



US010212404B2

(12) **United States Patent**
Staton et al.

(10) **Patent No.:** **US 10,212,404 B2**
(45) **Date of Patent:** **Feb. 19, 2019**

(54) **PROJECTION MAPPING SYSTEM AND APPARATUS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/036,772**

(22) Filed: **Jul. 16, 2018**

(65) **Prior Publication Data**

US 2018/0367771 A1 Dec. 20, 2018

Related U.S. Application Data

(63) Continuation-in-part of application No. 15/622,959, filed on Jun. 14, 2017, now Pat. No. 10,027,937.

(51) **Int. Cl.**
G03B 21/14 (2006.01)
H04N 9/31 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04N 9/3185** (2013.01); **G01S 17/08** (2013.01); **G03B 21/147** (2013.01); **G06F 17/30247** (2013.01); **H04N 9/3173** (2013.01)

(58) **Field of Classification Search**
CPC G03B 21/147; G03B 21/14; H04N 9/3179; H04N 9/3185; H04N 9/3188; H04N 9/3194

See application file for complete search history.

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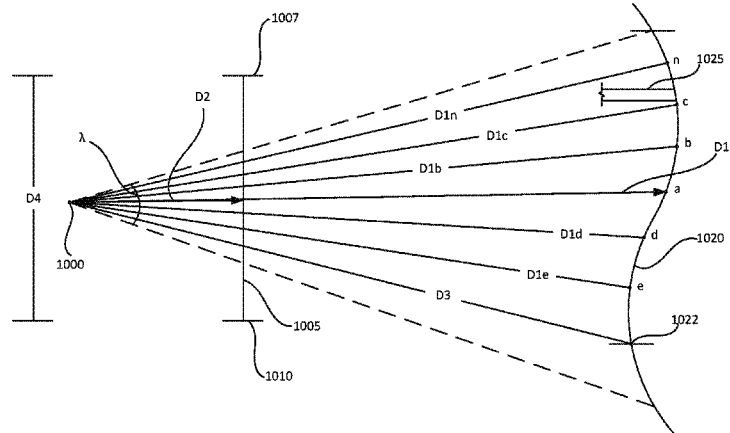
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(57) **ABSTRACT**

A projection system includes a projection apparatus embodied in a housing secured to a user. The projection apparatus has a processor in data communication with a networking device, at least one input/output device, and computer memory. The computer memory includes a program with machine readable instructions that, when effected by processor, perform the following steps: (a) determine an edge of a surface to be measured; (b) project an initial image onto the surface, the initial image being based on a predetermined set of conditions; (c) determine a substantially perpendicular distance D1 between the projection apparatus and the surface; (d) determine a distance D2 between the projection apparatus and the edge of the surface; (e) calibrate the initial image based on the distances D1 and D2 determined in steps (c) and (d); and (f) project an updated image onto the surface.

15 Claims, 9 Drawing Sheets



- (51) **Int. Cl.**
G01S 17/08 (2006.01)
G06F 17/30 (2006.01)

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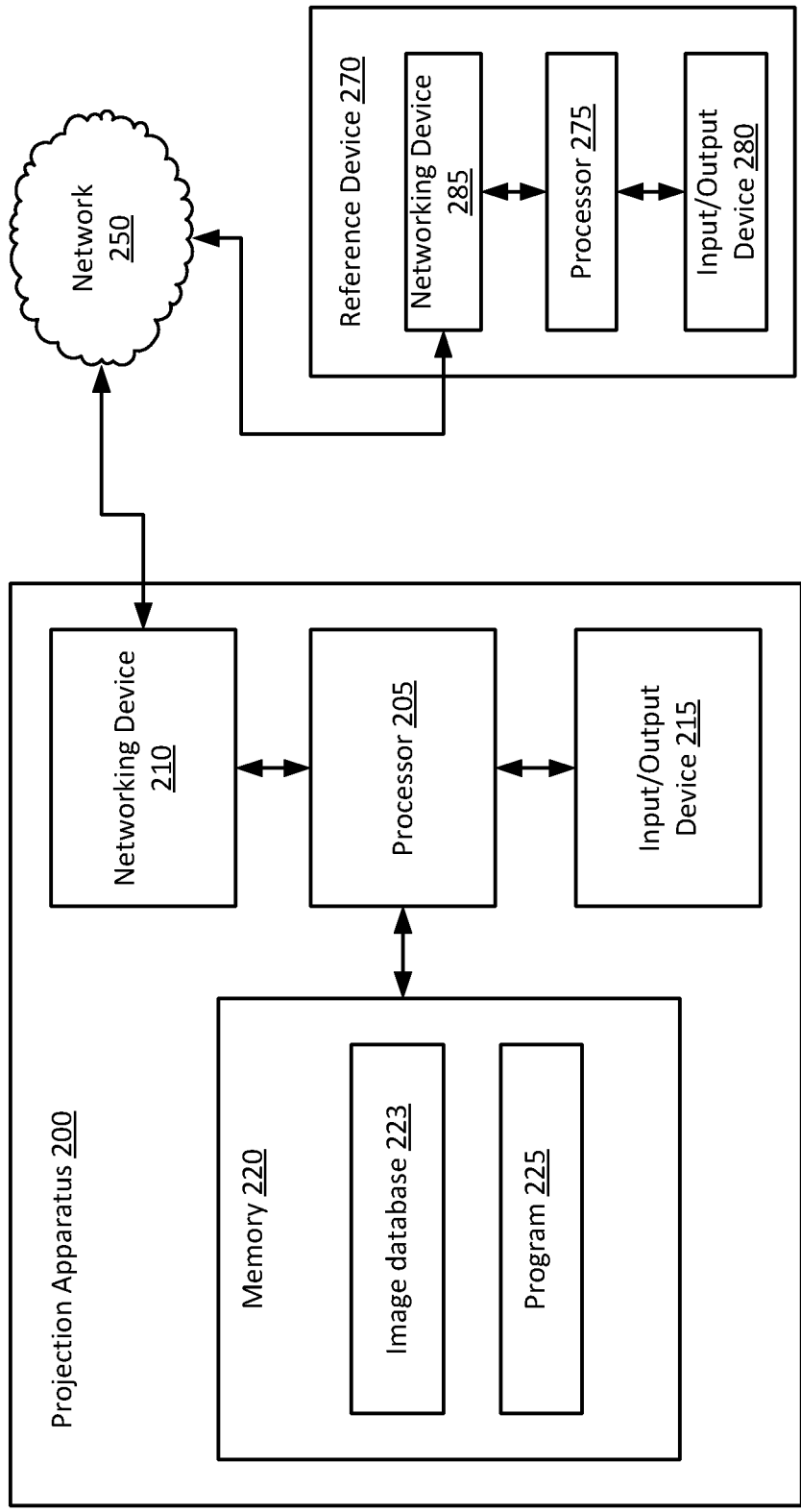


