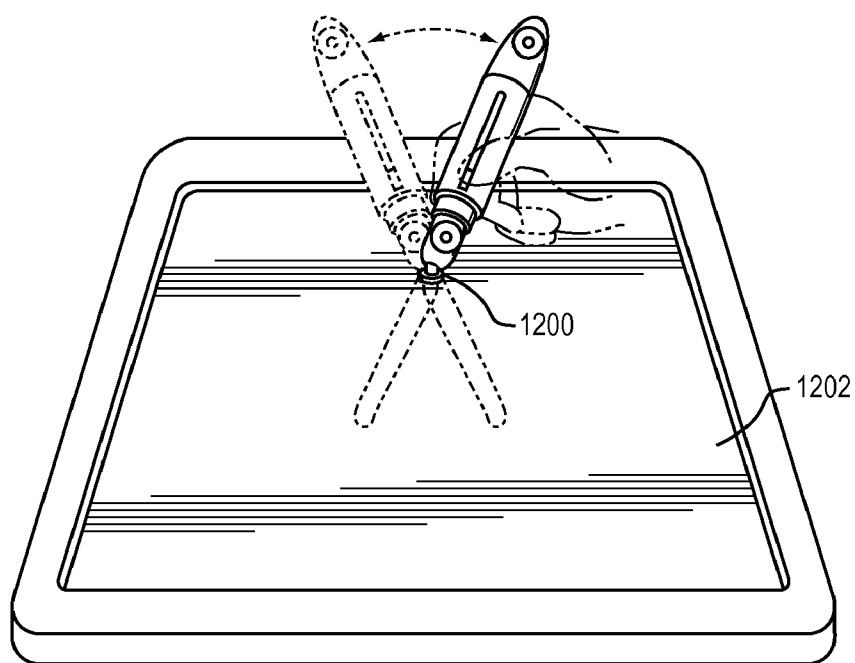


FIG. 10

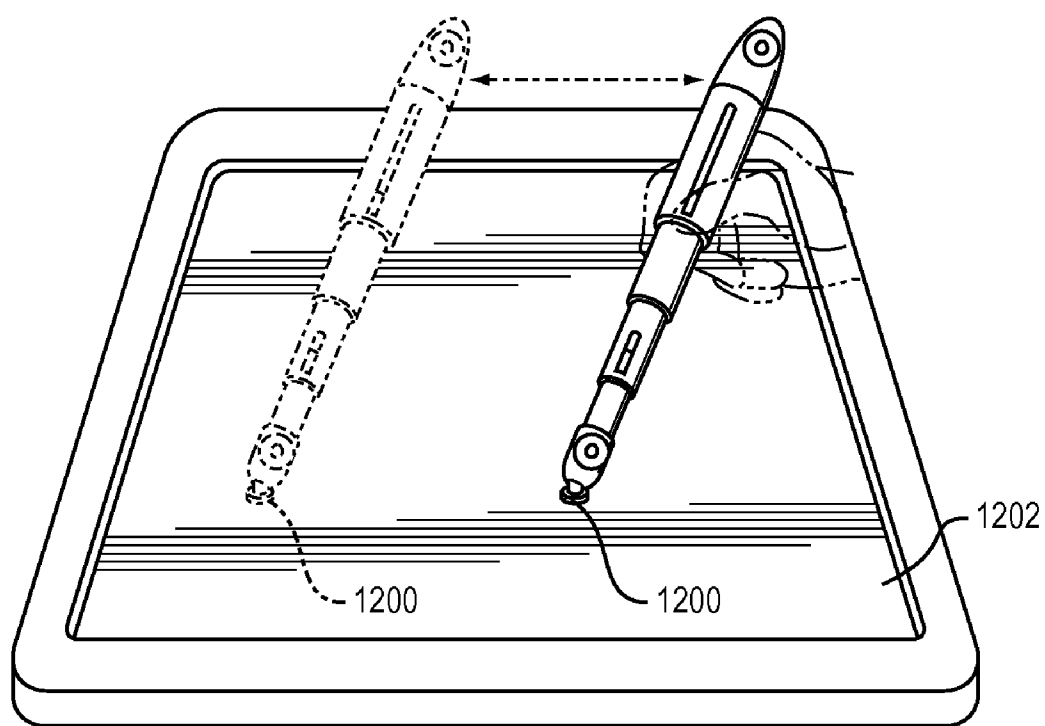


FIG. 11

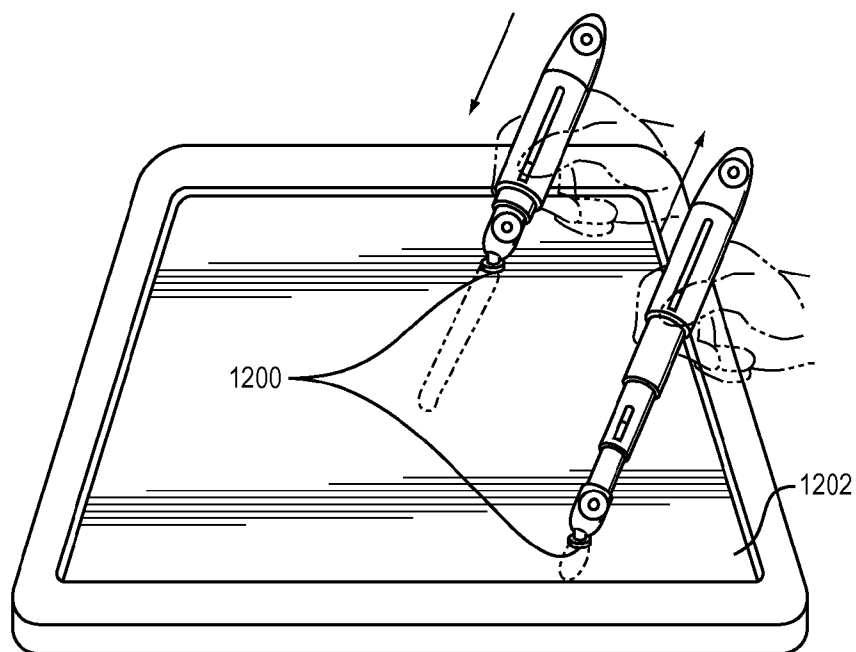


FIG. 12A

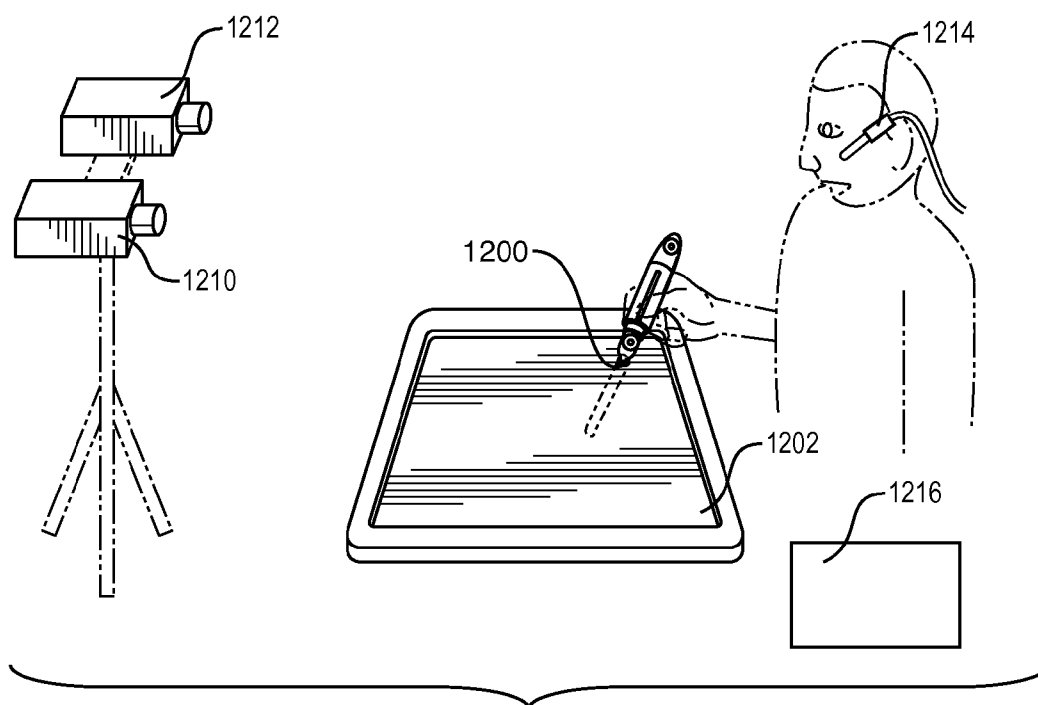


FIG. 12B

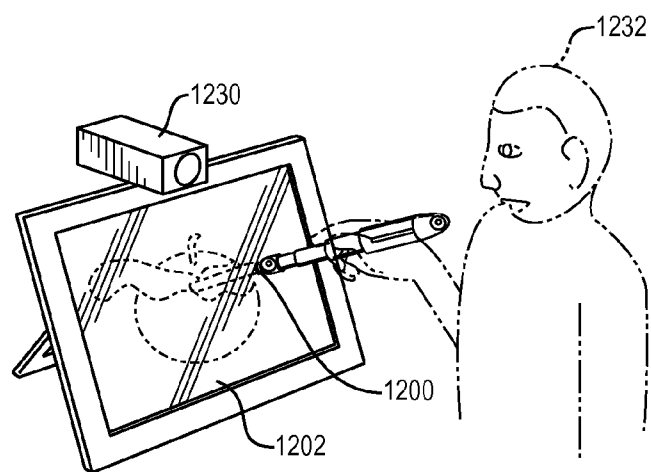


FIG. 12C

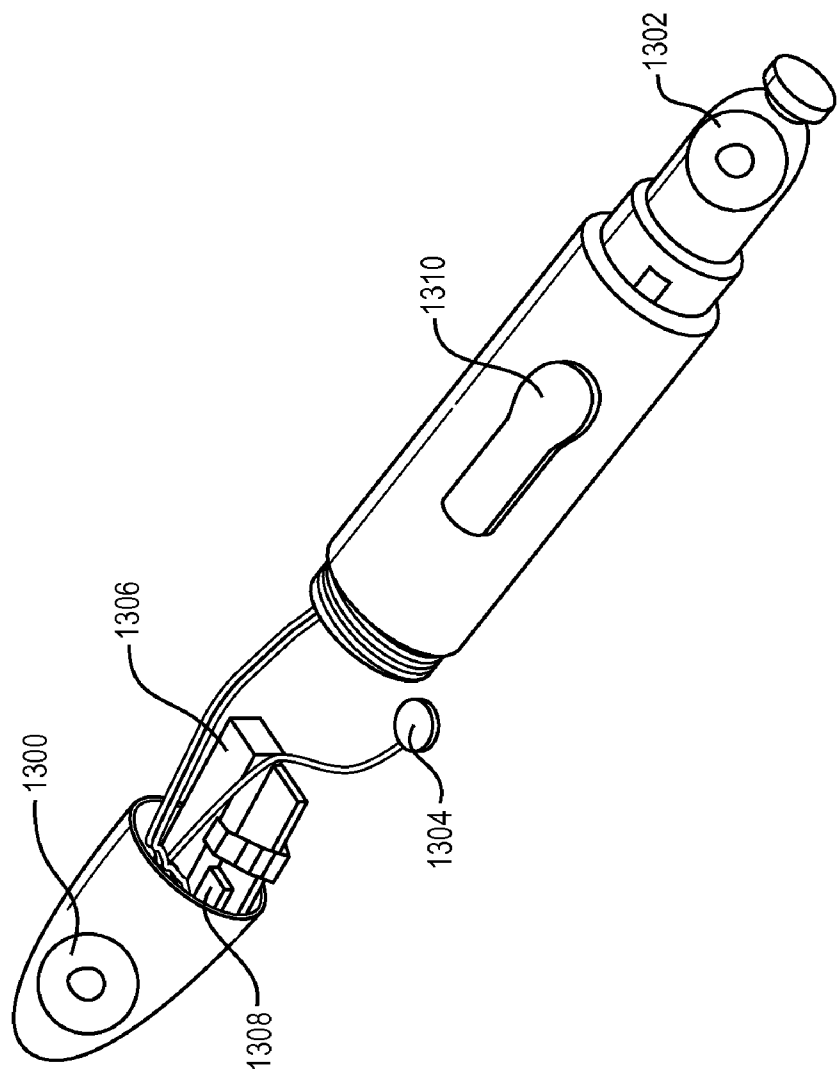


FIG. 13

