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PESCE

(54) **GENERATING GRAPHICAL REPRESENTATIONS FOR VIEWING 3D DATA AND/OR IMAGE DATA**

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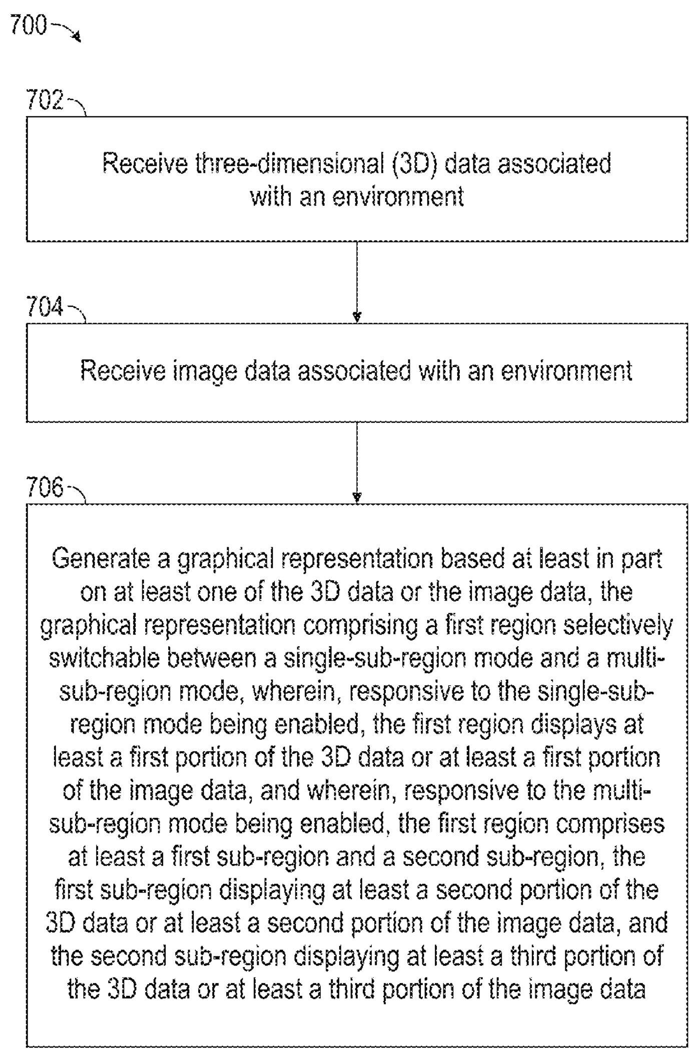
CPC ***G06T 17/00*** (2013.01)

(57) **ABSTRACT**

A method includes receiving three-dimensional (3D) data and image data. The method further includes generating a graphical representation based at least in part on at least one of the 3D data or the image data, the graphical representation including a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode. Responsive to the single-sub-region mode being enabled, the first region displays at least a first portion of the 3D data or at least a first portion of the image data. Responsive to the multi-sub-region mode being enabled, the first region includes at least a first sub-region and a second sub-region. The first sub-region displays at least a second portion of the 3D data or at least a second portion of the image data, and the second sub-region displays at least a third portion of the 3D data or at least a third portion of the image data.