FIG. 1

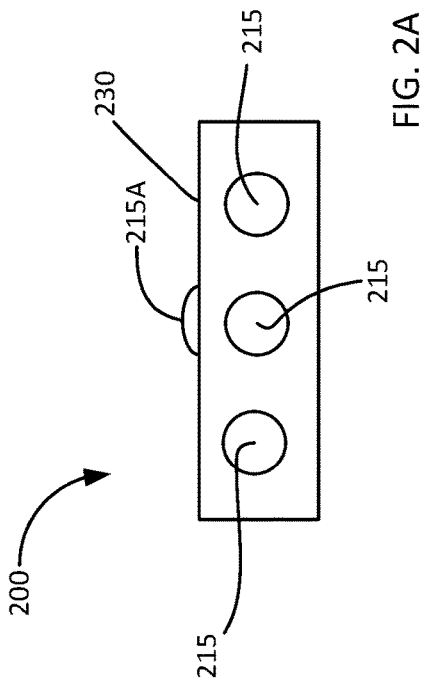


FIG. 2A

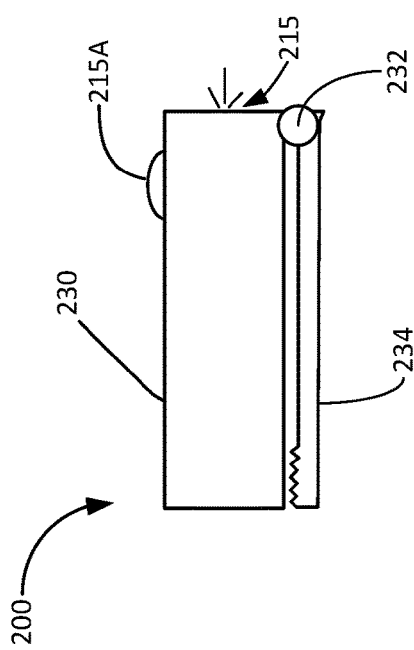


FIG. 2B

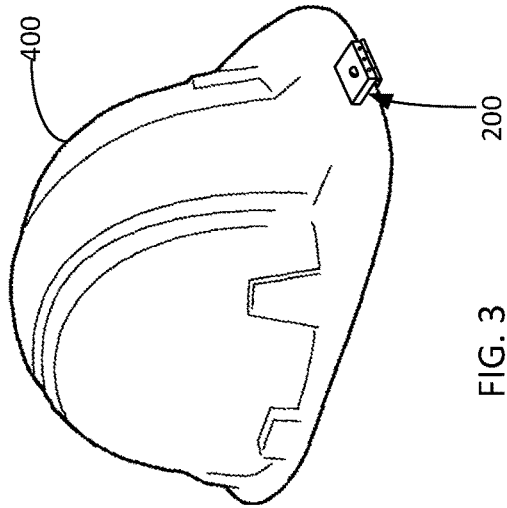


FIG. 3

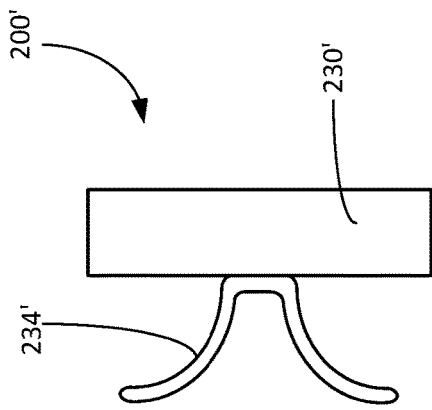


FIG. 4A

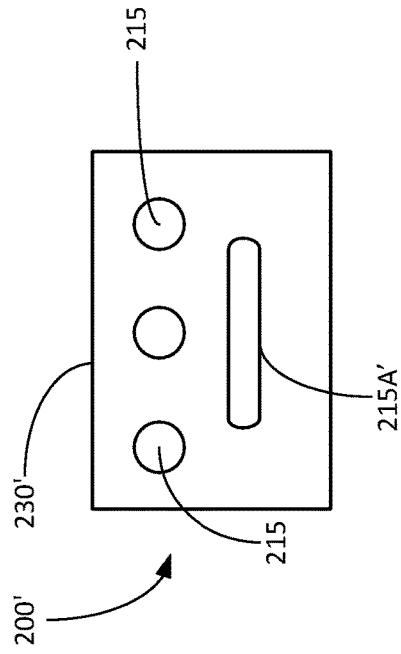


FIG. 4B

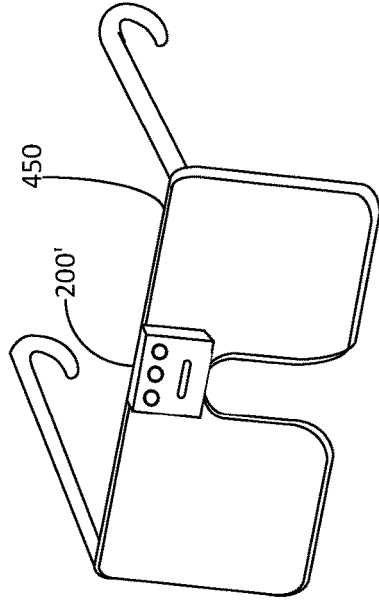