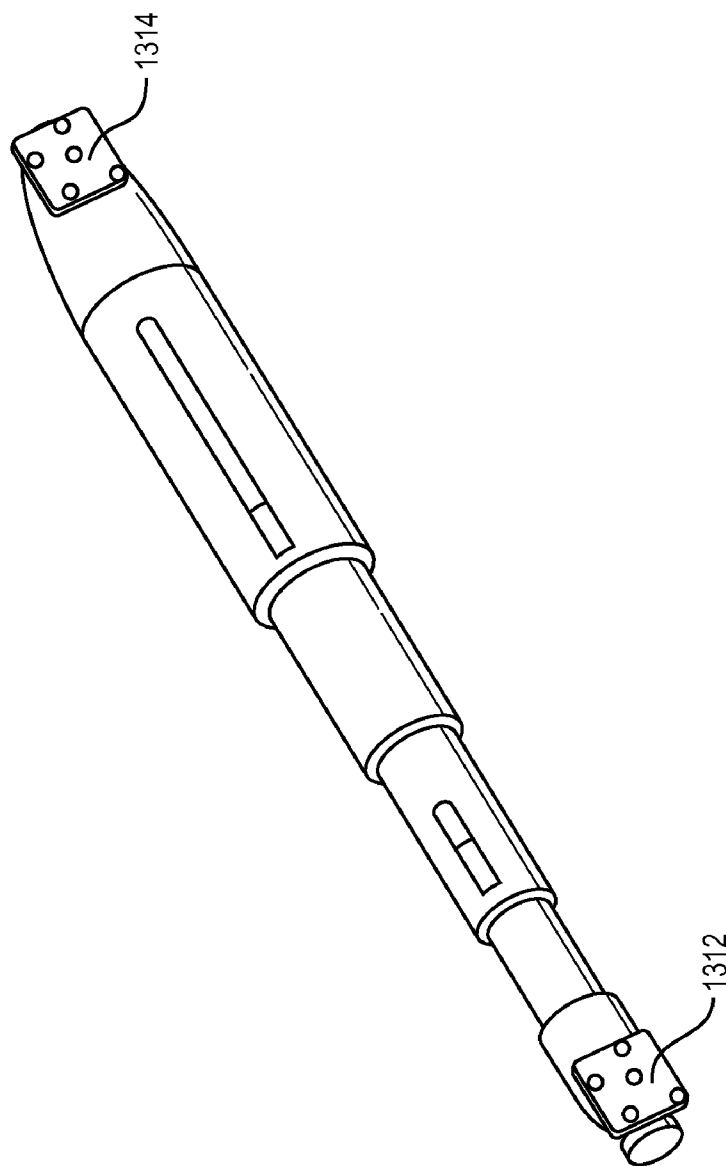


FIG. 14

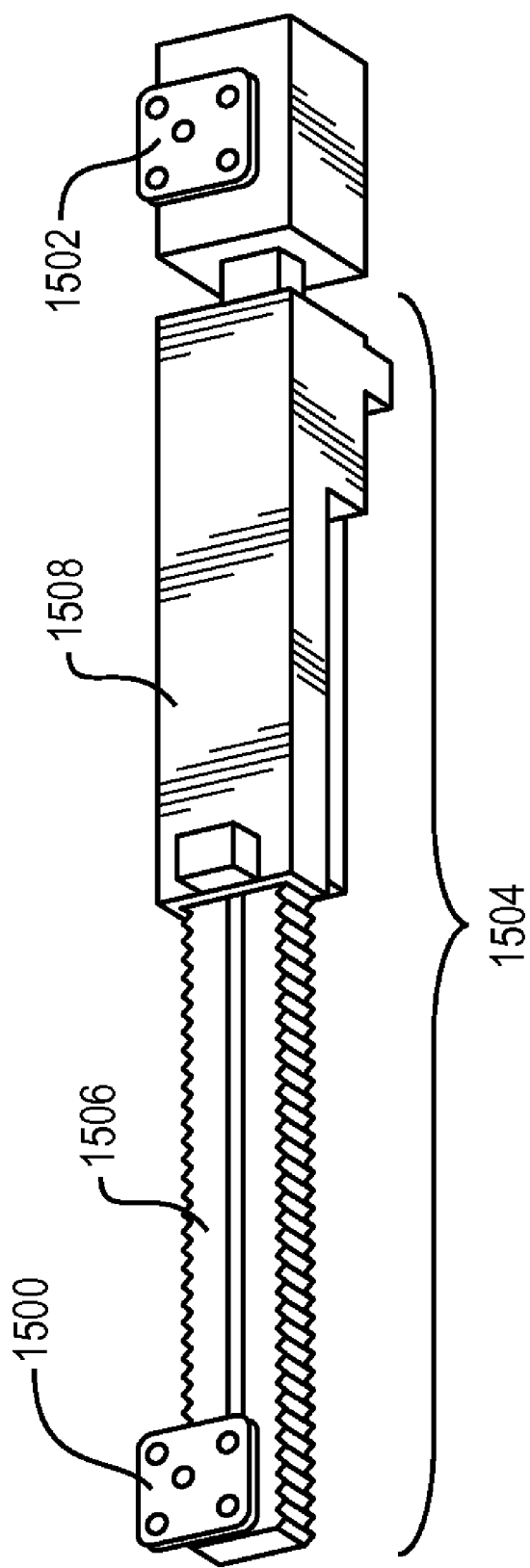


FIG. 15

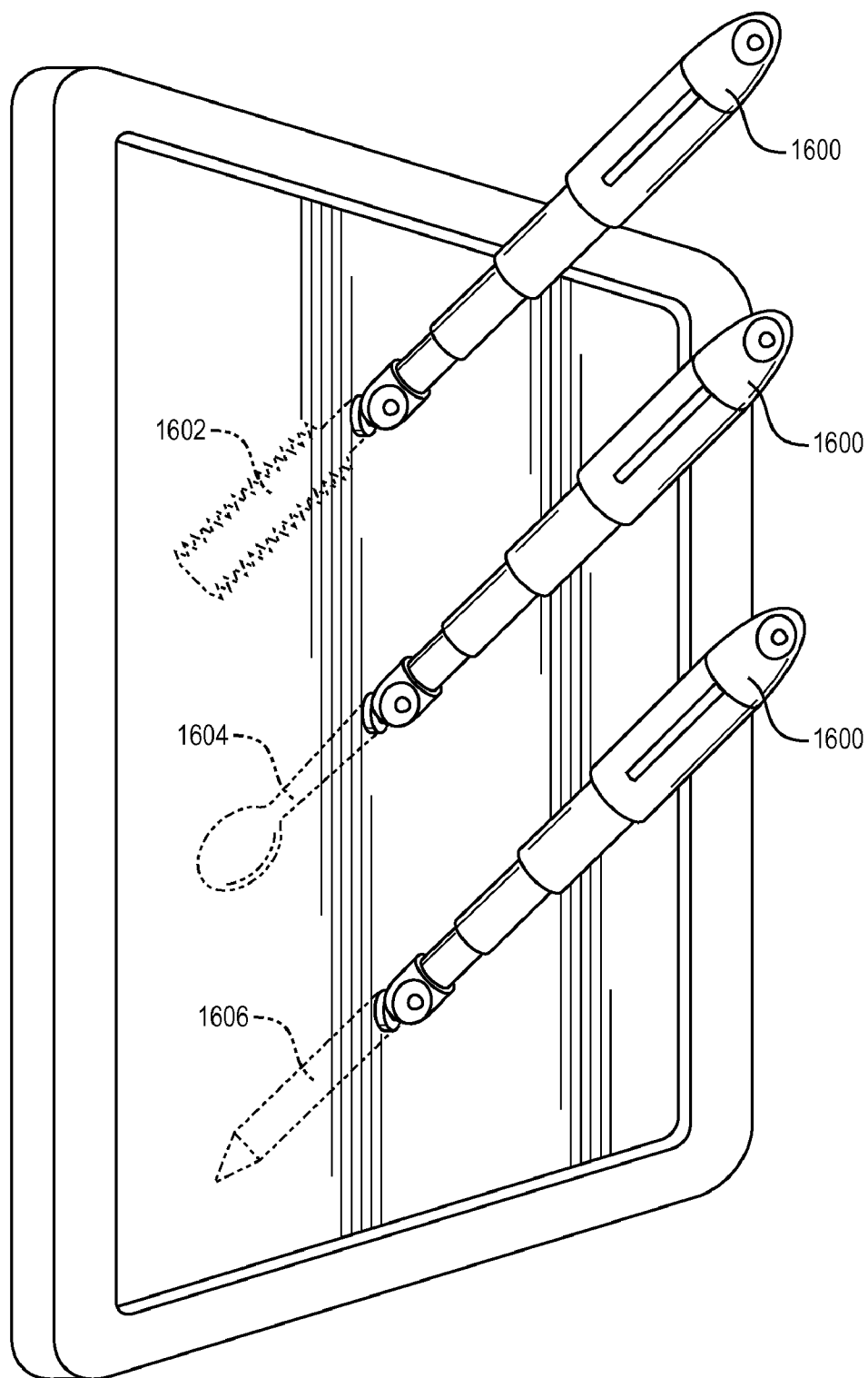


FIG. 16

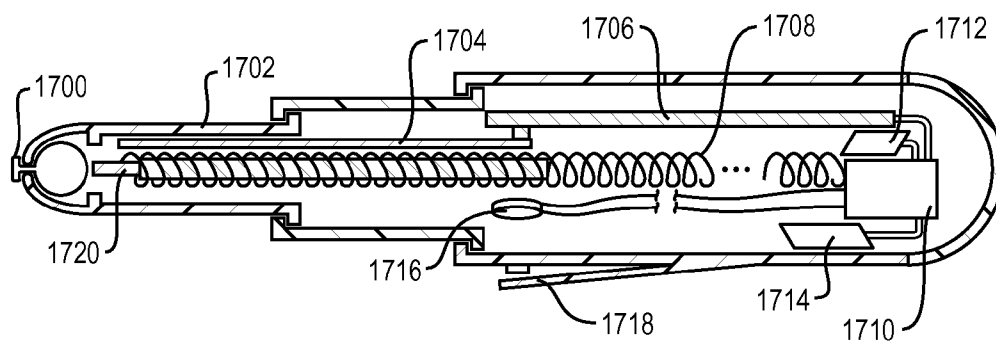


FIG. 17A

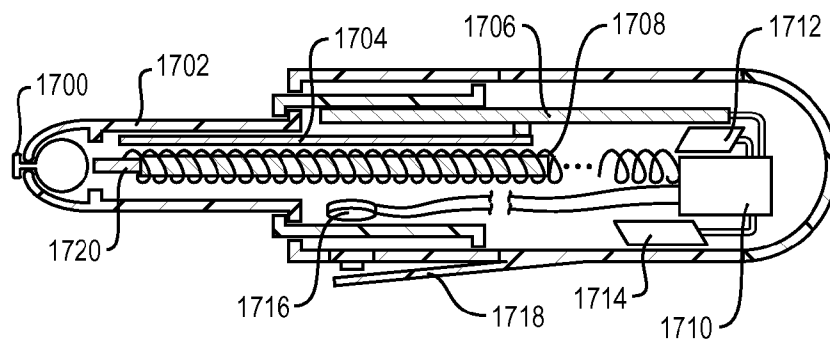


FIG. 17B

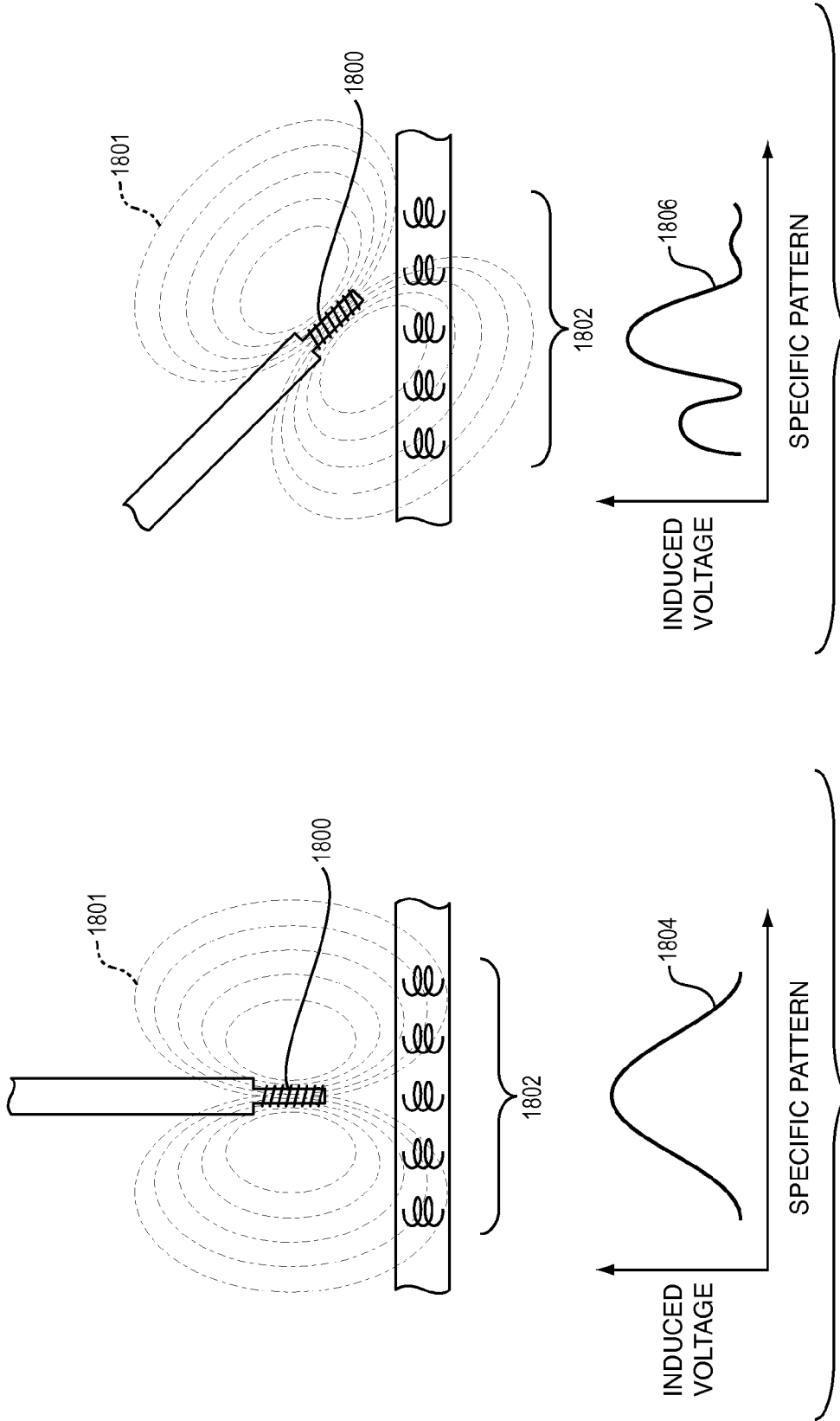


FIG. 18B

FIG. 18A