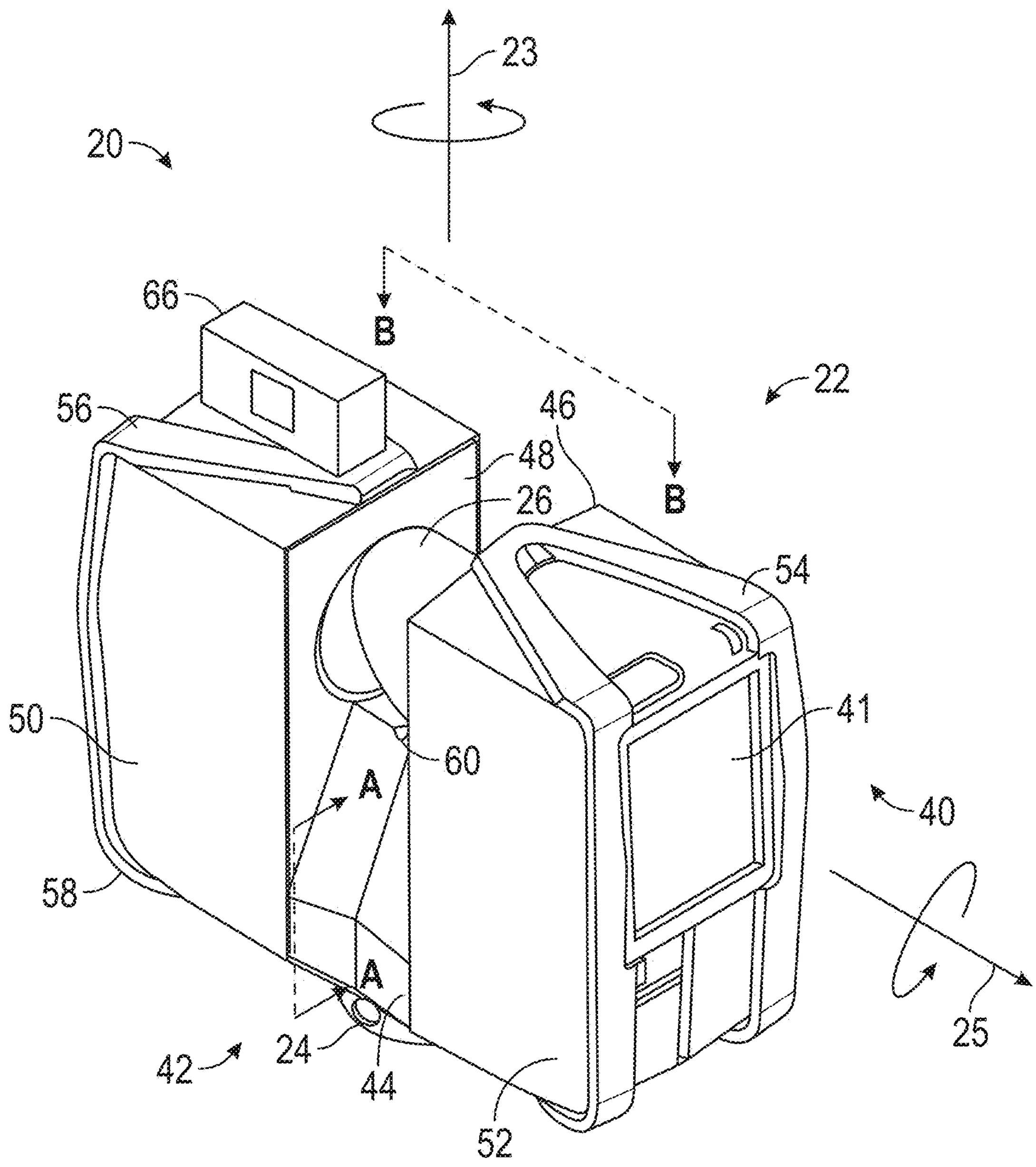


FIG. 1

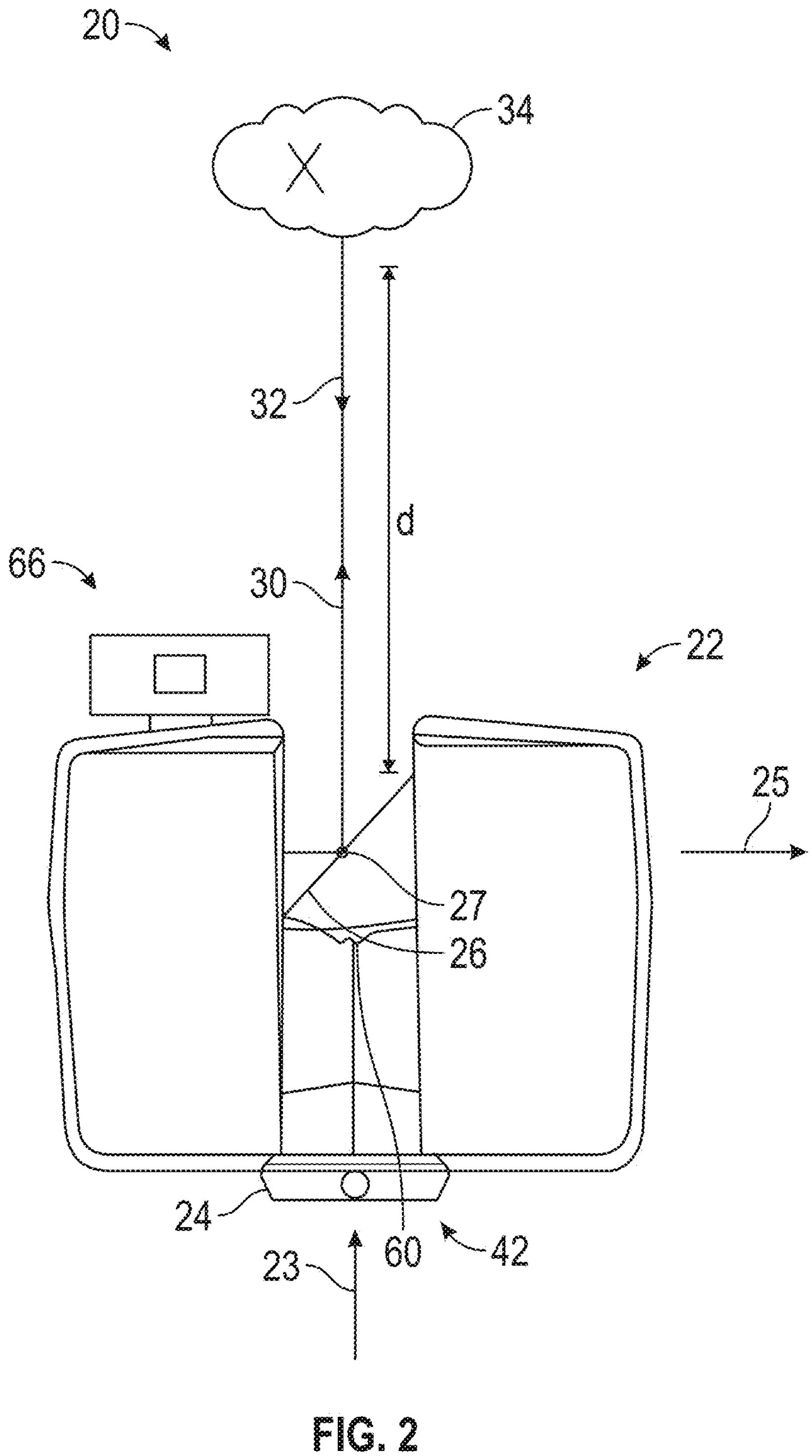


FIG. 2

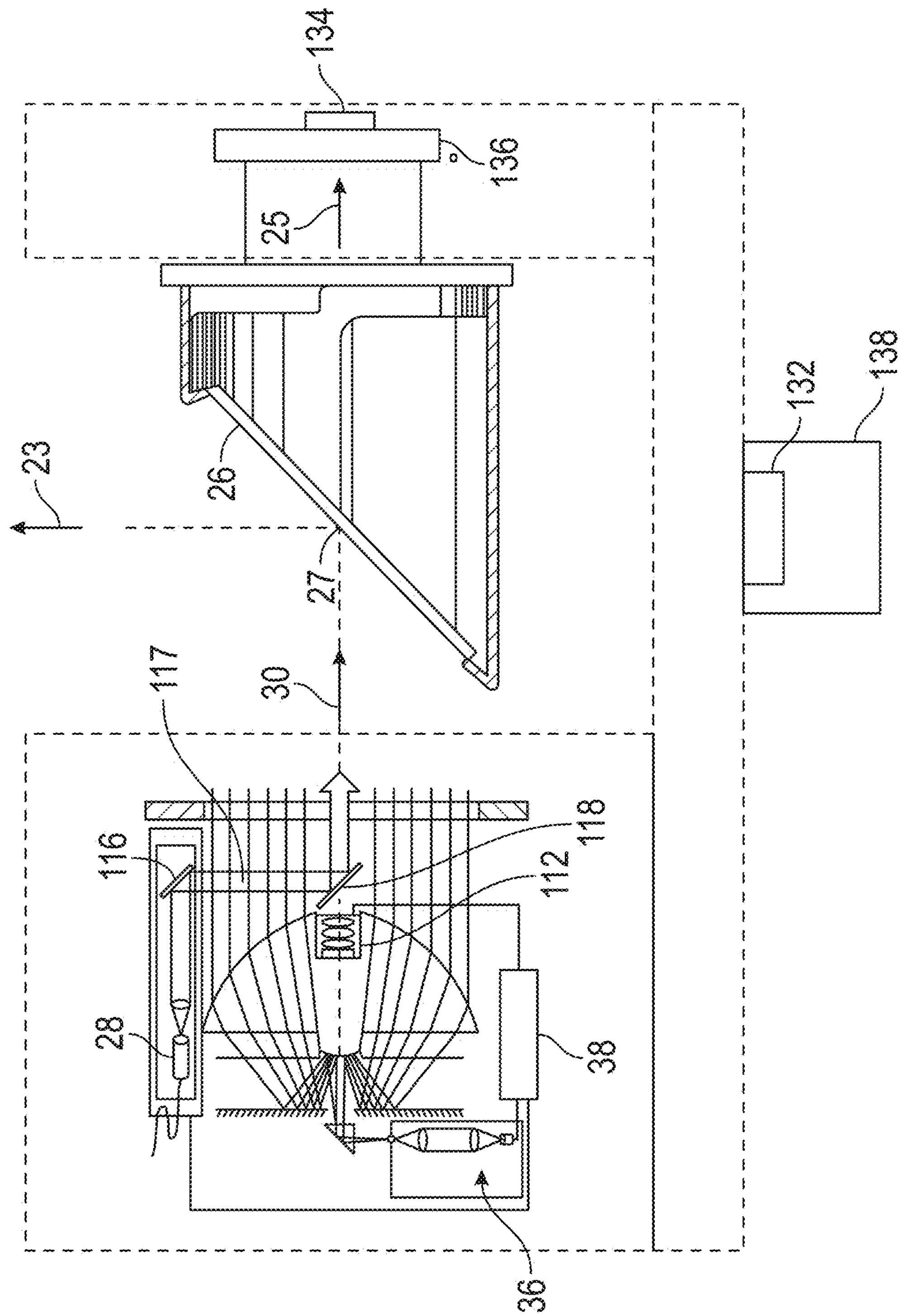


FIG. 3

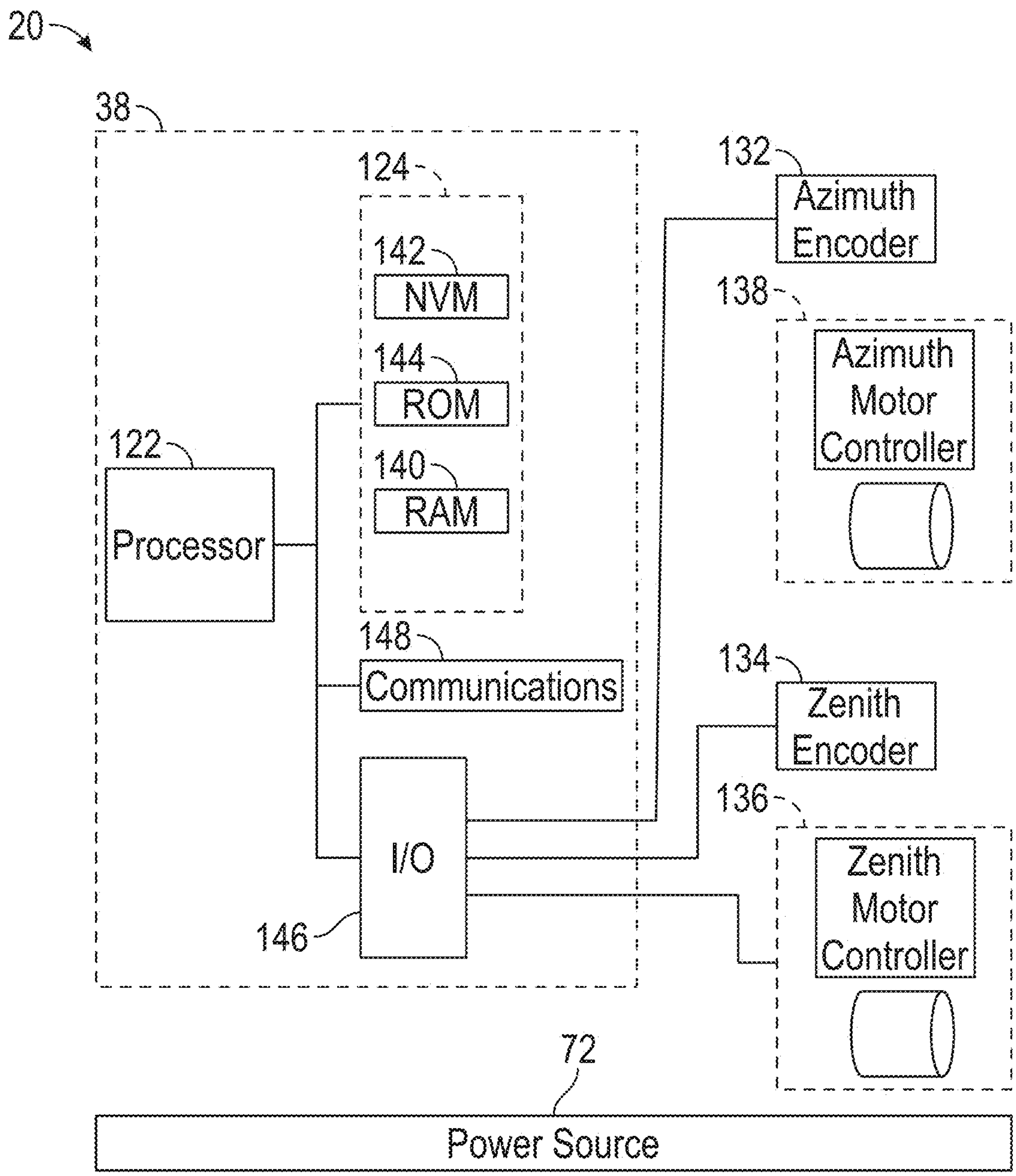

20
38
124
142
NVM
144
ROM
140
RAM
122
Processor
148
Communications
I/O
146
132
Azimuth Encoder
138
Azimuth Motor Controller
134
Zenith Encoder
136
Zenith Motor Controller
72
Power Source