FIG. 5

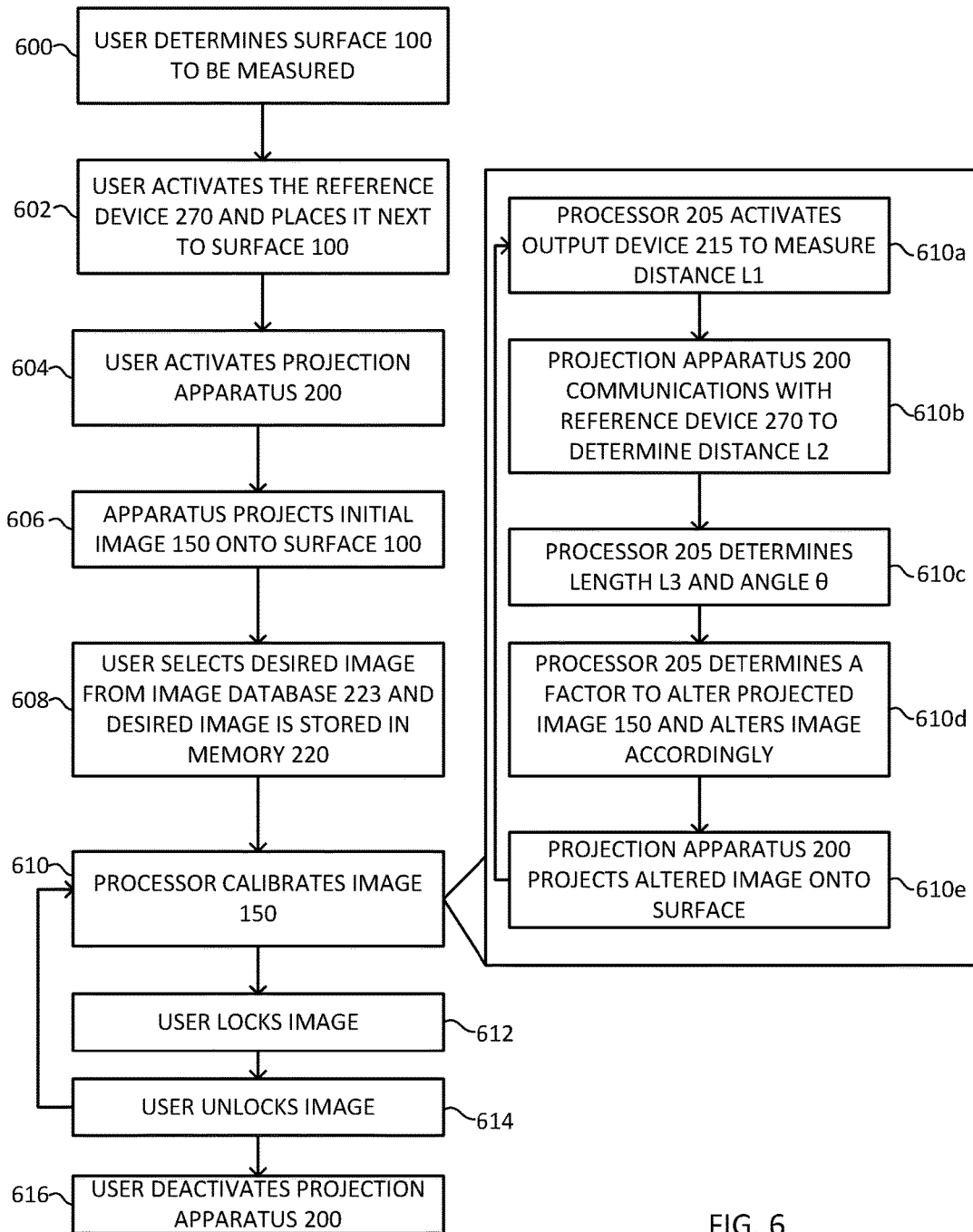


FIG. 6

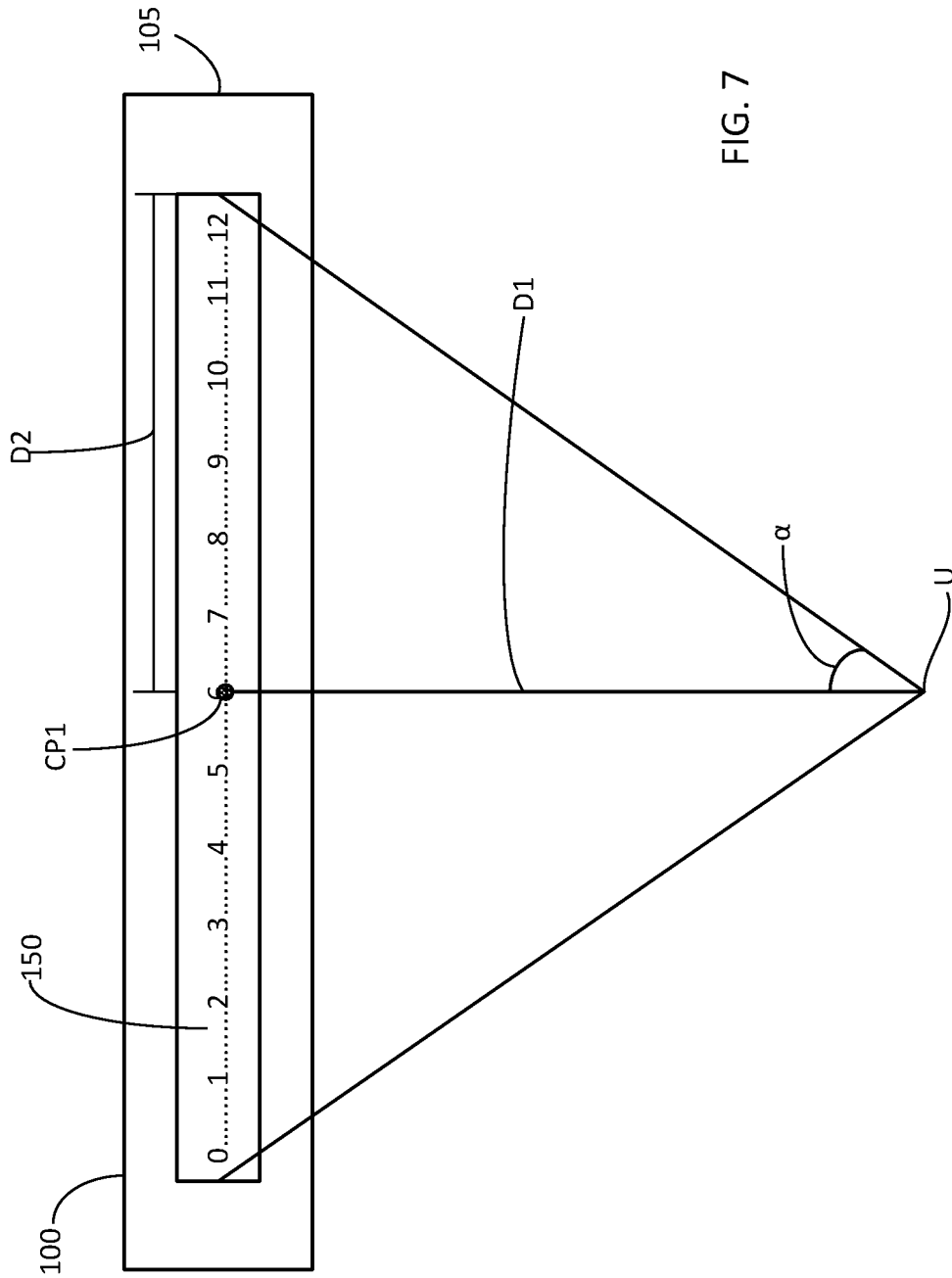


FIG. 7

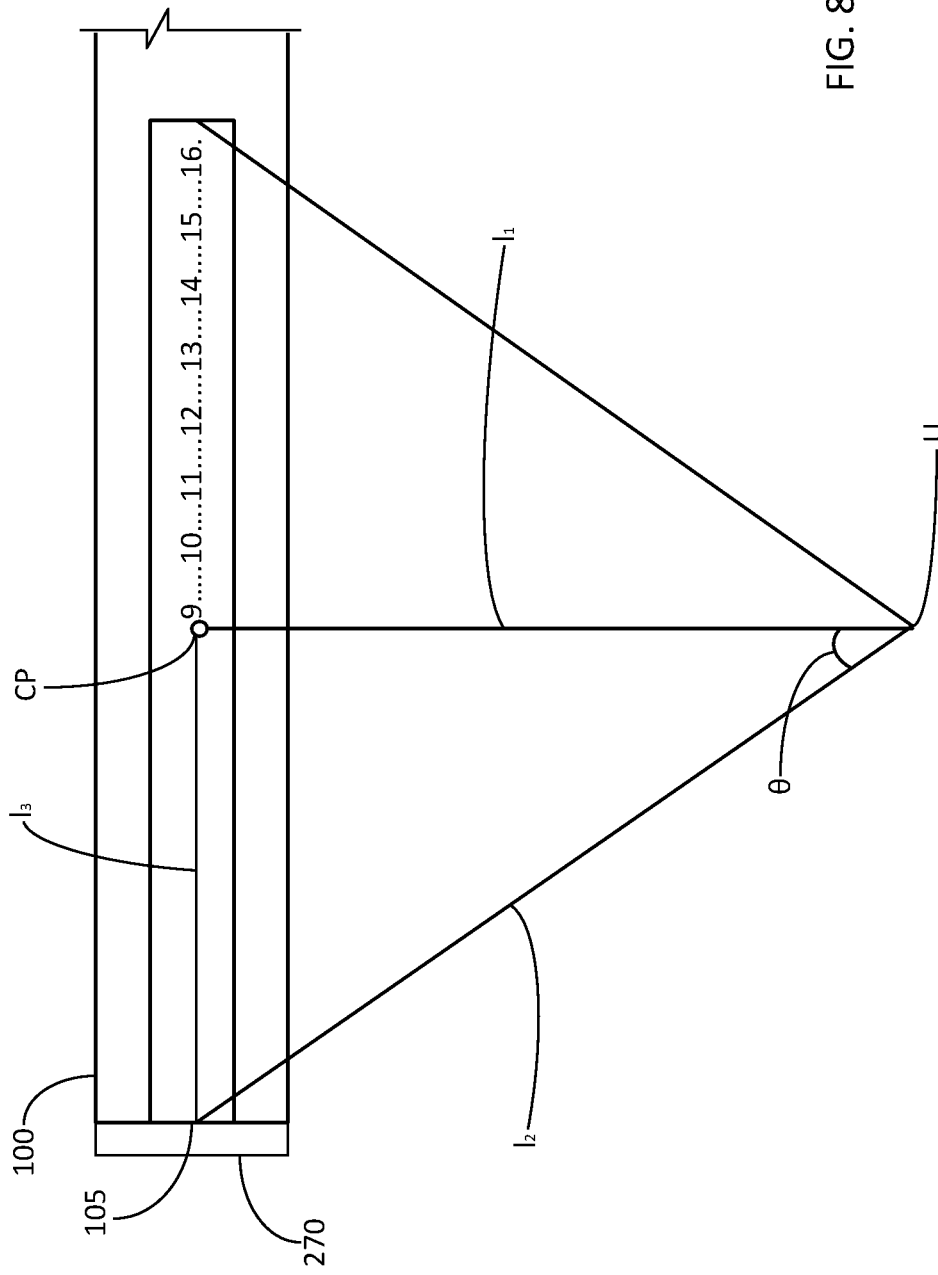


FIG. 8

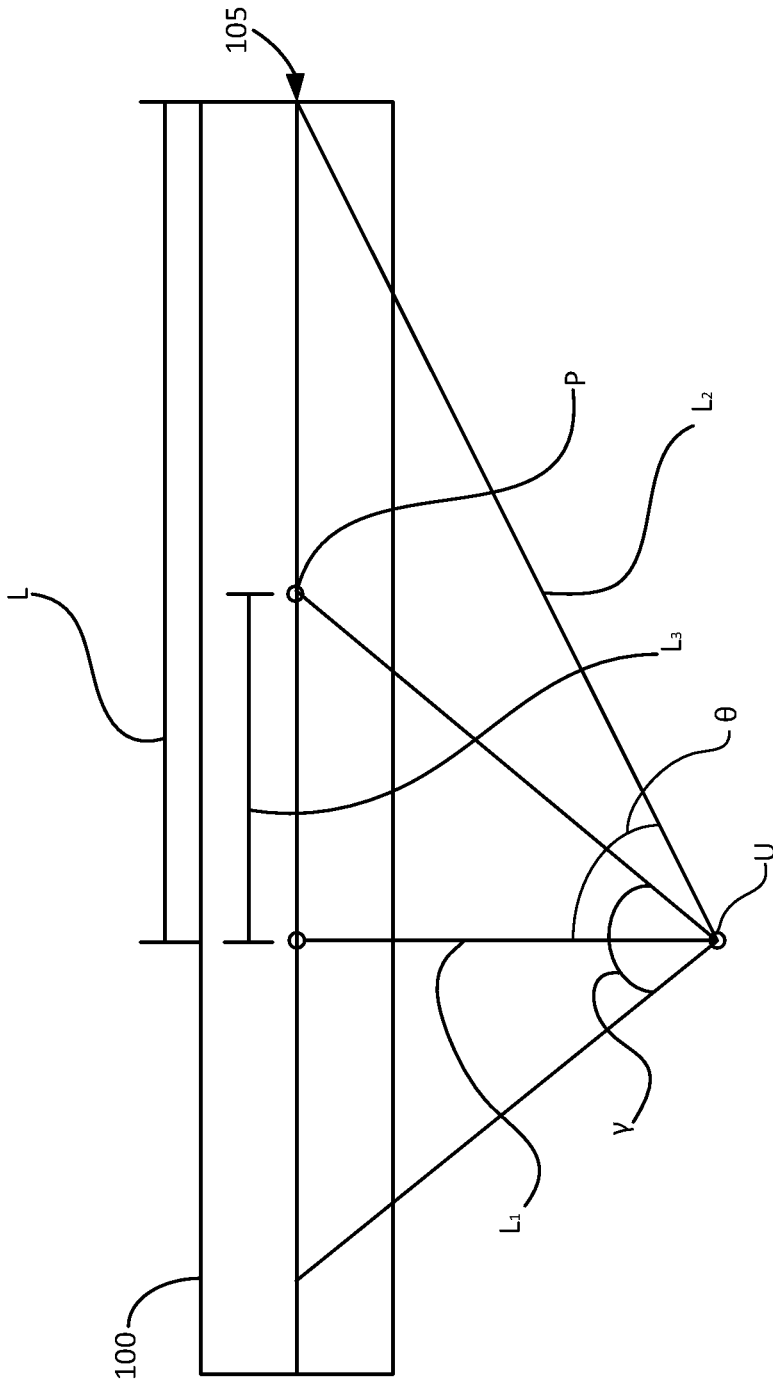


FIG. 9

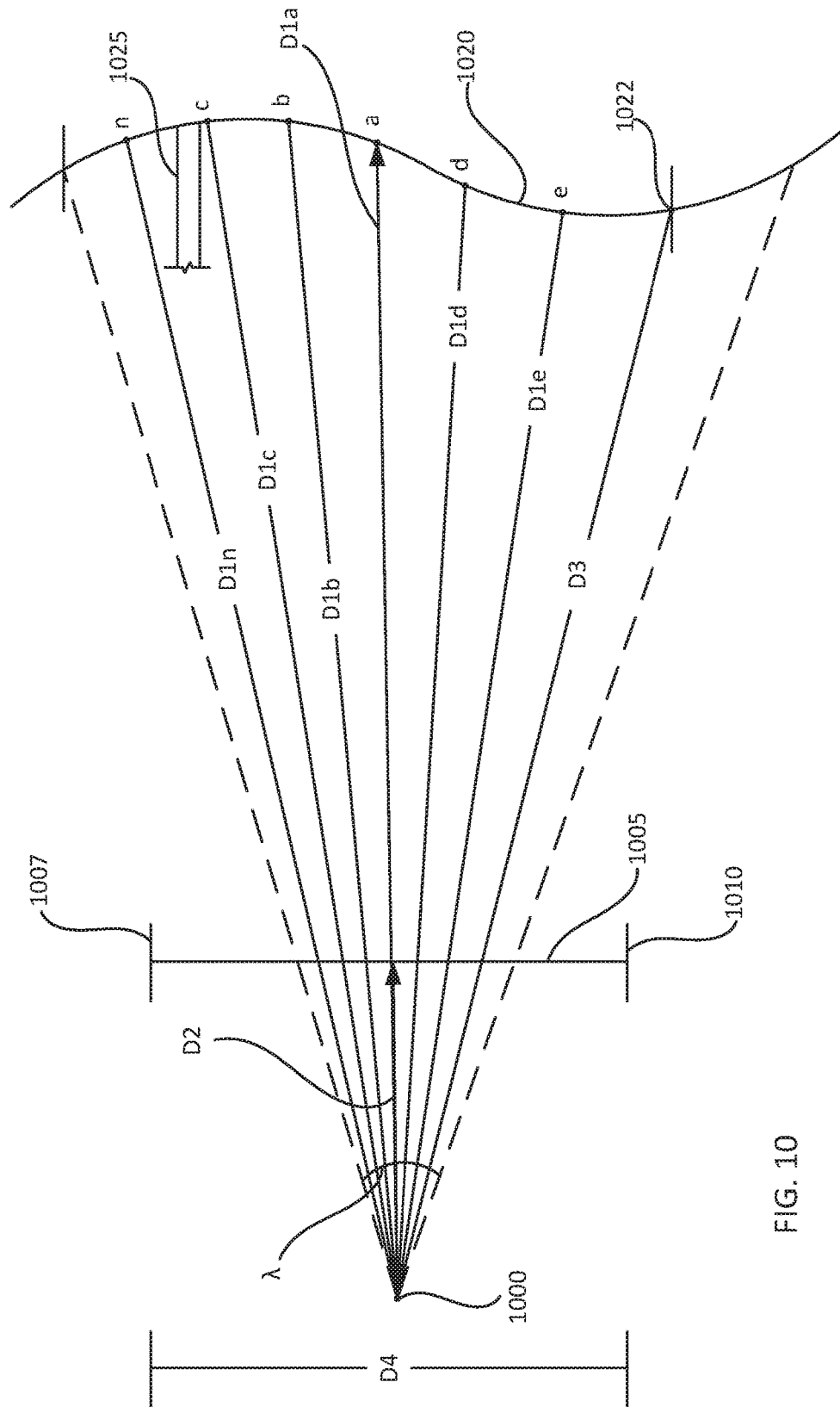


FIG. 10

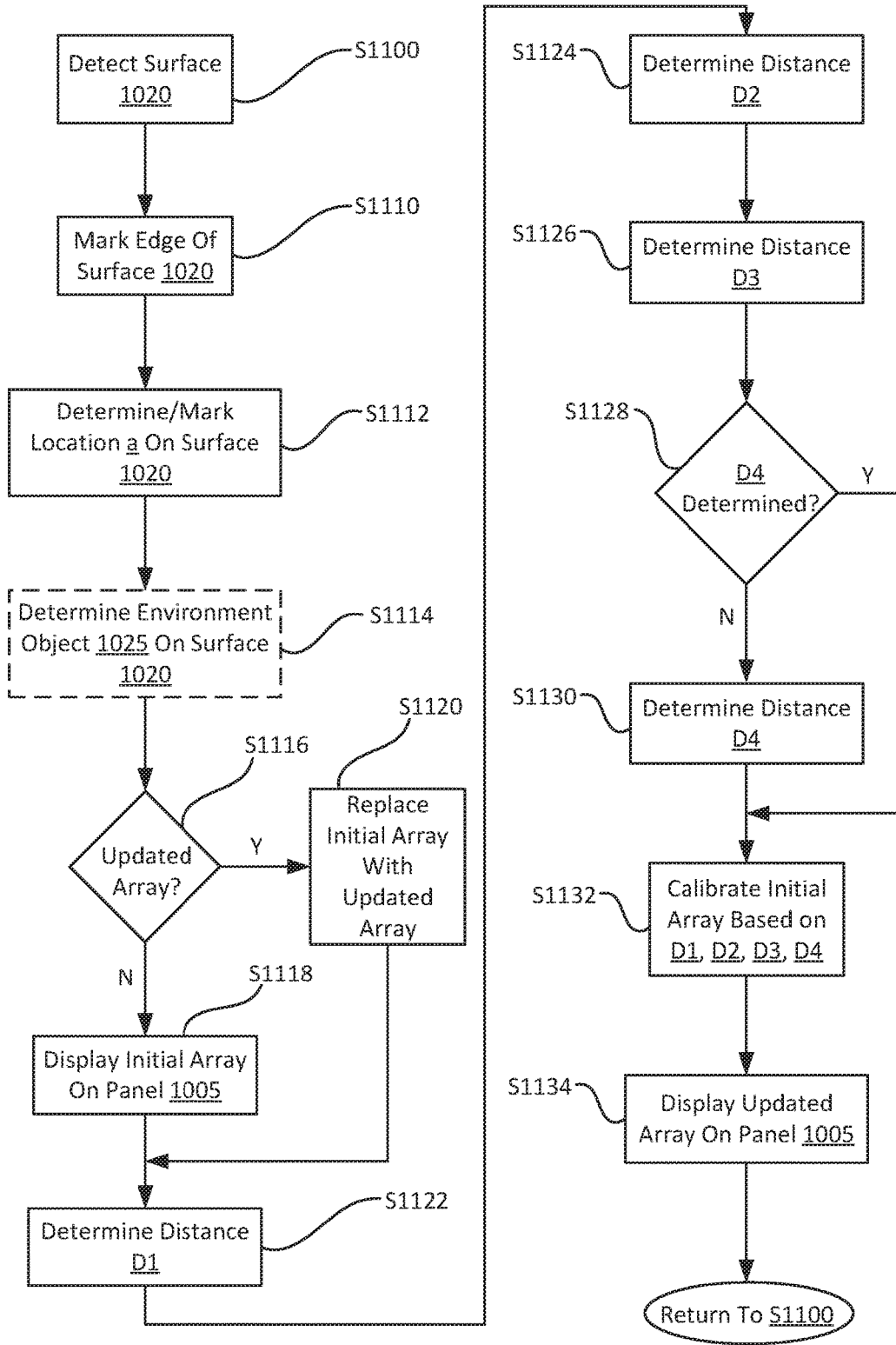


FIG. 11

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PROJECTION MAPPING SYSTEM AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 15/622,959, filed Jun. 14, 2017, which is pending. The entirety of the application is incorporated herein by reference in its entirety.