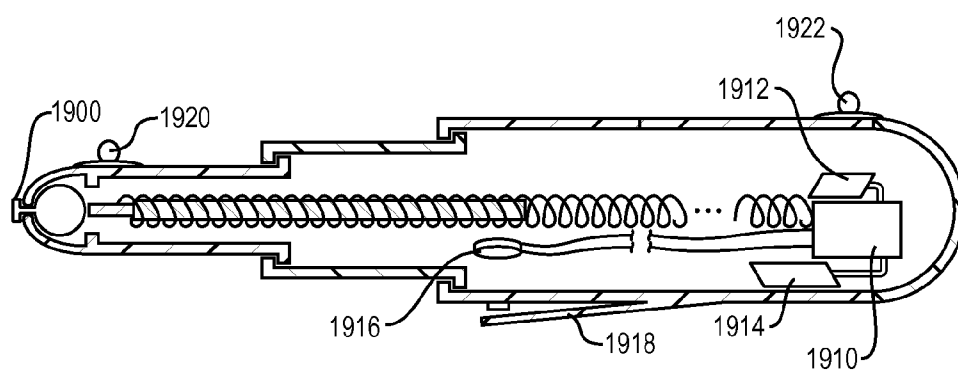


FIG. 19

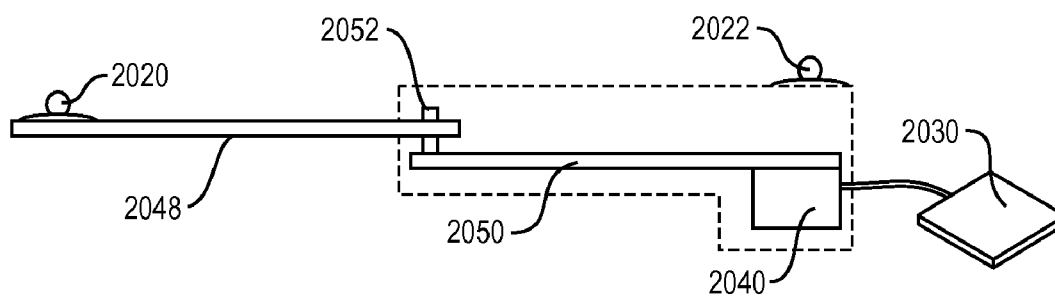


FIG. 20A

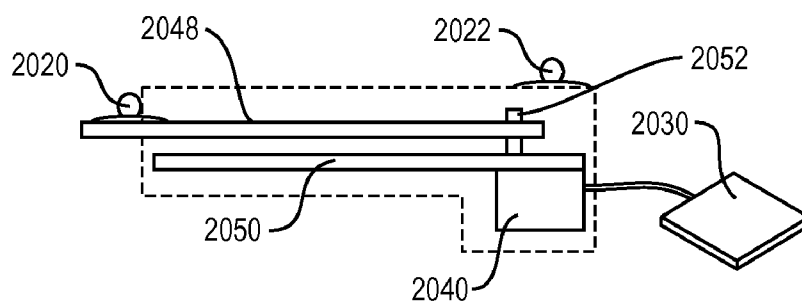


FIG. 20B

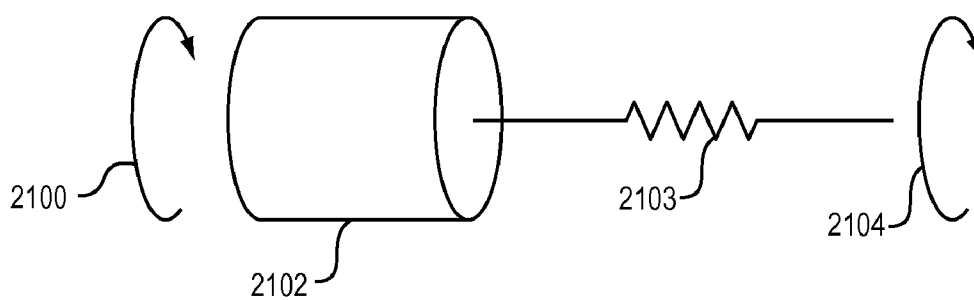


FIG. 21

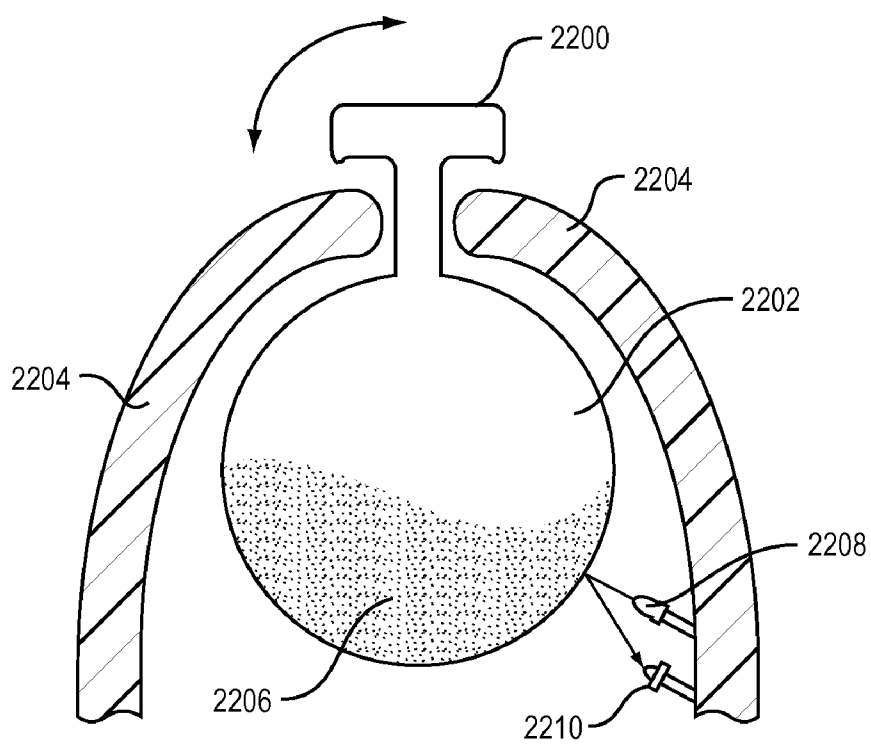


FIG. 22

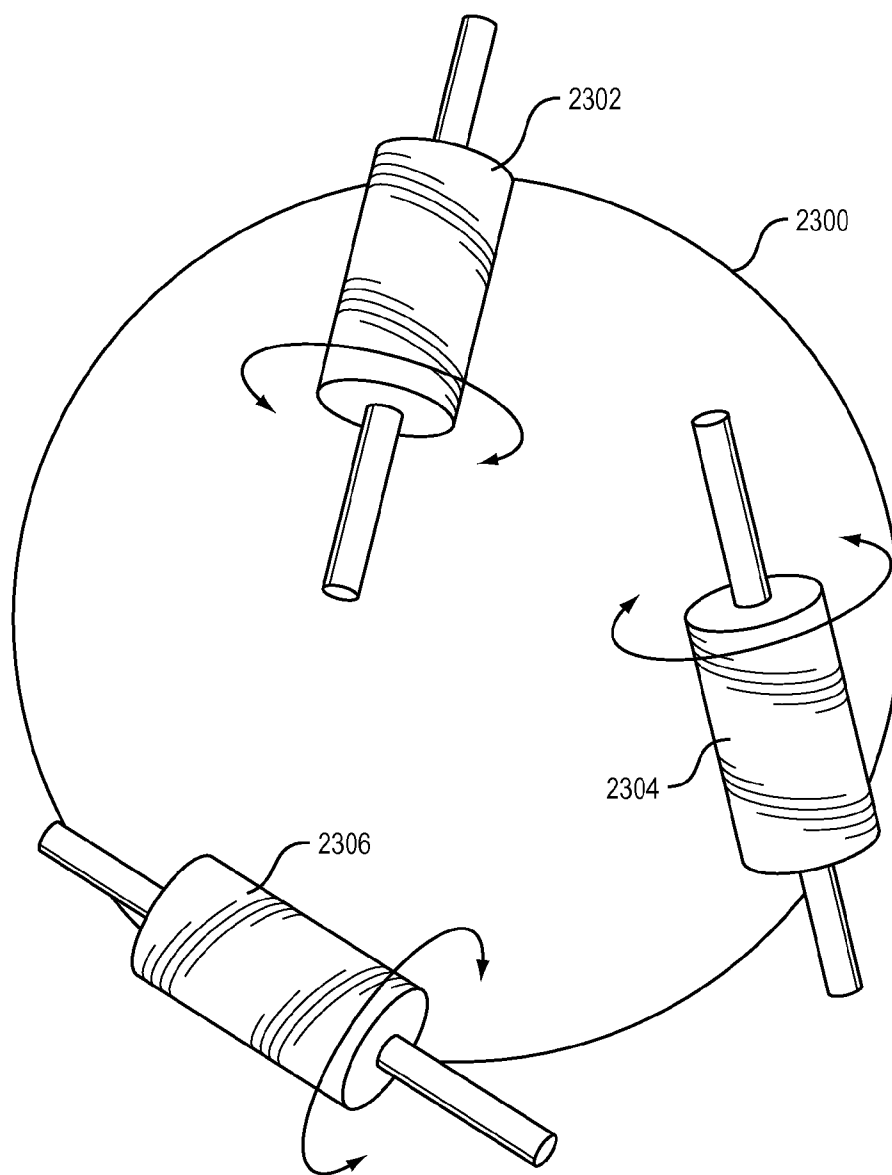


FIG. 23

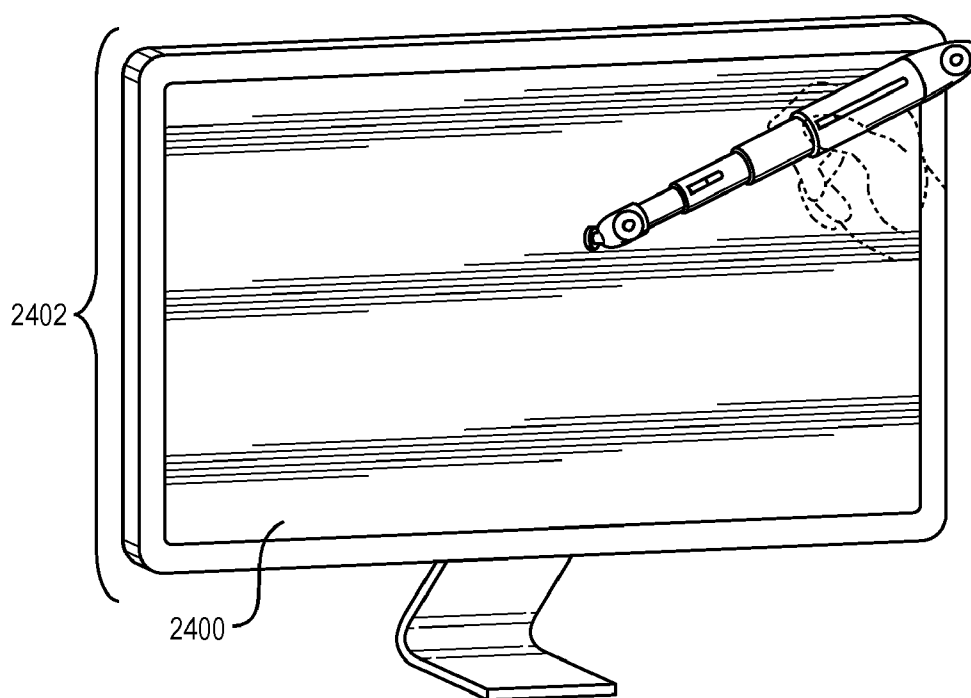