FIG. 4

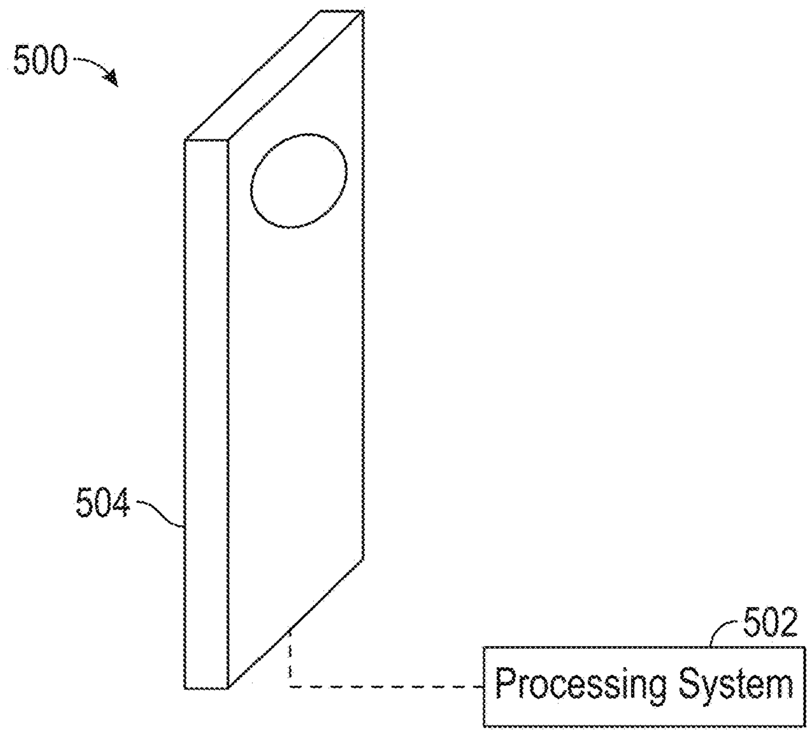


FIG. 5A

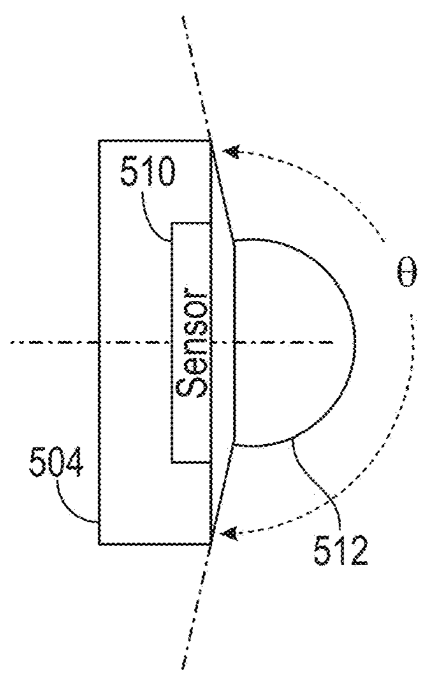


FIG. 5B

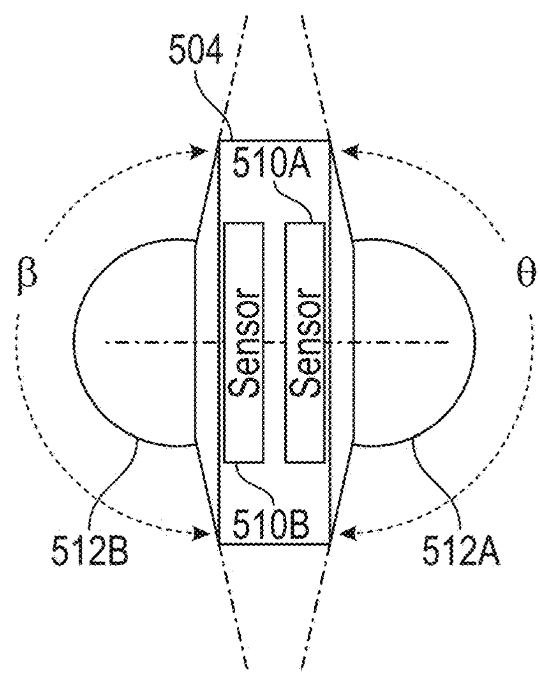


FIG. 5C

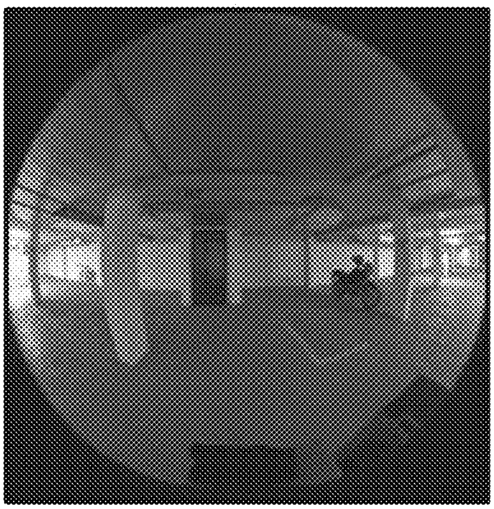


FIG. 5D

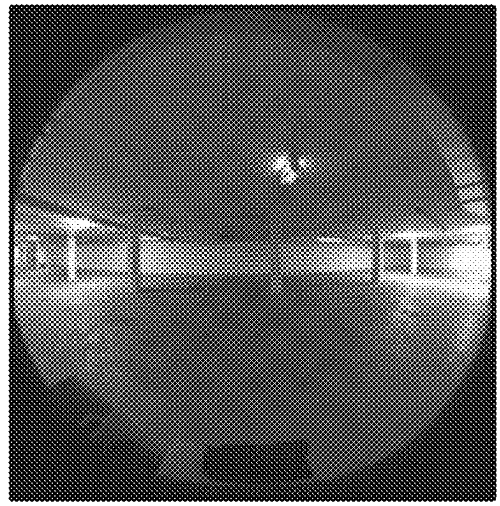


FIG. 5E

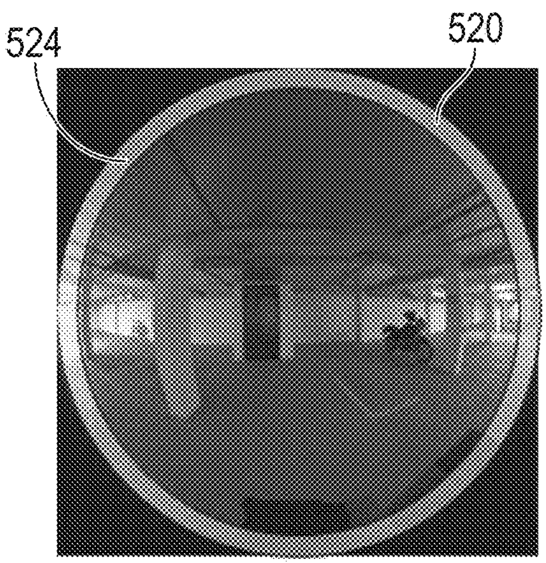


FIG. 5D'

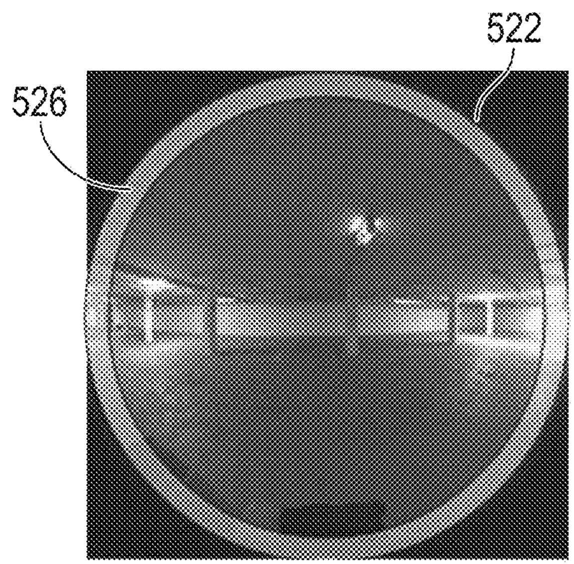


FIG. 5E'