FIELD OF INVENTION

The invention relates to projection mapping apparatus. More specifically, the invention relates to an apparatus for projecting an image onto a surface. The image may or may not be human readable.

BACKGROUND

Projection displays have been around for several years in many different forms. While many industries take advantage of projection technology, one industry where such technology has been largely ignored is hand tools. Generally speaking, hand tools have seen relatively few advancements over the years. This is especially true when it comes to tape measures.

Currently, tape measures are effective for their intended purpose. However, they tend to be bulky and somewhat difficult to use, as a user must both lay out the tape measure upon a surface and mark the surface while attempting to hold the tape measure in position. This often results in frustration, especially when the tape measure becomes dislodged from its desired position, twists, or the user has to take measure many different surfaces. Accordingly, it would be desirable to have a projection tape measure which allows a user to measure a surface without requiring him or her to physically hold any device.

SUMMARY

The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an extensive overview of the invention. It is not intended to identify critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented elsewhere herein.

In one embodiment, a projection system includes a projection apparatus embodied in a housing secured to a user. The projection apparatus has a processor in data communication with a networking device, at least one input/output device, and computer memory. The computer memory includes a program with machine readable instructions that, when effected by processor, perform the following steps: (a) determine an edge of a surface to be measured; (b) project an initial image onto the surface, the initial image being based on a predetermined set of conditions; (c) determine a substantially perpendicular distance $D1$ between the projection apparatus and the surface; (d) determine a distance $D2$ between the projection apparatus and the edge of the surface; (e) calibrate the initial image based on the distances $D1$ and $D2$ determined in steps (c) and (d); and (f) project an updated image onto the surface.

In another embodiment, a projection system comprises a reference device comprising a processor in data communi-

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cation with a networking device and at least one input/output device. The reference device is placed at an edge of a surface to be measured. The system further includes a projection apparatus embodied in a housing secured to a user. The projection apparatus comprises a processor in data communication with a networking device, at least one input/output device, and computer memory. The computer memory includes a program having machine readable instructions that, when effected by processor, performs the following steps: (a) projecting an initial image onto the surface, the initial image being based on a predetermined set of conditions; (b) determining a substantially perpendicular distance $D1$ between the projection apparatus and the surface; (c) determining a distance $D2$ between the projection apparatus and the reference device; (d) calibrating the initial image based on the distances $D1$ and $D2$ determined in steps (b) and (c); (e) projecting an updated image onto the surface; and (f) repeating steps (b)-(e). The reference device and the projection apparatus communicate over a network.

In still another embodiment, a projection system has a reference device and a projection apparatus embodied in a housing secured to a user. The projection apparatus includes a processor in data communication with a networking device, at least one input/output device, and computer memory. The computer memory includes a program having machine readable instructions that, when effected by processor, perform the following steps: (a) projecting an initial image onto the surface, the initial image being based on a predetermined set of conditions; (b) determining a substantially perpendicular distance $D1$ between the projection apparatus and the surface; (c) determining a distance $D2$ between the projection apparatus and the reference device; (d) calibrating the initial image based on the distances $D1$ and $D2$ determined in steps (b) and (c); (e) projecting an updated image onto the surface; and (f) repeating steps (b)-(e).

In still another embodiment, a marking and display system includes a first array display apparatus having a viewing angle. The display apparatus has a processor in data communication with a networking device, at least one input/output device, and computer memory. The computer memory includes a program having machine readable instructions that, when effected by processor, iteratively perform the following steps: (a) determining the presence of a distant surface; (b) marking, within the viewing angle, an edge of the distant surface and a plurality of locations on the distant surface; (c) displaying an initial array onto an array receiving panel having a first panel edge and a second panel edge; (d) determining a distance $D1a-D1n$ between the display apparatus and each of the plurality of locations on the distant surface; (e) determining a forward distance $D2$ between the display apparatus and the array receiving panel; (f) determining a distance $D3$ between the display apparatus and the edge of the distant surface; (g) determining a distance $D4$ between the first panel edge and the second panel edge; (h) calibrating the initial array on the array receiving panel based on the distances $D1a-D1n$, $D2$, $D3$, and $D4$; and (i) projecting an updated array onto the array receiving panel.

In a further apparatus, a marking and display system has an array display apparatus with a viewing angle. The system comprises a processor in data communication with a networking device, at least one input/output device, and computer memory, the computer memory comprising a program having machine readable instructions that, when effected by processor, iteratively perform the following steps: (a) determining the presence of a distant surface; (b) marking, within

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the viewing angle, an edge of the distant surface and a plurality of locations on the distant surface; (c) displaying an initial array onto an array receiving panel having a first panel edge and a second panel edge; (d) determining a distance $D1_a$ - $D1_n$ between the display apparatus and each of the plurality of locations on the distant surface; (e) determining a forward distance $D2$ between the display apparatus and the array receiving panel; (f) determining a distance $D3$ between the display apparatus and the edge of the distant surface; (g) determining a distance $D4$ between the first panel edge and the second panel edge; (h) calibrating the initial array on the array receiving panel based on the distances $D1_a$ - $D1_n$, $D2$, $D3$, and $D4$; (i) projecting an updated array onto the array receiving panel; (k) repeating steps (a) through (f) and (h). At step (c), the initial array displayed on the array receiving panel is substituted with the updated array from step (j); and the updated array at step (j) is replaced by a second updated array.

In still yet another embodiment, a marking and display system includes an array display apparatus having a viewing angle. The system further comprises a processor in data communication with a networking device, at least one input/output device, and computer memory, the computer memory comprising a program having machine readable instructions that, when effected by processor, iteratively perform the following steps: (a) determining the presence of a distant surface; (b) marking, within the viewing angle, an edge of the distant surface and a location on the distant surface; (c) determining the presence of an environmental object of the distant surface; (d) displaying an initial array onto a windshield having a first edge and a second edge, the initial array being based on the environmental object; (e) determining a distance $D1$ between the display apparatus and the location on the distant surface; (f) determining a forward distance $D2$ between the display apparatus and the windshield; (g) determining a distance $D3$ between the display apparatus and the edge of the distant surface; (h) determining a distance $D4$ between the windshield first edge and second edge; (i) calibrating the initial array on the windshield based on the distances $D1$, $D2$, $D3$, and $D4$; and (j) projecting an updated array onto the array receiving panel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a projection apparatus and system according to an embodiment of the invention.

FIG. 2A is a front view of an embodiment of the projection apparatus of FIG. 1.

FIG. 2B is a side view of the projection apparatus of FIG. 2A.

FIG. 3 is a perspective view of the projection apparatus of FIG. 2A incorporated into a hat.

FIG. 4A is a side view of another embodiment of the projection apparatus of FIG. 1.

FIG. 4B is a front view of the projection apparatus of FIG. 4A.

FIG. 5 is a perspective view of the projection apparatus of FIG. 4A incorporated onto a pair of glasses.

FIG. 6 is a flowchart illustrating various steps performed by projection apparatus systems according to an embodiment of the invention.

FIG. 7 is a perspective view of a projection apparatus system according to an embodiment of the invention.

FIG. 8 is a perspective view of a projection apparatus system according to another embodiment of the invention.

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FIG. 9 is a perspective view of a projection apparatus system according to still another embodiment of the invention.

FIG. 10 is a perspective view of a projection apparatus system according to another embodiment of the invention.

FIG. 11 is a flowchart illustrating various steps performed by projection apparatus systems according to an embodiment of the invention.

DETAILED DESCRIPTION

Currently, the majority of hand tools do not incorporate any type of projection system. One exception is distance finders which use ultrasonic and/or laser reflection techniques to determine a distance from the user to a surface. The user points the tool at a surface, presses a button to activate the laser, and the tool measures the distance to the location where the laser is pointed. While these devices are useful for determining the distance to a point, they are not tape measures. A tape measure cannot be substituted for a laser pointer where the user desires to, for example, mark a surface for cutting.