FIG. 24A

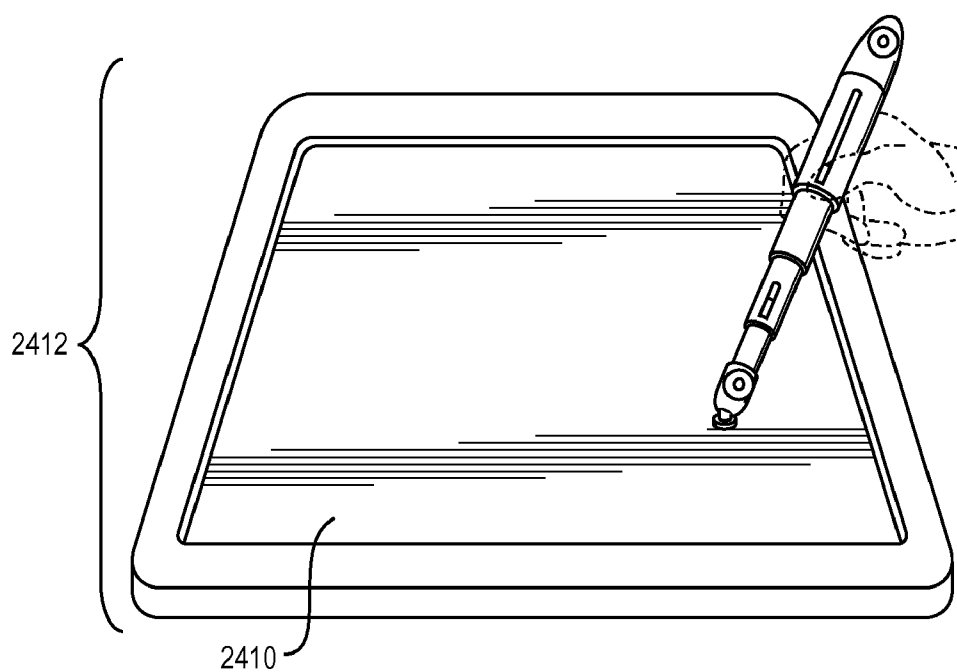


FIG. 24B

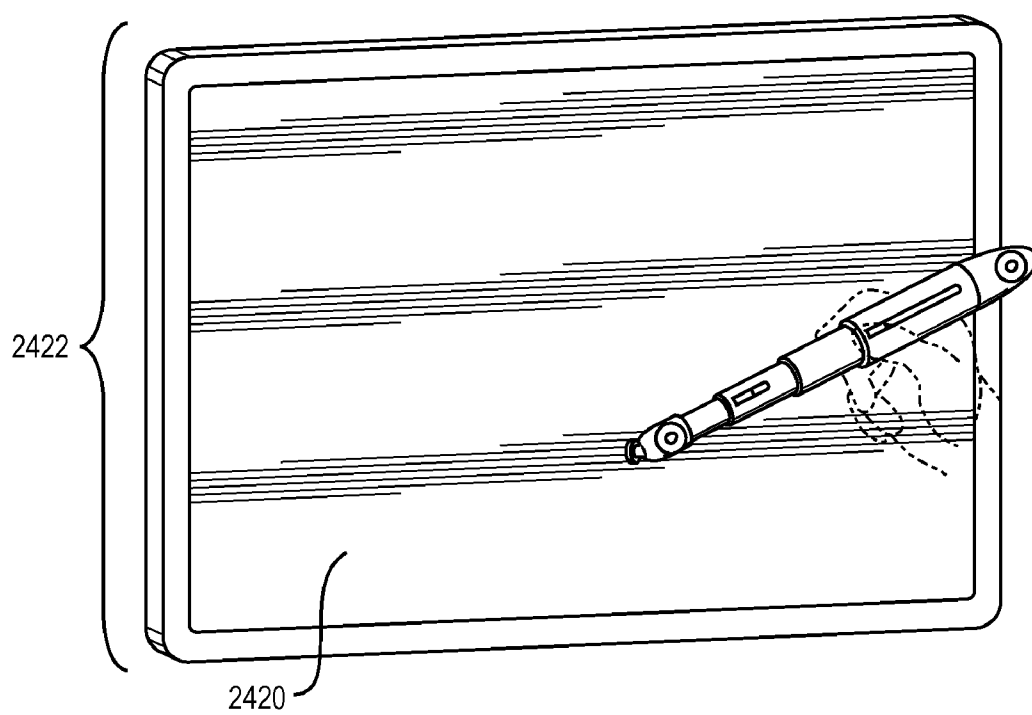


FIG. 24C

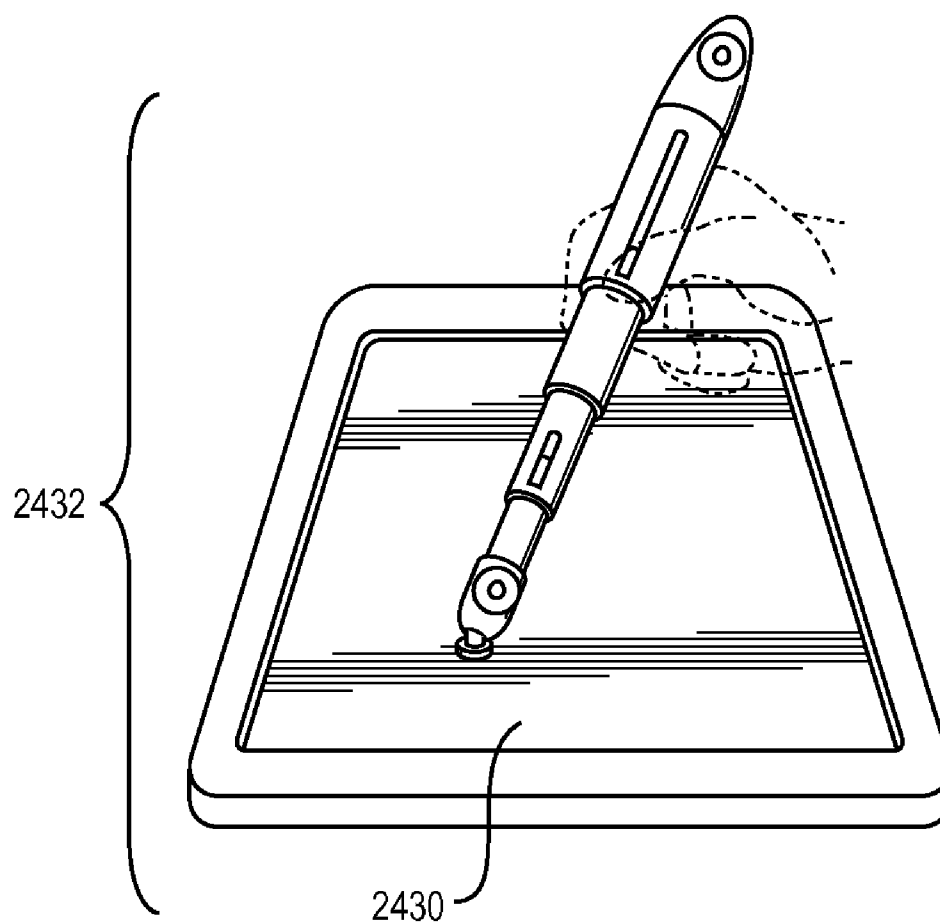
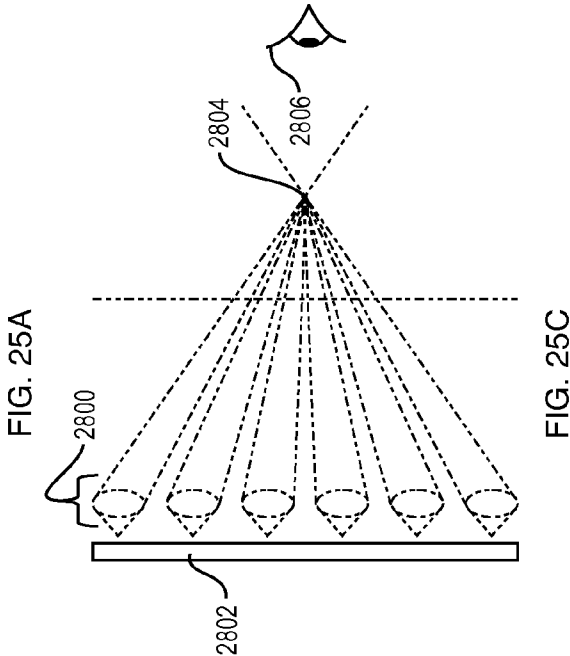
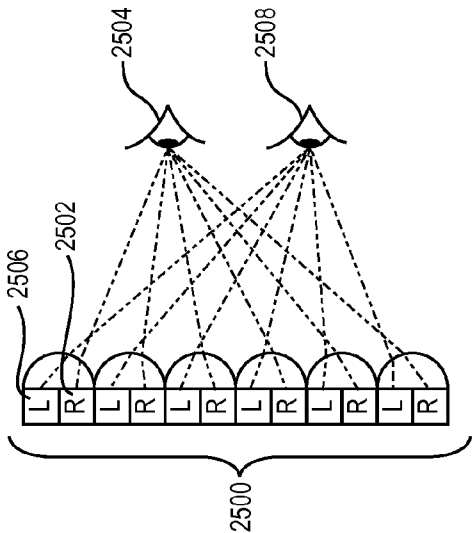
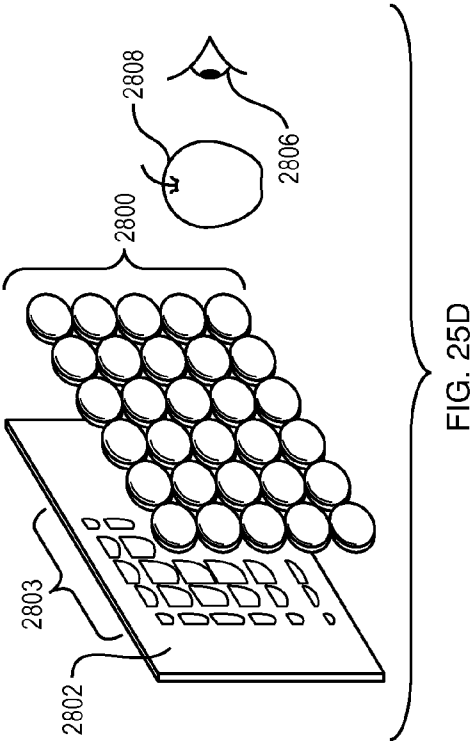
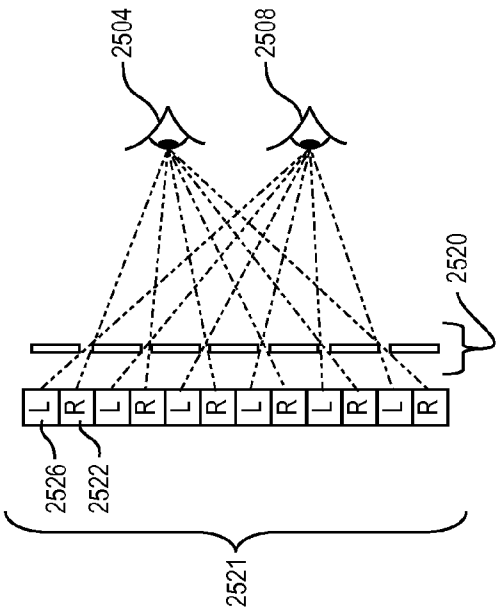