FIG. 5F

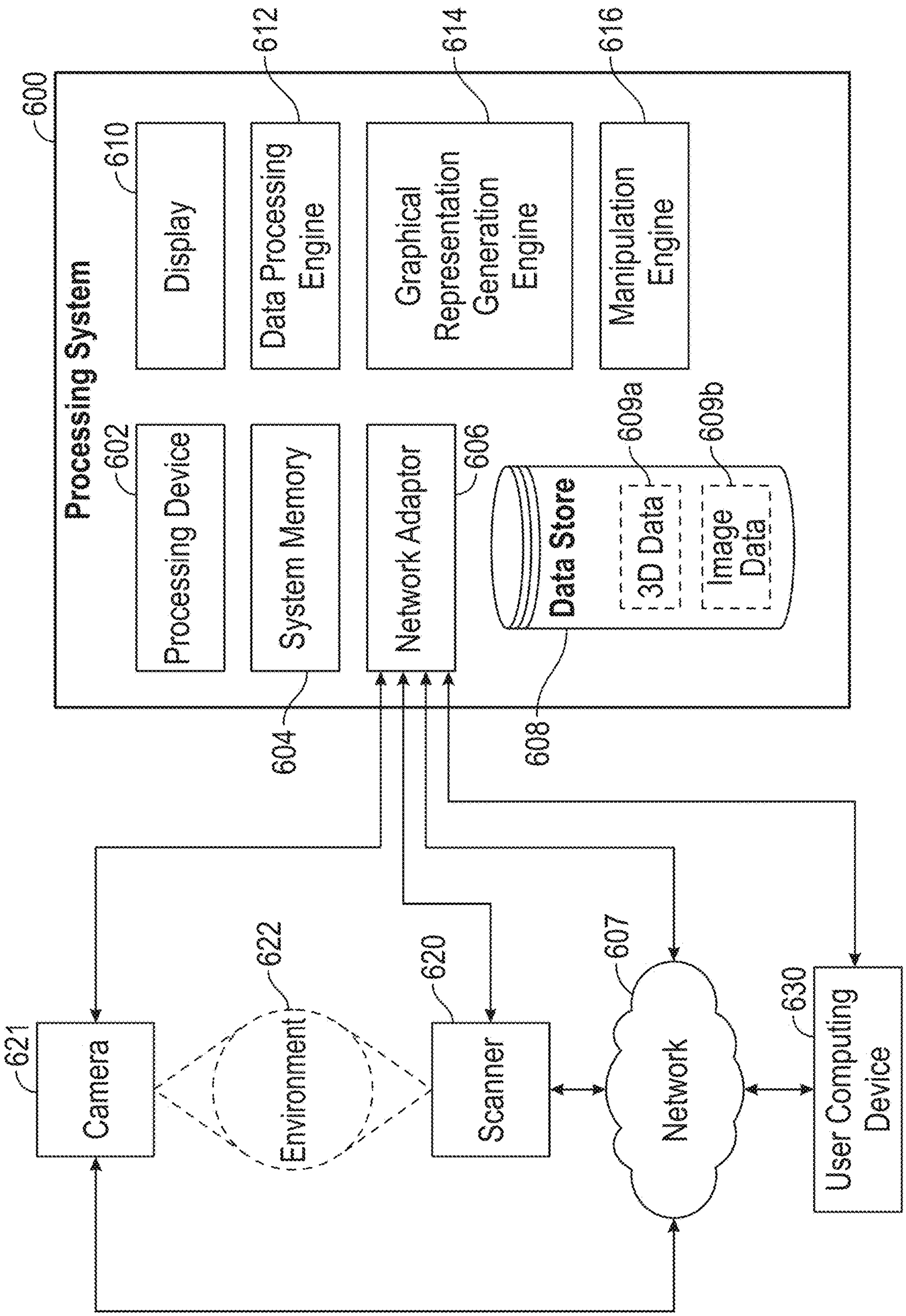

600
Processing System
602
Processing Device
604
System Memory
606
Network Adaptor
608
Data Store
609a
3D Data
609b
Image Data
610
Display
612
Data Processing Engine
614
Graphical Representation Generation Engine
616
Manipulation Engine
621
Camera
622
Environment
620
Scanner
607
Network
630
User Computing Device

FIG. 6

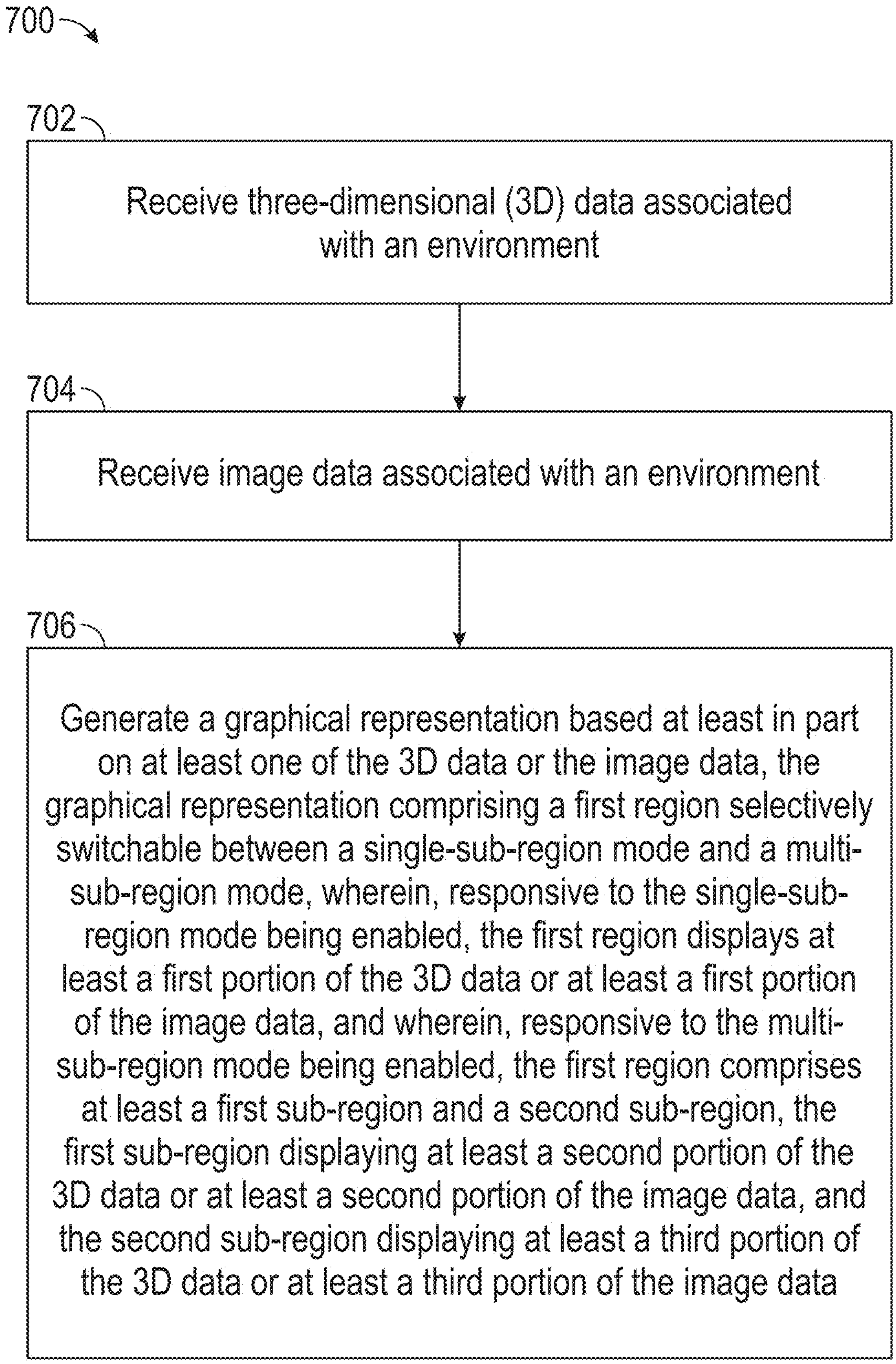

700
702
Receive three-dimensional (3D) data associated with an environment
704
Receive image data associated with an environment
706
Generate a graphical representation based at least in part on at least one of the 3D data or the image data, the graphical representation comprising a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode, wherein, responsive to the single-sub-region mode being enabled, the first region displays at least a first portion of the 3D data or at least a first portion of the image data, and wherein, responsive to the multi-sub-region mode being enabled, the first region comprises at least a first sub-region and a second sub-region, the first sub-region displaying at least a second portion of the 3D data or at least a second portion of the image data, and the second sub-region displaying at least a third portion of the 3D data or at least a third portion of the image data