Disclosed herein are embodiments of projection mapping apparatus which may be useful as a tape measure projection device. Those of skill in the art shall understand that while reference is made herein to apparatus that project tape measures, other projection apparatus are contemplated within the scope of the invention and will become apparent from the description provided herein.

In one embodiment, a projection mapping system and apparatus includes a projection apparatus **200** which may be configured to attach to a user's person or incorporated into an article worn by the user as described herein. Electronic components of the projection apparatus **200** are illustrated in FIG. 1. The projection apparatus **200** includes a processor **205** communicatively coupled to a networking device **210**, one or more input/output devices **215**, and computer memory **220**. The processor **205** may be configured through particularly configured hardware, such as an application specific integrated circuit (ASIC), field-programmable gate array (FPGA), etc., and/or through execution of software (e.g., program **225**) to perform functions in accordance with the disclosure herein.

Memory **220** represents one or more of volatile memory (e.g., RAM) or non-volatile memory (e.g., ROM, FLASH, magnetic media, optical media, etc.). Although shown within the projection apparatus **200**, the memory **220** may be, at least in part, implemented as network storage external to the projection apparatus **200** which may be accessed via the network device **210**. The network device **210** may be implemented as one or both of a wired network interface and a wireless network interface (e.g., Wi-Fi, Internet, Bluetooth, etc.), as is known in the art.

The network device **210** may allow the projection apparatus **200** to communicate over a network **250** with a reference device **270**. The network **250** may be a wireless network, such as Wi-Fi, Bluetooth, or other wireless (or wired) network.

Program **225** may be stored in a transitory or non-transitory portion of the memory **220**. Program **225** includes machine readable instructions that, when executed by the processor **205**, perform one or more of the functions of the device **200**. In embodiments, the program **225** may include instructions for calculating distances and scales and projecting an image onto a surface (e.g., surface **100**) as described in greater detail below with reference to FIG. 6.

An image database **223** may additionally be stored in the memory **220**, or alternately may be stored in remote storage accessible over the network **250**. The image database **223** may contain various images of tape measures which may be projected onto a surface **100** via the projection apparatus **200** according to the description provided herein. For example, there may be tape measure images that display measurements according to the metric system, and other tape measure images that display measurements according to the imperial system. Additionally, the user may prefer one color over another, and therefore there may be multiple images of tape measures in varying colors. Traditionalists may prefer the projection to show the tape measure in yellow, which others may prefer a different color (e.g., white, blue, green, orange, etc.). Accordingly, various images may be stored in the image database **223** accessible by the processor **205**.

The input/output device **215** may include one or more input and/or output devices which may be embodied in a single device or multiple devices. In one embodiment, the input/output device **215** includes at least a projector for projecting an image onto a surface (e.g., surface **100**). The input/output device **215** may additionally include a laser and/or a camera. Optionally, the input/output device **215** includes a UV laser for marking purposes, as is described below. In one embodiment, the input/output device **215** may further include a speaker. The input/output device **215** may still further include a button **215A** and **215A'** (FIGS. 2B and 4B), for example, to allow the user to interact with the apparatus **200** and/or the reference device **270**, as described herein.

The reference device **270** may have a processor **275** communicatively coupled to an input/output device **280** and a network device **285**. The network device **285** may allow the reference device **270** to communicate over the network **250** with the projection apparatus **200**.

The input/output device **280** may be an emitting device which emits a signal (e.g., over the network **250**) which may be received by the projection apparatus **200** in order to determine the distance between the reference device **270** and the projection apparatus **200**. Alternately, the reference device **270** may be in communication (e.g., wired or wirelessly) with the projection apparatus **200** to communicate a distance from the projection apparatus **200** to the reference device **270**.

The projection apparatus **200** may be embodied in a variety of different devices. In one embodiment, the projection apparatus **200** may be incorporated into a handheld device, similar to a laser measuring device or flashlight. In another embodiment, the projection apparatus **200** may be configured as a clip. FIGS. 2A, 2B, 4A, and 4B illustrate exemplary configurations of a clip. In FIG. 2A, the projection apparatus **200** is embodied in a clip having a housing **230** with apertures formed therein through which one or more input/output devices **215** may extend. It shall be understood by those of skill in the art that the input/output device(s) **215** may not extend all the way through the aperture, but the aperture may allow the input/output device(s) **215** to give and/or receive information to/from the system. The housing **230** further includes a button **215A** which the user may use to interact with the apparatus **200**. An arm **234** may rotatably attach to the housing **230** via a pin **232** (for example), and may be spring-loaded such that the arm **234** is maintained in a closed position unless the user forcibly opens the arm **234** (e.g., in order to attach the apparatus **200** to a wearable article). FIG. 3 shows a hard hat **400** with a projection apparatus **200** attached thereto. The projection apparatus **200** may alternately be attached to

other wearable articles, such as a baseball cap or other type of hat, or to an article of clothing, such as to the user's collar.

In FIGS. 4A, 4B, and 5, an apparatus **200'** is configured for attachment to safety goggles **450** or glasses. The apparatus **200'** includes a housing **230'** and a clip **234'** which may be configured to engage with the nose bridge of the glasses **450**. The clip **234'** may be adjustable to ensure that the apparatus **200'** is securely attached to the goggles **450**. The apparatus **200'** includes at least an input/output device **215**, and may additionally include a button **215A'** as shown in FIGS. 4B and 5.

The projection apparatus **200** may preferably be adjustable such that the input/output device **215** is appropriately oriented. For example, the housing **230** may be adjustably attached to a plate which may be secured to the arm **234** via the pin **232**. The position of the housing **230** may therefore be adjusted as necessary. Alternately, in embodiments, the projection apparatus **200** may be incorporated directly into items such as the hard hat or safety goggles.

The electronic components of the apparatus **200** may be battery operated, solar powered, or may receive power by any other means now known or later developed. In one embodiment, the apparatus **200** includes a rechargeable battery which may be recharged using solar power, electrical power, etc.

The features of the various components described herein shall be further understood by way of examples of the projection apparatus **200** in a use configuration. Referring now to FIG. 6, an exemplary set of process steps is illustrated according to an embodiment of the invention. The process begins at step **600**, when the user determines that a surface requires a measurement. At step **602**, the user may activate the reference device **270** and places the reference device **270** such that it abuts one end of the surface **100**, as shown in FIG. 8. Further discussion of the reference device **270** is provided below.

Moving on to step **604**, the projection apparatus **200** is activated. The projection apparatus **200** may be activated via, for example, a button **215A** on the apparatus **200**. The button **215A** may cause the apparatus **200** to turn to an "on" mode. Alternately, the apparatus **200** may be equipped with, for example, a gyroscope which may detect movement of the user's head. When the user shakes his or her head, the apparatus **200** may be activated.

At step **606**, upon activation, the apparatus **200** may project an initial image **150** onto the surface **100** (see FIG. 7). The initial image **150** may not yet be the user's desired depiction of a tape measure. For example, the projection apparatus **200** may be initially programmed to project an image from the image database **223** of a tape measure showing measurements according to the imperial measurement system. However, the user may prefer that the measurements be shown according to the metric system. Additionally, the initial image **150** may be programmed to project the initial image **150** based on pre-set reference conditions. However, the reference conditions may not accurately portray the position of the user in reference to the surface **100**, and therefore, the initial image **150** may project inaccurate units of measurement (e.g., one inch as projected in the initial image **150** is not a true representation of one inch).

Nevertheless, the process moves to step **608**, wherein the user selects the desired tape measure image from the image database **223**. The user may be able to change the image in order to customize the system of measurement (e.g., imperial or metric) by toggling through the images stored on the image database **223** to arrive at the desired image, e.g., via the button **215A** or **215A'**. Additionally, the user may be able

to select an image that is color preferential to the user. Once the user arrives at his or her preferred image, the user's preferences may be automatically stored in the memory 220 and recalled each time the user activates the projection apparatus 200.