FIG. 24D



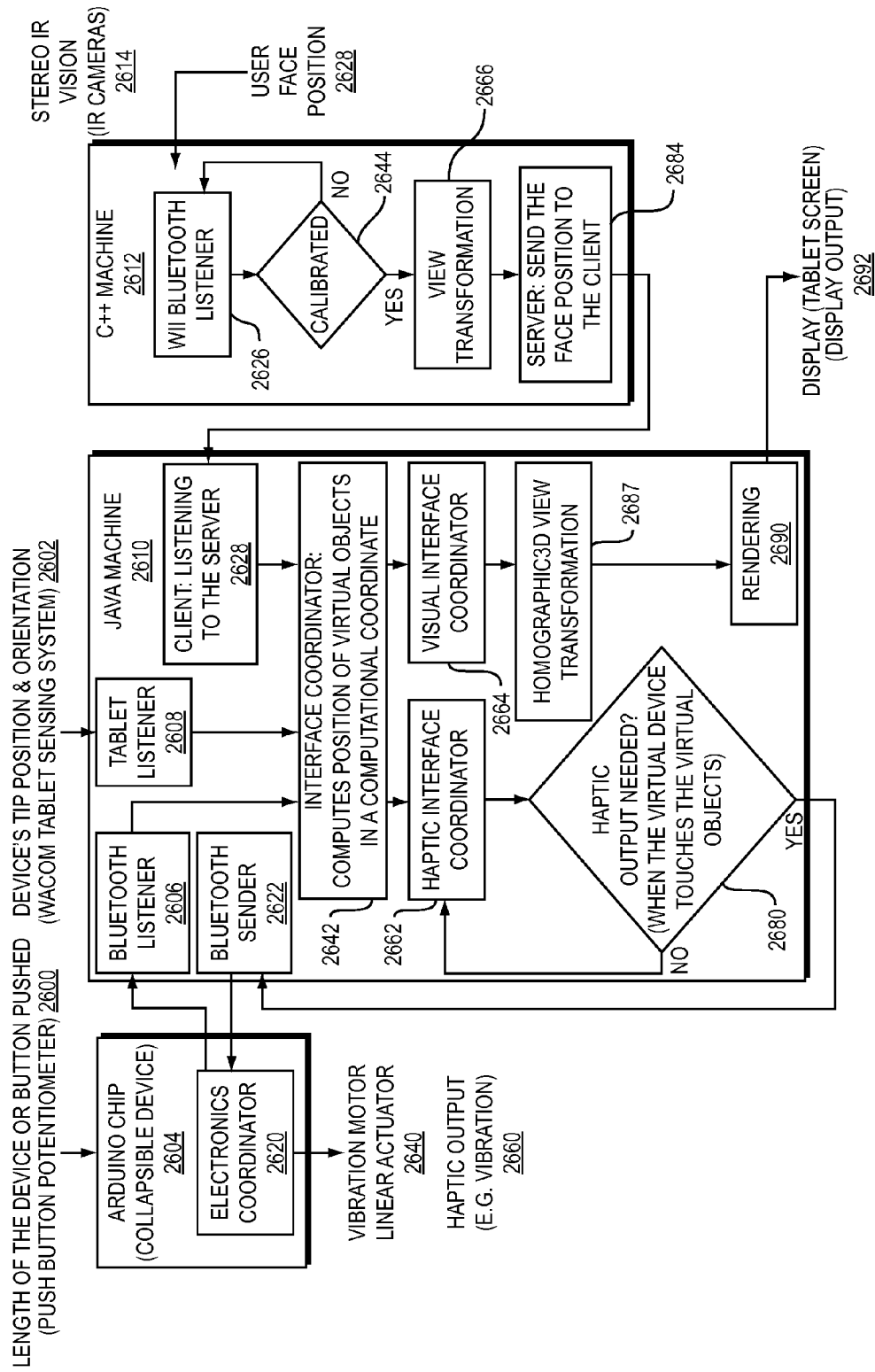


FIG. 26

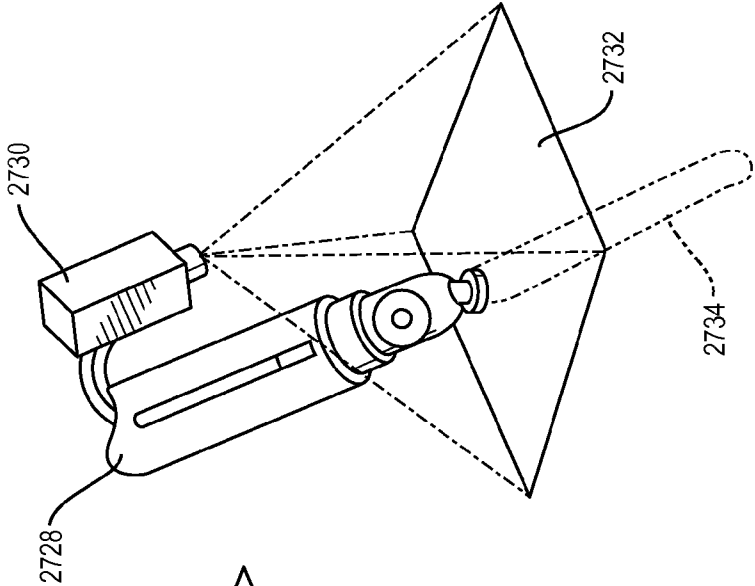


FIG. 27C

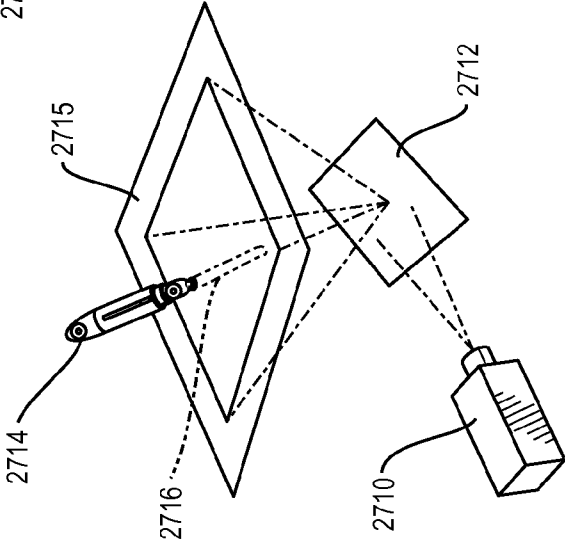


FIG. 27B

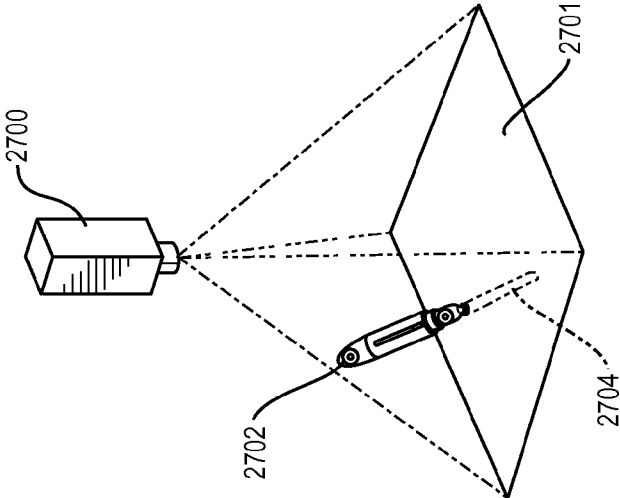


FIG. 27A

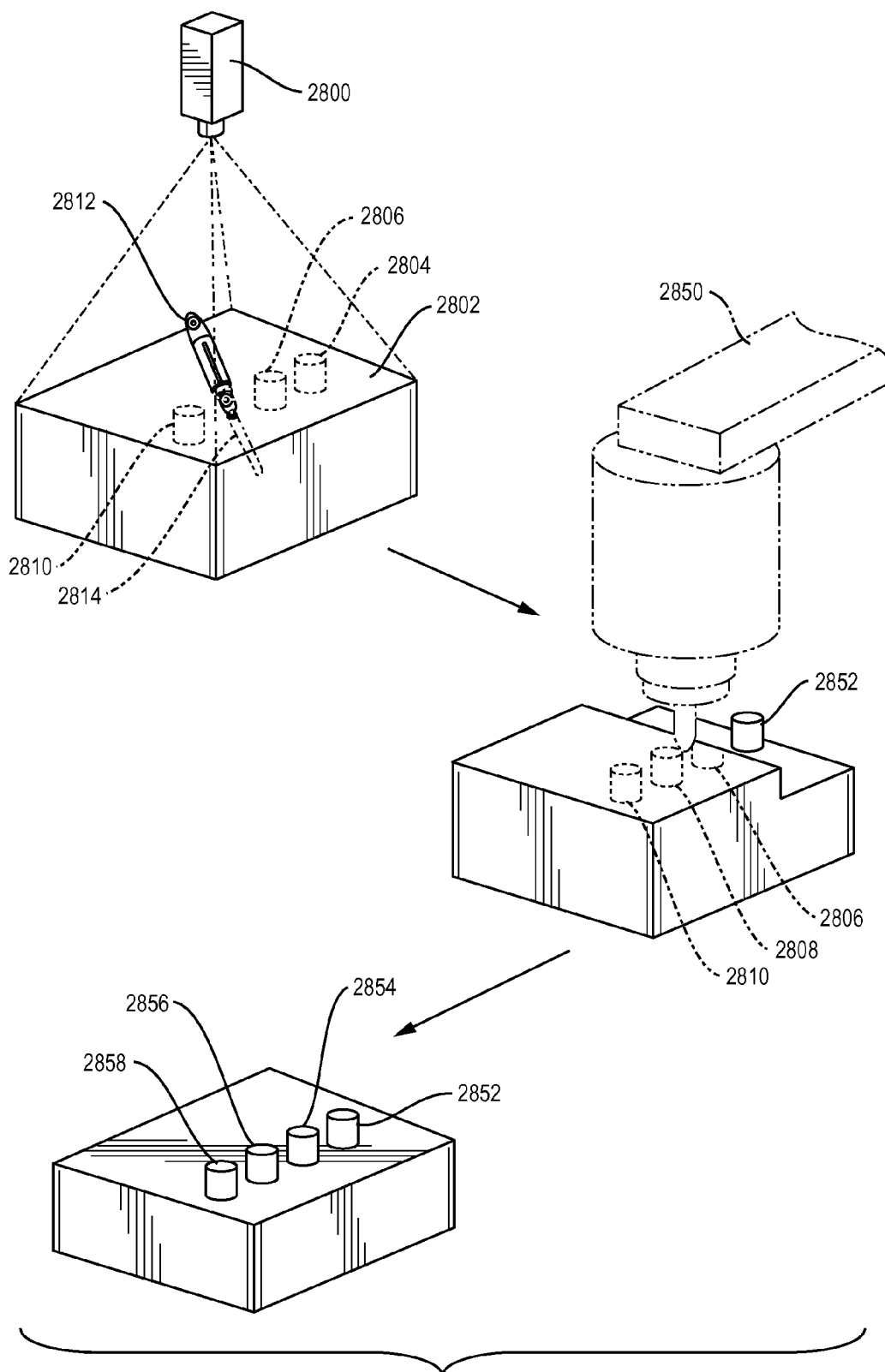


FIG. 28

COLLAPSIBLE INPUT DEVICE

FIELD OF THE TECHNOLOGY

[0001] The present invention relates generally to input and interaction technologies.

SUMMARY

[0002] In exemplary implementations of this invention, a handheld, collapsible input device (CID) may be employed by a user to input and manipulate 3D information. The CID is long, like a pencil or pen. It telescopes in length. As a user presses the CID against a display screen, the physical length of the CID shortens: i.e., the CID physically collapses. As it does so, the display screen displays a virtual end of the CID that appears to project through the screen into the virtual 3D space behind the screen. The total apparent length of the CID, comprised of a physical portion and a virtual portion, remains the same (after taking into account foreshortening).

[0003] Based on the length, position, and orientation of the device, the part of the device that is physically collapsed is rendered on the screen such that the user perceives that the CID continues into the virtual world beyond the screen.

[0004] Thus, the user experience is that, as the user holds the physical CID and pushes it against a display screen, the end of the CID appears to be pushed through the display screen into the virtual 3D space beyond it.

[0005] In exemplary implementations, the CID may be used to manipulate 3D information in a variety of ways. For example, a user may draw virtual 3D objects, such as a chair, using the virtual tip of the CID. Or a user may cut a virtual slice out of a virtual apple, using a virtual end of a CID which is, for that purpose, shaped like a saw or serrated cutting edge. From the user's perspective, it appears that the CID is directly manipulating 3D information beyond the screen.

[0006] Also, a user may create virtual 3D objects by selecting from a menu of shapes. For example, a user may cause a virtual rectangle to be formed adjacent to the virtual tip of a CID, and then cause a virtual rectangular cuboid to be extruded from the rectangle. The shape may be selected from a menu by selecting an icon on a display screen. Or a user may select a shape from the menu by making a hand gesture with one hand, while holding the CID with the other hand.

[0007] In exemplary embodiments, a grid function may be employed. It allows the virtual tip of the CID to snap to a point on a virtual 3D grid, making it easier for the user to create 3D objects with precise dimensions. Furthermore, a user may use the virtual tip of the CID to select three points to define a plane in virtual 3D space, then move the 3D plane to the 2D display surface and draw on that plane, and then reinsert the plane (with the drawing on it), into the virtual 3D space.

[0008] In exemplary embodiments, haptic feedback is employed to heighten the illusion that the CID is directly interacting with virtual 3D objects in the virtual space beyond the display screen. This haptic feedback may be vibratory. Alternately, a linear actuator in the CID may stop the physical CID from collapsing further, or even push the physical CID back into the user's hand, when the virtual end of the CID interacts with a virtual object.

[0009] A number of working prototypes of this invention have been built.

[0010] In two of these prototypes, reflective IR tags are used to determine the physical length of the CID as well as the 2D position and tilt angle of the CID relative to the display

screen. In a third prototype, a linear potentiometer in the CID measures the physical length of the CID. In this third prototype, magnetic sensors in the display screen measure the 2D position and tilt angle of the CID relative to the display screen.