FIG. 7

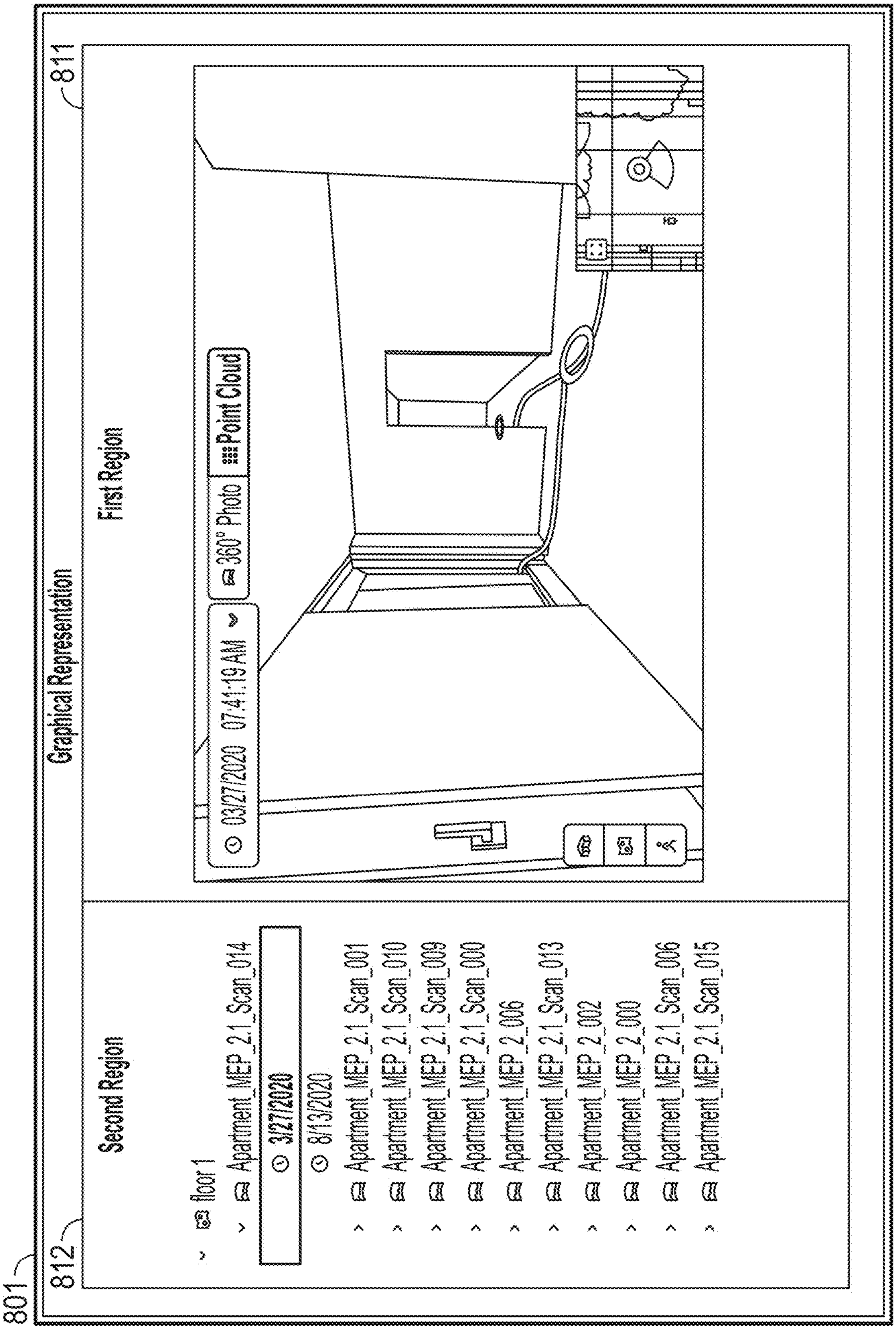

801
811
812
Graphical Representation
First Region
Second Region
03/27/2020 07:41:19 AM
360° Photo
Point Cloud
floor 1
Apartment_MEP_2.1_Scan_014
3/27/2020
8/13/2020
Apartment_MEP_2.1_Scan_001
Apartment_MEP_2.1_Scan_010
Apartment_MEP_2.1_Scan_009
Apartment_MEP_2.1_Scan_000
Apartment_MEP_2_006
Apartment_MEP_2.1_Scan_013
Apartment_MEP_2_002
Apartment_MEP_2_000
Apartment_MEP_2.1_Scan_006
Apartment_MEP_2.1_Scan_015

FIG. 8A

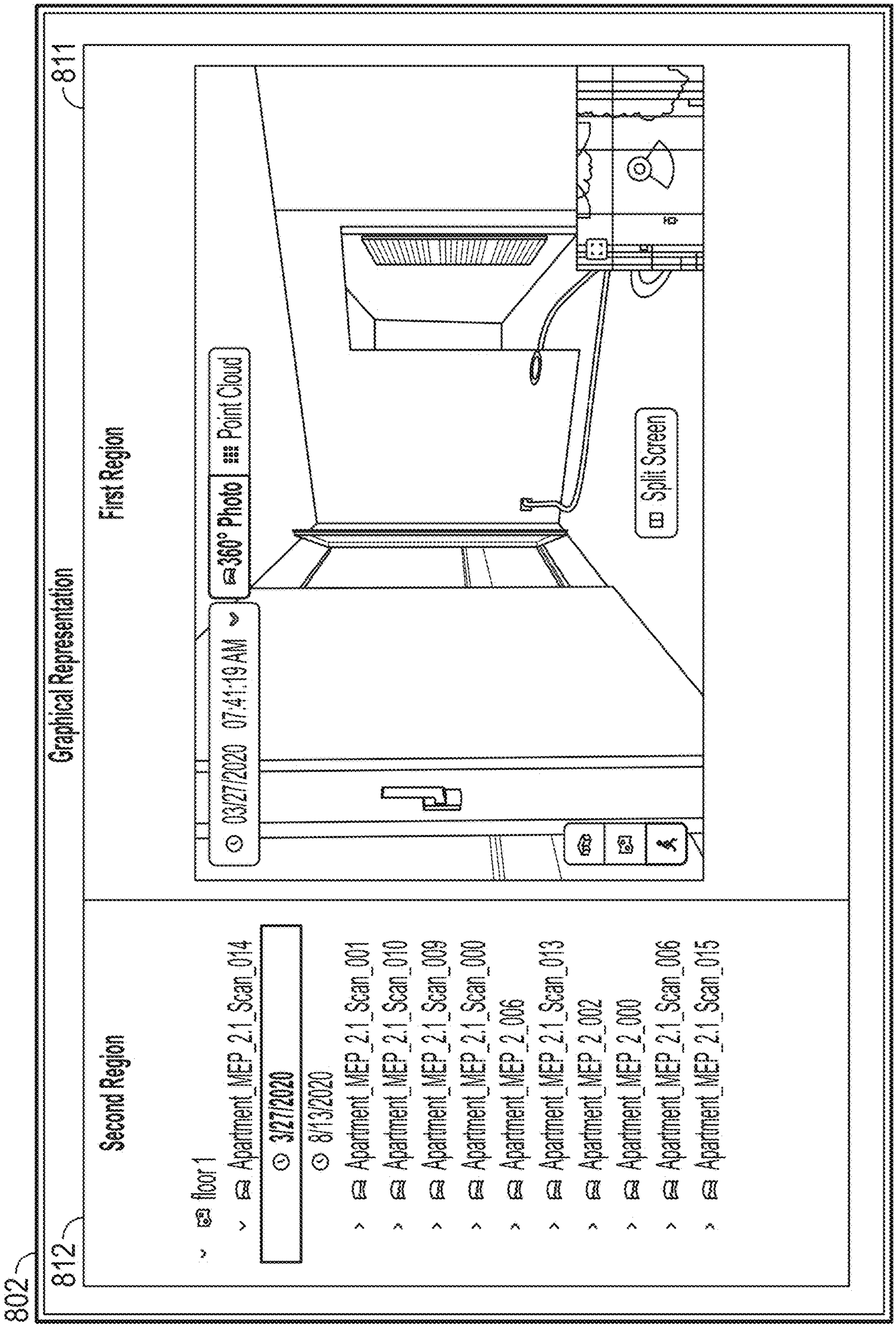

802
812
811
Graphical Representation
Second Region
First Region
floor 1
Apartment_MEP_2.1_Scan_014
3/27/2020
8/13/2020
Apartment_MEP_2.1_Scan_001
Apartment_MEP_2.1_Scan_010
Apartment_MEP_2.1_Scan_009
Apartment_MEP_2.1_Scan_000
Apartment_MEP_2_006
Apartment_MEP_2.1_Scan_013
Apartment_MEP_2_002
Apartment_MEP_2_000
Apartment_MEP_2.1_Scan_006
Apartment_MEP_2.1_Scan_015
03/27/2020 07:41:19 AM
360° Photo
Point Cloud
Split Screen