Moving on to step 610, once the user has selected his or her preferred image, the processor 205 begins the process of calibrating the projected image to the user's position in relation to the surface 200. As noted above, the projection apparatus 200 may be programmed to project an initial image 150 based on pre-set reference conditions at which the projected image portrays units of measurement in accurate one-inch units. For example, referring again to FIG. 7, the reference conditions may assume that a distance D1 from the projection apparatus 200 to the surface 100 is equal to 2 feet, and the distance D2 from the edge of the surface 105 to the center point CP1 of the projected image is 6 inches. At these conditions, a reference angle α between the user and the end of the surface 105, calculated using the equation $\sin \theta = D1/D2$, is 26.56 degrees. At these conditions, the projection apparatus 200 may project an image of a tape measure, wherein the increments of measurement are shown at exactly 1 inch. However, it is unlikely that the user will maintain these reference conditions. As the user moves closer to or away from the surface 100, the scale of the image must be altered such that the projected image still accurately displays the units of the tape measure. Accordingly, the position of the user relative to the surface 100 must be determined.

At step 610a, the processor 205 causes the projection apparatus 200 to activate one or more output devices 215 (e.g., a laser) to measure the actual distance l_1 (FIG. 8) from the user U (having the projection apparatus 200 attached thereto) to the center point CP at surface 100. Using techniques known to those of skill in the art, the distance l_1 may be ascertained.

At step 610b, the projection apparatus 200 communicates with the reference device 270, e.g., over the network 250 via networking devices 210 and 285, respectively, to determine the location of the reference device 270. Knowing the location of the reference device 270, the processor 205 is able to determine the distance l_2 between the projection apparatus 200 and the reference device 270.

The reference device 270 may, in one embodiment, be a smart phone equipped with downloadable software (e.g., a smart phone application) that allows it to communicate with the projection apparatus 200. In order to use the smart phone as the reference device 270, the user may access the smart phone application on the phone, which may, among other things, activate the networking device 285 such that the projection apparatus 200 may communicate with the phone. For example, after the distance l_2 is determined, a planar verification display pattern may be projected onto the surface intended to be measured. The projected display pattern could show geometric shapes with known ratios such as squares, circles, etc. The projected sequence of predictable patterns may be shown sequentially along the surface in order to verify that the surface is flat (or being measured on a common plane). Adjustments in software can be made to adjust for planar integrity for any skewing of the plane of measurement. In one embodiment, the software may be configured to adjust for contoured surfaces utilizing 3D mapping and marking techniques including stereoscopic viewing of the projected display pattern.

In embodiments, the reference device 270 may be omitted. For example, in one embodiment, the projection apparatus 200 may include a camera (e.g., as an input/output

device 215). Using traditional gradient image processing techniques, the processor 205 may be able to ascertain the end 105 of the surface 100, and thus determine the length l_2 . In still another embodiment, the end 105 of the surface 100 may be marked with a marker (e.g., via a marking device such as a UV laser, etching, red dot marking, or via any other marker currently in use or later developed). The projection apparatus 200 may be configured to recognize the marker in order to ascertain the position of the end 105 of the surface 100, and thus determine the length l_2 .

Moving on, at step 610c, the processor 205 determines the missing length l_3 based on the Pythagorean Theorem for right triangles: $a^2 + b^2 = c^2$. The unit of the length l_3 may be determined based on the user's selection of the system of measurement. For example, if the user selects the imperial system, then the lengths l_1 , l_2 , and l_3 may be measured and determined in inches and feet. Alternately, if the user selects the metric system, then the lengths l_1 , l_2 , and l_3 may be measured and determined in centimeters and meters. More advanced non-linear methods may alternately be used to calculate the measurement of length l_3 . One such reiterative method involves differential calculus which would allow contoured measurements of surfaces that are not residing on a single flat plane.

Having determined the length l_3 , the processor 205 then calculates the angle θ between the user and the end of the surface 105. For example, if the user is 2.7' (32.4 inches) from the surface 100 (l_1), and the distance l_2 is determined to be 40 inches, then the angle θ between the user and the end of the surface 105 as determined by trigonometric principles is 35.9 degrees. Once the processor 105 determines the length l_3 , and the angle θ , the process moves to step 610d. The processor 205 is not limited to a single angle θ measurement in order to provide more precise results in measurement. Multiple calculations may be made in succession in order to provide a desired precision resulting measurement.

At step 610d, the processor 205 determines the factor by which the size of the projected image must be altered such that the units of measurement of the projected image correspond with the length l_3 determined at step 610c. In our example, the ratio of the reference angle to the actual angle is 0.74. Therefore, the image must be scaled down in length by a factor of 0.74. Using methods of scaling known to those of skill in the art, the program may be configured to scale the projected image 150 by the appropriate factor.

At step 610e, the projection apparatus 200 projects the altered image onto the surface 100, wherein the altered image is appropriately scaled based on the position of the user to the surface 100 as described above.

In one embodiment, illustrated in FIG. 9, the user may be a distance L from the end of the surface 105. Those of skill in the art may recognize that in order for the projected image to be as accurate as possible, it may be desirable for the user to be positioned such that the projection apparatus 200 is substantially perpendicular to the surface 100. Therefore, to measure distances that are farther away from the end of the surface 105 (e.g., distances greater than the beam angle γ , or the angle of the beam from the projection apparatus 200), the user may have to move into the general vicinity of the final measurement. The distance L may be greater than the beam angle γ . Here, the distances L_1 and L_2 may be determined as described above regarding l_1 and l_2 . Using the Pythagorean Theorem, the program 223 may determine the distance L. Additionally, as the beam angle γ from the projection apparatus is known, and the distance L_1 may be determined as described herein, the distance L_3 between the center point

of the projection beam and the edge of the beam may be determined. For example, using the equation $\tan \gamma = L_3/L_1$ (wherein γ is $1/2$ the beam angle), the program may determine distance L_3 . Since the user may not be standing at the end **105** of the surface **100**, and the beam of projection is limited, the image of the tape measure may start at point U, the unit of which may be equal to the distance L less distance L_3 . For example, if the user is standing 20 inches from the end of the surface **105**, and the beam projects an image 8 inches across, the point P will show the beginning of the tape measure starting at 16 inches.

The process may repeat steps **610a** through **610e** in a continuous loop to ensure that the projected image of the tape measure is consistently accurate. In one embodiment, multiple differential calculations may be made and accumulated to provide increased precision to the overall measurement results to the user.

Optionally, in one embodiment, the process moves to step **612**, where the user may be able to lock the projected image. For example, the user may press the button **215A** or **215A'** (e.g., two quick presses of the button) to lock the image in place. Alternately, the user may be able to effectuate a movement by his head to lock the image (e.g., moving his head in a quick up-and-down movement). By locking the image in place, the user may cause the process to stall at step **620** until the image is unlocked. The user may unlock the image at step **614** by pressing the button, shaking his head, or other means. Once the image is unlocked, the process may return to step **610** as described above.

The process ends at step **616** with the user deactivating the projection apparatus **200**.

In another embodiment, a projection apparatus is configured to project an image onto a surface. The image may be based on one or more direct and/or indirect measurements. In other words, one or more direct and/or indirect measurements may be utilized to provide a unique projected perspective image. In one embodiment, the projection apparatus is substantially similar to the projection apparatus **200**, and includes a processor in data communication with a networking device, at least one input/output device, and computer memory that has programming that, when effected by a processor, performs various steps for providing an image. The steps include determining a distance between the projection apparatus **200** and at least one surface, and projecting an image that is based on the determined distance. The process may be iterative, and it should be understood that the image which may be projected can be dynamic, or may change over time. The image may change incrementally, or may change substantially over time.

According to another embodiment of the invention, illustrated in FIG. **10**, a display apparatus **1000** is disposed near an array receiving surface **1005**, such as a windshield. The array receiving surface **1005** has a first edge **1007** and a second edge **1010**. The display apparatus **1000** has a viewing angle λ (represented by the broken lines in FIG. **10**). The display apparatus **1000** may be similar to the projection apparatus **200**, except as is shown and described herein. Here, display apparatus **1000** is operable to determine a distance to a surface **1020** in front of the apparatus **1000**, and to display an image onto the array receiving surface **1005** that is based on information about the surface **1020**. In an embodiment, the information about the surface **1020** is one or more utility lines **1025** which may be disposed above ground or underground. The information may optionally also include the surface **1020** itself. In other words, the image displayed on the array receiving surface **1005** may be of the environmental object **1025**, and/or of the surface

1020. Accordingly, a user may be presented with an alternative view of the surface **1020** and the environmental objects **1025**. Preferably, however, a user has an unobstructed view the surface **1020** together with a layered image of the environmental objects **1025** in order to provide the user with a useful, real-time accurate image of objects within the field of view of the apparatus **1000**.