[0011] In some prototypes, a user's head position is tracked using stereo infrared cameras and an ear-mounted infrared LED. The user's head position is used to determine the user's line of gaze into the virtual space beyond the display screen. This allows virtual objects, such as the virtual tip of the CID, to be displayed from the correct angle from the user's perspective. In another prototype, a user's head position is determined by face recognition. Alternately, gaze tracking may be used to determine a user's line of sight.

[0012] The CID housing may include a push button for user input.

[0013] The above description of the present invention is just a summary. It is intended only to give a general introduction to some illustrative implementations of this invention. It does not describe all of the details of this invention. This invention may be implemented in many other ways.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 shows a collapsible input device (CID) being held by a user, with the virtual end of the CID projecting beyond the display screen into the virtual 3D space behind the screen.

[0015] FIG. 2A shows a CID, with full physical extension and no virtual end.

[0016] FIG. 2B depicts the same thing as FIG. 1, from a different perspective.

[0017] FIG. 3 shows a user holding a CID, and using it to carve a virtual 3D slice from a virtual 3D apple. The virtual cutting edge of the CID appears to project beyond the display screen into the virtual 3D space behind the screen.

[0018] FIG. 4A shows various ways in which a CID may be moved.

[0019] FIG. 4B shows the virtual end of a CID being used to draw a 3D virtual chair.

[0020] FIG. 5A to 5C show a user holding a CID in one hand, and making gestures with the other hand. The various gestures cause different 3D virtual shapes to be formed. The virtual end of the CID may be used to position these 3D shapes.

[0021] FIG. 5A shows a virtual square being created in this way.

[0022] FIG. 5B shows a virtual rectangular cuboid being extruded in this way.

[0023] FIG. 5C shows a virtual ellipsoid being created in this way.

[0024] FIG. 6 shows different hand gestures that may be used, to cause various 3D shapes to be created.

[0025] FIG. 7 shows a screen displaying a menu of shapes, from which a user may select in order to create different virtual 3D shapes.

[0026] FIG. 8A shows existing technology (prior art), in which a CAD drawing program has a 2D grid feature.

[0027] FIG. 8B shows a 3D grid feature being used with a CID.

[0028] FIG. 9 shows a CID being used, first, to specify three 3D points to define a virtual 3D plane, second, to draw on that plane after it has been brought up to the virtual 2D surface of the display screen, and third, to reinsert the plane, with the drawing on it, into virtual 3D space.

[0029] FIG. 10 shows how a user may tilt a CID back and forth.

[0030] FIG. 11 shows how a user may move a CID laterally along a display surface.

[0031] FIG. 12A shows how the physical length of a CID may be shortened, while the virtual end of CID lengthens, or vice versa.

[0032] FIG. 12B shows a system in which a user's head position is estimated by stereo infrared cameras. The user's head position is used to calculate the angle of the user's view into the virtual 3D space beyond the display screen.

[0033] FIG. 12C shows a system in which a user's head position is tracked using a single camera and face recognition.

[0034] FIG. 13 shows a prototype in which reflective IR tags on the CID are used to determine the length, position and orientation of the CID.

[0035] FIG. 14 shows the same prototype, with the mounts for the IR tags exposed.

[0036] FIG. 15 shows the shaft for an actuator and linear potentiometer, in a prototype.

[0037] FIG. 16 shows how the shape of the virtual end of the CID may change.