FIG. 8B

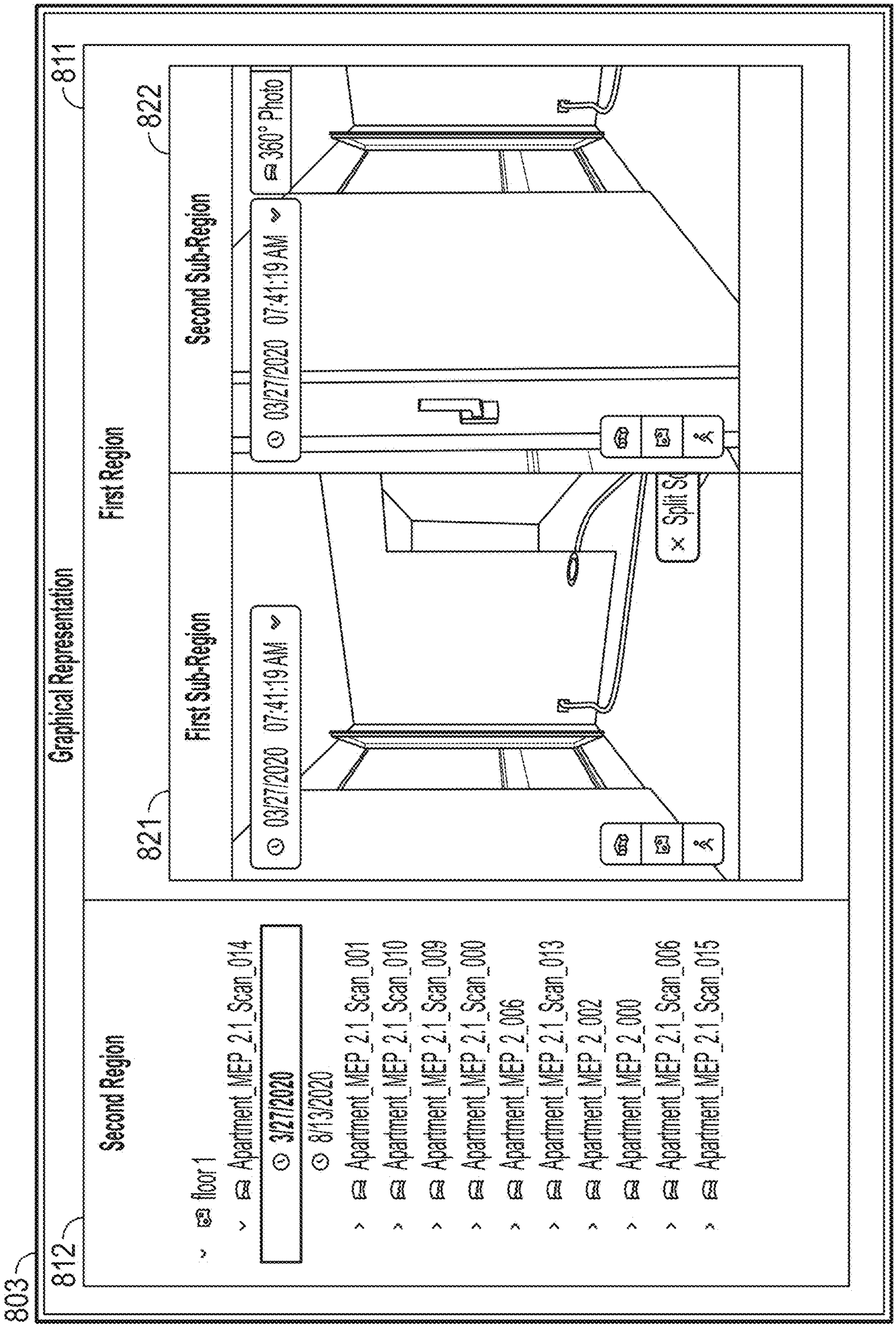

803
812
811
Graphical Representation
Second Region
First Region
821
822
First Sub-Region
Second Sub-Region
03/27/2020 07:41:19 AM
03/27/2020 07:41:19 AM
360° Photo
floor 1
Apartment_MEP_2.1_Scan_014
3/27/2020
8/13/2020
Apartment_MEP_2.1_Scan_001
Apartment_MEP_2.1_Scan_010
Apartment_MEP_2.1_Scan_009
Apartment_MEP_2.1_Scan_000
Apartment_MEP_2_006
Apartment_MEP_2.1_Scan_013
Apartment_MEP_2_002
Apartment_MEP_2_000
Apartment_MEP_2.1_Scan_006
Apartment_MEP_2.1_Scan_015