Various methods may be used to determine the information about the surface **1020**. In embodiments, the display apparatus **1000** may be equipped with a camera which may scan the surface **1020** for information which is readily seen by the camera. In other embodiments, the display apparatus **1000** may be equipped with sonar technology, which may be used to send sound waves underground to determine the presence of underground utility lines. Other methods of determining underground objects, whether now known or later developed, may be used to detect the presence of objects on or under the surface **1020**.

FIG. **11** is a flowchart illustrating a closed loop system having various steps performed by the display apparatus **1000** in conjunction with programming effected by a processor. The process starts at step **S1100**, where the display apparatus **1000** detects the presence of a surface **1020**. The surface **1020** may be, for example, an area of earth or an object within the viewing panel of the display apparatus **1000**. At step **S1110**, the apparatus **1000** marks an edge **1022** of the surface **1020**. The edge **1022** is within the viewing panel of the display apparatus **1000**. The apparatus **1000** then determines and marks one or more locations a-n on the surface **1020** at step **S1112**. Optionally, at step **S1114**, the apparatus **1000** may determine the presence of an environmental object (e.g., a utility line **1025**) on or under the surface **1020**. At step **S1116**, the programming determines whether the system has an updated array. If not (e.g., the first time through the process), the apparatus **1000** displays an initial array onto the image receiving surface **1005** at step **S1118**. If the system has an updated array, then the apparatus **1000** replaces the initial array with the updated array at step **S1120**, and the process moves to step **S1122**.

At step **S1122**, one or more distances $D1a-D1n$ between the apparatus **1000** and the locations a-n on the surface **1020** are determined. At step **S1124**, a distance $D2$ between the apparatus **1000** and the image receiving surface **1005** is determined. At step **S1126**, a distance $D2$ is determined between the apparatus **1000** and the edge **1022** of the surface **1020**. At step **S1128**, the system determines whether a distance $D4$ has been previously determined. If not (e.g., the first time through the process) then the process moves to step **S1130**, wherein a distance $D4$ between the edges **1005** and **1007** of the image receiving surface **1005** is determined. If the distance $D4$ has been previously determined, then the process moves to step **S1132**, where the initial array displayed at step **S1118** is calibrated based on the determined distances $D1$, $D2$, $D3$, and $D4$. Step **S1132** may be similar to step **S610** described above, wherein the processor determines a factor to alter the image based on the distances $D1$, $D2$, $D3$, and $D4$. Finally, at step **S1134**, the display apparatus **1000** display an updated array on the image receiving surface **1005**. The process then repeats until the apparatus **1000** is deactivated.

Thus has been described systems, methods, and apparatus for projecting an image onto a surface. Many different arrangements of the described invention are possible without departing from the spirit and scope of the present invention. Embodiments of the present invention are described herein with the intent to be illustrative rather than restrictive. Alternative embodiments will become apparent to those

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skilled in the art that do not depart from its scope. A skilled artisan may develop alternative means of implementing the disclosed improvements without departing from the scope of the present invention.

Further, it will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations and are contemplated within the scope of the claims. Not all steps listed in the various figures and description need to be carried out in the specific order described. The description should not be restricted to the specific described embodiments.

The invention claimed is:

1. A marking and display system, comprising:
 - a first array display apparatus having a viewing angle, comprising a processor in data communication with a networking device, at least one input/output device, and computer memory, the computer memory comprising a program having machine readable instructions that, when effected by the processor, iteratively perform the following steps:
 - (a) determining the presence of a distant surface;
 - (b) marking, within the viewing angle, an edge of the distant surface and a plurality of locations on the distant surface;
 - (c) displaying an initial array onto an array receiving panel having a first panel edge and a second panel edge;
 - (d) determining a distance $D1_a-D1_n$ between the display apparatus and each of the plurality of locations on the distant surface;
 - (e) determining a forward distance $D2$ between the display apparatus and the array receiving panel;
 - (f) determining a distance $D3$ between the display apparatus and the edge of the distant surface;
 - (g) determining a distance $D4$ between the first panel edge and the second panel edge;
 - (h) adjusting the initial array on the array receiving panel based on the distances $D1_a-D1_n$, $D2$, $D3$, and $D4$; and
 - (i) projecting an adjusted array onto the array receiving panel.
 2. The marking and display system of claim 1, wherein the array receiving panel is substantially transparent.
 3. The marking and display system of claim 2, wherein step (b) comprises marking the distant surface with lasers.
 4. The marking and display system of claim 1, wherein the initial array is an image selected from a plurality of images stored in an image database in the computer memory.
 5. The marking and display system of claim 1, further comprising a second array display apparatus having a second viewing angle, the second array display apparatus comprising a processor in data communication with a networking device, at least one input/output device, and computer memory, the computer memory comprising a program having machine readable instructions that, when effected by processor, iteratively perform the following steps:
 - (a) marking, within the second viewing angle, a second edge of the distant surface and a second plurality of locations on the distant surface;
 - (c) displaying a second initial array onto a second array receiving panel having a pair of panel edges;
 - (d) determining a distance $D1'_a-D1'_n$ between the second array display apparatus and each of the second plurality of locations on the distant surface;

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- (e) determining a forward distance $D2'$ between the second array display apparatus and the second array receiving panel;
 - (f) determining a distance $D3'$ between the second array display apparatus and the second edge of the distant surface;
 - (g) determining a distance $D4'$ between the pair of panel edges of the second array receiving panel;
 - (h) adjusting the second initial array on the second array receiving panel based on: the distances $D1_a-D1_n$, $D2'$, $D3'$, and $D4'$; and
 - (i) projecting a second adjusted array onto the second array receiving panel.
6. The marking and display system of claim 5, wherein the first and second display apparatus communicate over a network, and wherein the first and second array receiving panels are the same.
 7. The marking and display system of claim 6, wherein the initial array and the second initial array from the respective first and second display apparatus are merged to form a single initial array.
 8. The marking and display system of claim 7, wherein the respective adjusted arrays from the first and second display apparatus are merged to form a single adjusted array.
 9. The marking and display system of claim 8, wherein the first viewing angle and the second viewing angle are overlapping.
 10. A marking and display system, comprising:
 - an array display apparatus having a viewing angle, comprising a processor in data communication with a networking device, at least one input/output device, and computer memory, the computer memory comprising a program having machine readable instructions that, when effected by processor, iteratively perform the following steps:
 - (a) determining the presence of a distant surface;
 - (b) marking, within the viewing angle, an edge of the distant surface and a plurality of locations on the distant surface;
 - (c) displaying an initial array onto an array receiving panel having a first panel edge and a second panel edge;
 - (d) determining a distance $D1'_a-D1'_n$ between the display apparatus and each of the plurality of locations on the distant surface;
 - (e) determining a forward distance $D2$ between the display apparatus and the array receiving panel;
 - (f) determining a distance $D3$ between the display apparatus and the edge of the distant surface;
 - (g) determining a distance $D4$ between the first panel edge and the second panel edge;
 - (h) adjusting the initial array on the array receiving panel based on the distances $D1_a-D1_n$, $D2$, $D3$, and $D4$;
 - (i) projecting an adjusted array onto the array receiving panel;
 - (j) repeating steps (a) through (f) and (h) through (i), wherein:
 - at step (c), the initial array displayed on the array receiving panel is substituted with the adjusted array from step (i); and
 - the adjusted array at step (i) is replaced by a second adjusted array.

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11. The marking and display system of claim **10**, wherein the image receiving panel is substantially transparent.

12. A marking and display apparatus, comprising:

an array display apparatus having a viewing angle, comprising a processor in data communication with a networking device, at least one input/output device, and computer memory, the computer memory comprising a program having machine readable instructions that, when effected by processor, iteratively perform the following steps:

- (a) determining the presence of a distant surface;
- (b) marking, within the viewing angle, an edge of the distant surface and a location on the distant surface;
- (c) determining the presence of an environmental object of the distant surface;
- (d) displaying an initial array onto a windshield having a first edge and a second edge, the initial array being based on the environmental object;
- (e) determining a distance D1 between the display apparatus and the location on the distant surface;

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(f) determining a forward distance D2 between the display apparatus and the windshield;

(g) determining a distance D3 between the display apparatus and the edge of the distant surface;

(h) determining a distance D4 between the windshield first edge and second edge;

(i) adjusting the initial array on the windshield based on the distances D1, D2, D3, and D4; and

(j) projecting an adjusted array onto the windshield.

13. The marking and display apparatus of claim **12**, wherein the windshield is substantially transparent when the initial array and the adjusted array are projected thereon.

14. The marking and display apparatus of claim **12**, wherein the environmental object is an underground utility line.

15. The marking and display apparatus of claim **14**, wherein the initial array is further based on the distant surface.

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