[0038] FIG. 17A is a diagram of a prototype in which the tip position and orientation of the CID are determined by magnetic sensors. In FIG. 17A, the prototype is fully extended to maximum physical length.

[0039] FIG. 17B is a diagram of the same prototype, with the prototype collapsed to a shorter physical length.

[0040] FIGS. 18A and 18B are diagrams showing sensor coils in a display screen. The sensor coils are used to detect changes in a magnetic field as a CID changes its tilt angle and 2D position relative to the display screen.

[0041] FIG. 19 is a diagram of a cross-section of a prototype, in which the position, length and orientation of the CID are determined by tracking the position of reflective RF tags on the CID.

[0042] FIGS. 20A and 20B show a linear potentiometer for measuring the length of a telescoping CID.

[0043] In FIG. 20A, the CID is extended to full physical length. In FIG. 20B, the CID is collapsed to a shorter length.

[0044] FIG. 21 is a diagram of a series elastic actuator for haptic feedback in a CID.

[0045] FIG. 22 shows a cross-section of the end of a CID that is generally closest to the display screen. It includes a light sensor for optically sensing the orientation of the CID.

[0046] FIG. 23 is a diagram that shows hardware for mechanically sensing the orientation of a CID.

[0047] FIGS. 24A to 24D show how the display screen may be implemented in various form factors. The form factors shown in FIGS. 24A, 24B, 24C and 24D, respectively, are a computer monitor, a table-mounted display, a wall-mounted display, and a handheld tablet computer.

[0048] FIGS. 25A to 25D show alternate ways of implementing 3D display for use with a CID.

[0049] FIG. 25A shows lenticular lenslets for 3D display.

[0050] FIG. 25B shows a parallax barrier for 3D display.

[0051] FIGS. 25C and 25D show integral imaging.

[0052] FIG. 26 is a flow chart for face tracking, 3D rendering, and haptic feedback, in a prototype of this invention.

[0053] FIGS. 27A to 27C show alternate embodiments, in which virtual images are displayed by projection. In FIG. 27A, an overhead projector is used. In FIG. 27B, the projection is from below. In FIG. 27C, a pico-projector is mounted on a CID.

[0054] The above Figures illustrate some illustrative implementations of this invention, or provide information that relates to those implementations. However, this invention may be implemented in many other ways. The above Figures do not show all of the details of this invention.

DETAILED DESCRIPTION

[0055] In exemplary implementations of this invention, a handheld, collapsible input device (CID) may be employed by a user to input and manipulate 3D information.

[0056] FIG. 1 shows a user holding a CID 1 and pressing the tip 2 of the CID 1 against a display screen 3. The display screen 3 displays a virtual end 4 of the CID. From the user's perspective, it appears that the CID is being pushed through the display screen 3 into a virtual 3D space beyond the screen.

[0057] FIG. 2A also shows a user holding a CID 1 and touching its tip 2 to the display screen 3. However, in FIG. 2A, the physical CID 1 is telescoped to its full length, and the display screen 3 does not display a virtual end of the CID. From a user's perspective, it appears that the CID 1 is resting on the surface of the display screen 3 and is not pushed through the display screen 3 into the virtual 3D space beyond the screen.

[0058] FIG. 2B depicts the same thing as FIG. 1, from a different perspective.

[0059] A note regarding an illustration convention used herein: For ease of illustration, in FIG. 2B, the virtual end 4 of the CID is displayed from the perspective of a viewer of FIG. 2B, rather than from the perspective of the user who is holding the CID. This illustration convention will generally be followed for the remaining Figures. However, in practice, virtual 3D objects (including the virtual end of the CID) are usually rendered on the display screen from the perspective of the user who is holding the CID. (In FIG. 1, the line of gaze of the user holding the CID and of a viewer of FIG. 1 coincide).

[0060] FIG. 3 shows a user holding a CID 301 and pressing the tip 302 against the display screen 303. In FIG. 3, the user is using the virtual end 304 of the CID to carve a virtual 3D slice 305 from a virtual 3D apple 306, leaving a virtual 3D hole 307 where the slice used to be. The virtual end 304 of the CID appears to be serrated or saw-like. More generally, the virtual end of a CID may be used to cut away portions of a virtual 3D object, or otherwise subtract from the volume of a virtual 3D object.

[0061] FIG. 4A shows some ways in which a CID may be moved. In FIG. 4A, a user presses the tip 402 of a CID 400 against a display screen 404. While doing so, the user may change the tilt angle of the CID relative to the display surface. For example, the user may move the top 410 of the physical CID 400 in a circular orbit 412 while keeping the tip 402 in one place. In that case, the end 406 of the virtual portion of the CID appears to orbit in virtual 3D space in the opposite direction.

[0062] The pad at the end of the tip 402 is sticky or otherwise has a high coefficient of friction, which tends to prevent the tip 402 from slipping across the display screen as a user changes tilt angle. The tip may remain flat against the display screen even though the main body of the CID is tilted relative to the screen.

[0063] The CID telescopes. Thus, in FIG. 4, if the user presses the CID 400 against the display surface 404, the physical CID shortens in length, while the length of the virtual portion 406 of the CID appears to increase. The total apparent length of the CID, comprised of a physical portion

and a virtual portion, remains the same (after taking into account foreshortening). Thus, the user experience is that, as the user holds the physical CID and pushes it toward a display screen, the end of the CID appears to be pushed through the display screen into the virtual 3D space beyond it. When the CID telescopes, it does so along its longitudinal axis, as indicated by arrow 408 in FIG. 4B.

[0064] Other movements are possible. For example, in FIG. 4A, a user may move the tip 402 of the CID laterally along the display surface 404 (e.g., along the x or y axes shown in FIG. 4A).

[0065] FIG. 4B shows the CID being used to make a 3D drawing. A user holds the tip 452 of a CID 450 against a display surface 454, and moves the virtual end 456 of the CID 450 to draw virtual 3D lines 458. In the example shown in FIG. 4B, the lines comprise a 3D drawing of a chair.

[0066] FIG. 5A to 5C show a user holding a CID in one hand, and making gestures with the other hand. The gestures cause different 3D virtual shapes to be formed. The CID may be used to position these shapes.

[0067] FIG. 5A shows a virtual square being created in this way. In FIG. 5A, a user holds a CID 500 in one hand. On the user's other hand 510, the user wears a glove 512. Fiducial markers 514, 516, 518 are affixed to the exterior of the glove's thumb and first two fingers. With this gloved hand 510, the user makes a gesture. In this case, the gesture is an instruction to form a square. A virtual square 520 is displayed. The virtual tip 504 of the CID is used to position the virtual square 520 thus formed. At least one camera is used to capture images of the gestures, and gesture recognition is performed by at least one processor.

[0068] FIG. 5B shows a virtual rectangular cuboid 550 being extruded in this way. In FIG. 5, the user has caused the cuboid to be extruded from the square shown in FIG. 5A.

[0069] FIG. 5C shows a virtual ellipsoid 560 being created in this way. The user is employing the virtual end 504 of the CID to position the ellipsoid 560 next to the rectangular cuboid 550.

[0070] FIGS. 6A to 6F show different hand gestures that may be used as instructions for creating and manipulating various virtual shapes. For example, the CID system may recognize the gestures shown in FIGS. 6A, 6B, 6C, 6D, 6E and 6F, respectively, as instructions to form a straight line, form a square, form an ellipse, extrude from an existing shape, lock a surface, or move in a specified direction.

[0071] FIG. 7 shows a screen displaying a menu of shapes, from which a user may select in order to create different virtual 3D shapes. A menu of shape icons 700 appears on the display screen 704. The user may select any of these icons in order to create a desired shape. In the example shown in FIG. 7, the user selected the cylinder icon 702 in order to form two virtual cylinders 706, 708. The virtual end 710 of the CID is used to position the cylinders in the virtual 3D space.

[0072] FIG. 8A shows existing technology (prior art), in which a CAD drawing program has a 2D grid feature. When the grid feature is "on", the cursor "snaps" to a point 800 on a 2D grid when the cursor comes sufficiently close to that point.

[0073] FIG. 8B shows a 3D grid feature being used with a CID. As the virtual end of the CID comes close to a point 850 in a virtual 3D grid, the virtual end of the CID snaps to that point. This makes it easier to make 3D drawings with precise dimensions and precise alignment of the drawn objects.

[0074] FIG. 9 shows a CID being used, first, to specify three points P1, P2, P3 to define a virtual 3D plane 901, second, to draw on that plane after it has been brought up to the virtual 2D surface 902 of the display screen, and third, to reinsert the plane, with the drawing on it, into virtual 3D space at position 904. This has the advantage of allowing users to draw on a flat surface in 2D space, which may be easier because issues such as foreshortening may be avoided. Then the drawing on a flat plane may put back into 3D space (e.g., in a virtual orientation that is not parallel to the display surface).

[0075] FIG. 10 shows how a user may tilt a CID back and forth. By rocking the physical CID back and forth while holding the tip 1200 in place on a display surface 1202, the user causes the virtual end of the CID to tilt back and forth.

[0076] FIG. 11 shows how a user may move the tip 1200 of a CID laterally along a display surface 1202.

[0077] FIG. 12A shows how the physical length of a CID may be shortened, while the virtual end of a CID lengthens, or vice versa. This may occur as a user presses a tip 1200 of the CID against a display screen 1202, or as an actuator provides haptic feedback.

[0078] FIG. 12B shows a system in which a user's head position is tracked by stereo infrared cameras 1210 and 1212. The user wears an ear-mounted infrared LED 1214. At least one processor 1216 uses the camera images to determine the user's head position relative to the display screen, and based on that head position, to calculate the angle of the user's view into the virtual 3D space beyond the display screen.

[0079] FIG. 12C shows a system in which a user's head position 1232 is tracked using a single camera 1230 and face recognition.

[0080] FIG. 13 shows a prototype in which reflective IR tags on the CID are used to determine the length, position and orientation of the CID. The reflective IR tags 1300, 1302 are affixed near the ends of the CID.

[0081] In FIG. 13, a push-button 1310 provides click and drag features. The push button is advantageous because it allows a user to indicate the beginning and ending of an interaction, and facilitates interactions such as selection and dragging of objects. The push button may be adapted to accept input from a user indicative of a variety of instructions.

[0082] In addition, FIG. 13 shows certain internal hardware of a CID prototype. This hardware includes a microcontroller 1306 for, among other things, controlling a vibration motor 1304 for haptic feedback. It also includes a bluetooth communications unit 1308 (including at least one transceiver) for communicating with at least one remote processor, which remote processor may in some cases be housed with or adjacent to the display screen. That remote processor may, for example, perform the rendering and other functions of the Java machine described in FIG. 26.

[0083] FIG. 14 shows the same prototype as FIG. 13, with the mounts 1312, 1314 for the IR reflective tags exposed.

[0084] FIG. 15 shows an embodiment of this invention, in which a moveable shaft 1508 transmits force from an actuator. The movement of the shaft 1508 is measured by a linear potentiometer to determine the length of the CID. The linear potentiometer and actuator are housed in housing 1508. Mounting stages 1500, 1502 for IR reflective tags are affixed near the ends of the CID. In the example shown in FIG. 15, the IR reflective tags are used to determine orientation of the CID.

[0085] FIG. 16 shows examples of how the shape of the virtual end of the CID may change. The same physical CID 1600 may at different times appear to project a virtual shape

in the form of a serrated saw **1602**, a spoon **1604**, or a pencil **1606**. The functionality of the CID may change appropriately. For example, the saw **1602** may be used for virtual cutting, the spoon **1604** for scooping material away from a virtual object, and the pencil **1606** for virtual drawing.

[0086] FIGS. 17 is a diagram of a prototype extended to full length. In this prototype, a circuit **1704** generates a magnetic field that is sensed by magnetic coils in a display screen (not shown in FIG. 17), in order to detect the tilt of the CID relative to the display screen and the 2D position of the CID tip **1700** relative to that screen. The CID has telescoping parts, including housing part **1702**. As the CID telescopes (increasing or decreasing in length) a connecting rod **1704** moves. That movement is sensed by a linear potentiometer **1706**. As the CID collapses, a spring **1708** provides some resistance felt by the user.

[0087] In FIG. 17A, a push button **1718** is adapted to accept input from a user, including input regarding click and drag, and input regarding when an operation starts and ends. A microcontroller **1710** controls a vibration motor **1716** for providing haptic feedback. A bluetooth communications unit **1714** communicates with at least one remote processor, as described in more detail with respect to FIG. 13. A battery **1712** provides power for the electronics in the CID.

[0088] FIG. 17B is a diagram of the same prototype as in FIG. 17A, with the prototype collapsed to a shorter physical length.

[0089] FIGS. 18A and 18B are diagrams showing a magnetic sensing system for detecting the 2D position and tilt angle of the CID relative to a display surface. A magnetic field **1801** created by a resonance circuit or coil in the tip **1800** of the CID induces voltage in sensor coils **1802** in the display surface. As the CID changes position or orientation, the magnetic field changes, and different patterns of induced voltages **1804**, **1806** result. Based on these patterns, the 2D position and orientation of the CID relative to the screen may be determined. This method of magnetic sensing (in a context other than a CID) is described in U.S. Pat. No. 5,748,110, the entire disclosure of which is incorporated by reference herein.

[0090] FIG. 19 is a diagram of a cross-section of a prototype, in which the length, orientation and position of the CID is determined by tracking the position of reflective RF tags **1920** and **1922** on the CID. In this prototype, the microcontroller **1910**, blue tooth communications unit **1914**, battery **1912**, push button **1918**, vibratory motor **1916** and pad **1900** at the tip of the CID correspond in structure and function to items **1700**, **1710**, **1714**, **1712**, **1718** and **1716** in FIG. 17, which items are described above.

[0091] FIGS. 20A and 20B show a linear potentiometer/actuator unit, in some embodiments of this invention. A connecting rod **2048** moves as the CID telescopes in and out. The movement of rod **2048** is detected by linear potentiometer **2052**, **2050**, in order to determine the length of the CID. A motor **2040** may be used to actuate movement of rod **2048**, for haptic feedback. An IC chip **2030** is used to control the motor **2040**. The CID may telescope for reasons other than actuation by motor **2040**. For example, it may increase in length due to force from a spring, or decrease in length as a user presses the CID against a display surface. IR reflective tags **2020** and **2022** may be mounted on the housing of the CID. As rod **2048** moves, the telescoping part of the housing to which tag **2020** is affixed moves with it.

[0092] In FIG. 20A, the CID is extended to full physical length. In FIG. 20B, the CID is collapsed to a shorter length.

[0093] FIG. 21 is a diagram of a model of a series elastic actuator (SEA) for haptic feedback in a CID. By using an SEA, accurate force feedback can be achieved dynamically regardless of the spring retraction. As shown in FIG. 21, an SEA may be implemented whereby torque **2100** from a motor is applied to a mass **2102**, causing a motor shaft to move, which transmits force through a spring **2103**, resulting in an outputted force **2104**.

[0094] In exemplary embodiments of this invention, haptic feedback is employed to heighten the illusion that the CID is directly interacting with virtual 3D objects in the virtual space beyond the display screen. For example, the CID may vibrate when the virtual end of the CID contacts a virtual object. Or, for example, the virtual end of a CID may be used to draw on a virtual tilted surface (i.e., a virtual surface whose apparent depth beyond the screen varies). As the virtual end of the CID moves from a lower point to a higher point **4** on the tilted surface, a linear actuator may provide haptic feedback by lengthening the physical CID, so that it feels to a user as if the CID is rising as it goes up the tilted surface.

[0095] FIG. 22 shows a cross-section of the end of a CID that is generally closest to the display screen. Sufficient space is left between the housing **2204** and a sphere **2202**, so that the sphere **2202** can tilt up to **30** degrees from the longitudinal axis of the CID in any direction. This allows a user to change the orientation of the CID relative to a display screen, while leaving the pad **2200** at the tip of the CID in a single place on the display screen. This pad **2200** at the tip of the CID may remain flat against the display while the tilt angle of the main body of the CID changes.

[0096] The movement of the sphere relative to the housing of the CID may be optically sensed, in order to determine the tilt angle of the CID relative to the display surface. A light source **2208** emits light that reflects off of the sphere **2202** and is detected by a light sensor **2210**. As the sphere **2202** moves relative to the housing **2204**, the pattern of dots **2206** on the surface of the sphere that are illuminated by the light source **2208** changes, thereby affecting the reflected light detected by the light sensor **2210**. From these changes in reflected light, the orientation of the CID relative to the display surface may be determined.

[0097] Alternately, rotation of the sphere may be mechanically sensed. For example, as shown in FIG. 23, the rotation of the sphere may mechanically cause elements **2302**, **2304**, **2306** to move, and the movement of these elements **2302**, **2304**, **2306** may be measured.

[0098] In addition, the orientation and/or position of the CID may be determined in other ways. For example, the tilt angle of the CID may be detected by gyroscopes and changes in lateral position or orientation of the CID may be detected with accelerometers.

[0099] FIGS. 24A to 24D show how a display screen **2400**, **2410**, **2420**, **2530** may be implemented in various form factors. The form factors shown in FIGS. 24A, 24B, 24C and 24D, respectively, are a computer monitor **2402**, a table-mounted display **2412**, a wall-mounted display **2422**, and a handheld tablet computer **2432**.

[0100] FIGS. 25A to 25D show some alternate ways of implementing 3D display for use with a CID.

[0101] FIG. 25A shows lenticular lenslets for 3D display for use with a CID. An array of lenticular lenslets **2500** in a display surface refracts light so that the right eye **2504** and left eye **2508** of a user see different pixels, e.g., pixels **2502** and **2506**.

[0102] FIG. 25B shows a parallax barrier for 3D display for use with a CID. Light from an array of pixels 2521 in a display surface passes through gaps in the parallax barrier 2520. The pixels and parallax barrier are arranged so that different pixels, e.g., 2526 and 2522, are seen by a viewer's right eye 2504 and left eye 2508.

[0103] FIGS. 25C and 25D show integral imaging. A display screen 2802 displays elemental images 2803. The light from these elemental images 2803 is refracted by an array of lenslets 2800, causing a real image 2808 to appear at a convergence point 2804 between the user's eye 2806 and the lenslets.

[0104] FIG. 26 is a flow chart for face tracking, 3D visual display and haptic feedback, in a prototype of this invention. Stereo IR cameras 2614 capture images of user's face position 2628. A C++machine 2612 communicates with the cameras using a bluetooth unit 2626. The C++machine checks if the head tracking is calibrated 2644. If it is, the C++machine performs view transformation 2666 and directs 2684 a server to send the user's face position to a client. If the head tracking is not calibrated, calibration is performed, as described below.

[0105] In the example shown in FIG. 26, the CID's tip position and orientation are detected using magnetic sensors 2602. A Java machine 2610 includes: a client 2628 that communicates with the server regarding face position, a communications unit 2608 for communicating with the magnetic sensors regarding the CID's tip position and orientation, a bluetooth listener 2606 for receiving communications from a chip in the CID, an interface coordinator 2642 that computes position of virtual objects in a computational coordinate, and a visual interface coordinator 2664. The Java machine 2610 performs homographic 3D view transformation 2687 and rendering 2690, and outputs signals for display 2692 of images. The Java machine also includes a haptic interface coordinator 2662 that checks 2680 if haptic output is needed (i.e., whether the virtual end of the CID is touching a virtual object). If it is, instructions for haptic feedback are sent via a bluetooth sender 2622 to a chip 2604 in the CID. The chip 2604 includes an electronics coordinator 2620 for controlling a vibration motor or linear actuator 2640 that delivers haptic output 2660, such as vibration, lengthening or shortening of the telescoping CID, or resistance to force applied by the user.

[0106] IR head tracking may be calibrated by moving an infrared LED to four calibration points on the display screen, one at a time.

[0107] In some embodiments, the CID interacts with a projected visual display. As shown in FIG. 27A, an overhead projector 2700 may project images of virtual objects on a surface 2701. As a user presses a physical CID 2702 against the surface 2701, the physical CID 2702 collapses (shortens) and it appears to a user as if the virtual end 2704 pushes through the surface 2701 to the virtual space beneath the surface 2701.

[0108] Alternately, the projection may be from below. As shown in FIG. 27B, a projector 2710 projects light that reflects off a mirror 2712 to form an image on a display screen 2715 that is visible to a user viewing that screen from above. When the CID 2714 is pressed against the display screen

2715, it appears to a user as if the virtual end 2716 of the CID goes through the screen into the virtual space beneath the screen.

[0109] Alternately, as shown in FIG. 27C, a pico projector 2730 may be mounted on the CID 2728 to project images onto a surface 2732, and the virtual end 2734 of the CID may appear to push into the virtual space beneath that surface.

[0110] In some embodiments, a CID may be used to control CNC milling or other subtractive manufacturing. As shown in FIG. 28, a projector 2800 may project images on a surface 2802, such the top surface of a table remote from the CNC milling machine or even the top surface of material to be cut by the CNC milling machine. A CID 2812 may be used to input and interact with virtual images 2804, 2806, 2808, 2810 displayed on the surface by the projector. Digital information regarding those virtual 3D objects may be exported to a CNC milling machine 2850. The CNC milling machine 2850 may remove material, leaving physical objects, e.g. 2852, 2854, 2856, 2858, that conform to this 3D information. Alternately, the CNC milling machine may drill cavities for a mold, which cavities conform to this 3D information. This approach is not limited to CNC milling, but may be used with any digitally controlled method of subtractive manufacturing.

[0111] Item 1216 in FIG. 12B is the one or more processors that may be employed for this invention, including for computing tip position, orientation and length of the CID, for face or head tracking, for face or gesture recognition, for rendering and visual display of images, for control of haptic feedback, for sound output, and for the other functions described in FIG. 26. These one or more processors may be located in various positions. For example, they may be housed in whole or part in a projector, a display screen, a CID, a CNC milling machine, or in one or more remote computers, including website servers.

[0112] This invention may be implemented in many other ways, besides those described above. For example, gesture recognition may be implemented without fiducial markers or gloves. Or, for example, the push button unit may comprise multiple devices for accepting input from a user, including multiple buttons, dials, slider controls, piezoelectric sensors to measure the strength of the user's grip, or capacitive sensors for detecting touch input. Or, for example, gestures made by moving the CID in the air when it is not touching a display screen may be used to input user intent. Such gestures may be tracked, for example, by accelerometers, gyroscopes or other inertial measurement units.

Conclusion

[0113] It is to be understood that the methods and apparatus which have been described above are merely illustrative applications of the principles of the invention. Numerous modifications may be made by those skilled in the art without departing from the scope of the invention. The scope of the invention is not to be limited except by the claims that follow.

What is claimed is:

1. a collapsible input device.

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