FIG. 8C

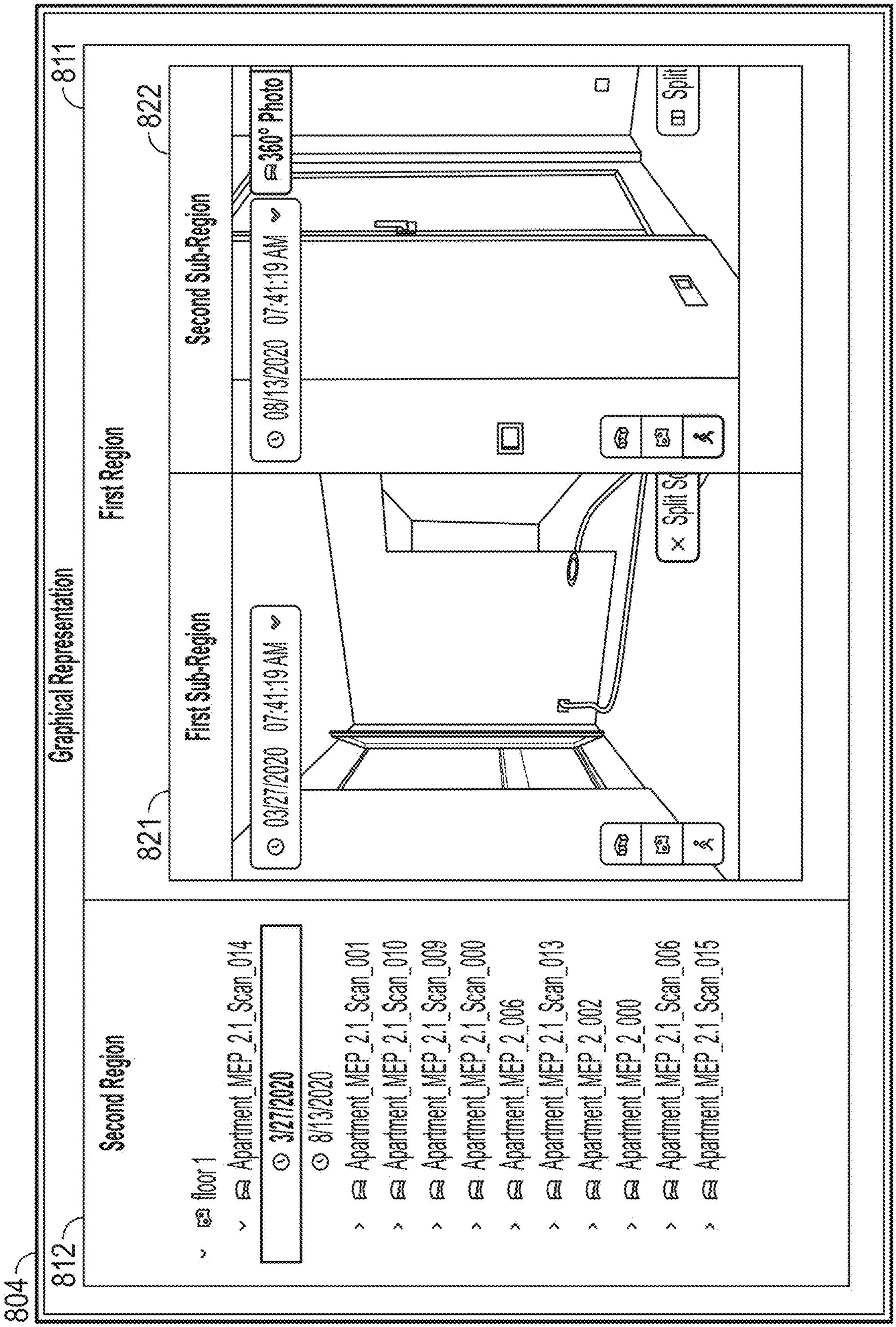

804
811
812
821
822
Graphical Representation
Second Region
First Region
floor 1
Apartment_MEP_2.1_Scan_014
3/27/2020
8/13/2020
Apartment_MEP_2.1_Scan_001
Apartment_MEP_2.1_Scan_010
Apartment_MEP_2.1_Scan_009
Apartment_MEP_2.1_Scan_000
Apartment_MEP_2_006
Apartment_MEP_2.1_Scan_013
Apartment_MEP_2_002
Apartment_MEP_2_000
Apartment_MEP_2.1_Scan_006
Apartment_MEP_2.1_Scan_015
First Sub-Region
03/27/2020 07:41:19 AM
Second Sub-Region
08/13/2020 07:41:19 AM
360° Photo

FIG. 8D

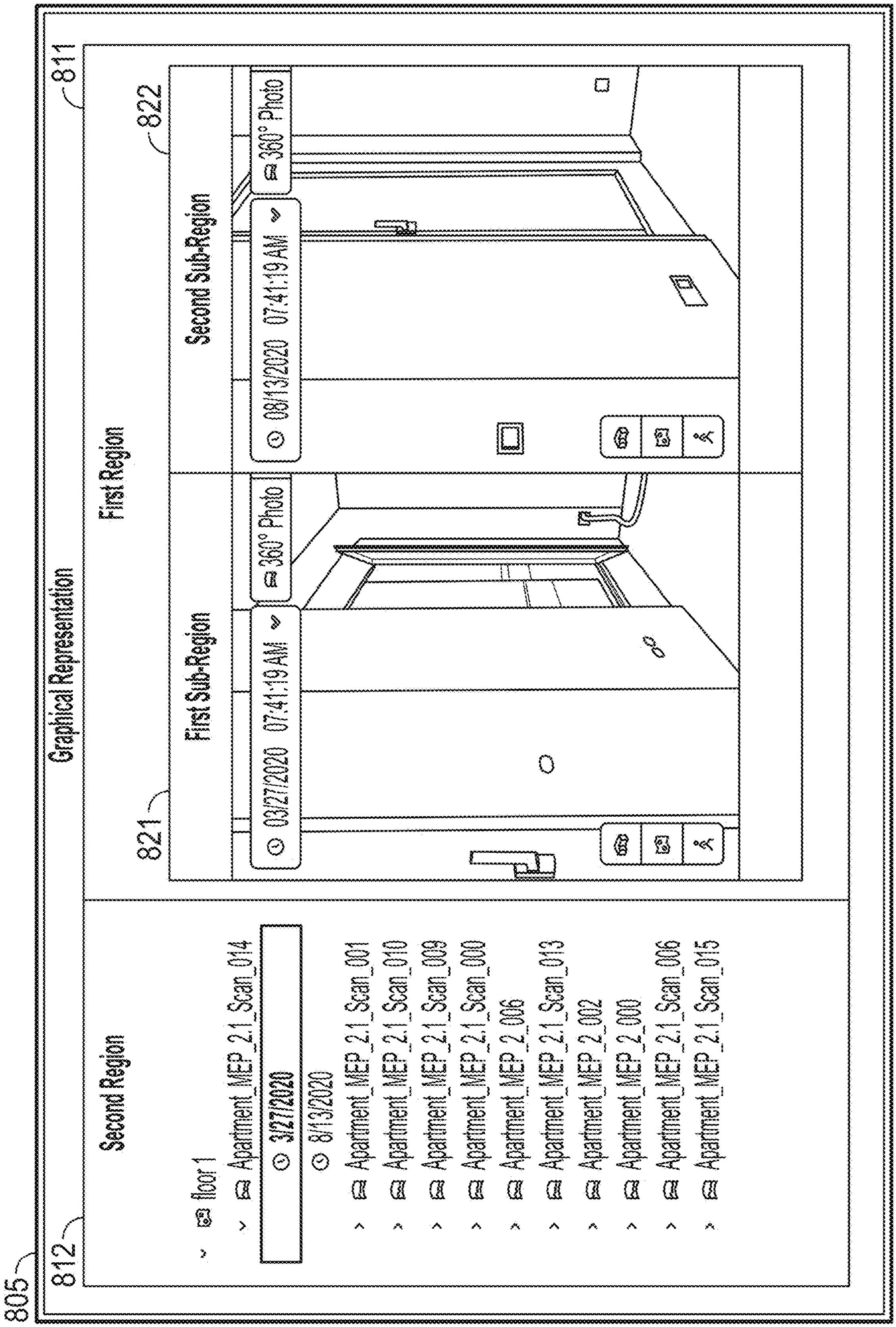

805
811
812
821
822
Graphical Representation
First Region
Second Region
First Sub-Region
Second Sub-Region
03/27/2020 07:41:19 AM
08/13/2020 07:41:19 AM
360° Photo
360° Photo
floor 1
Apartment_MEP_2.1_Scan_014
3/27/2020
8/13/2020
Apartment_MEP_2.1_Scan_001
Apartment_MEP_2.1_Scan_010
Apartment_MEP_2.1_Scan_009
Apartment_MEP_2.1_Scan_000
Apartment_MEP_2_006
Apartment_MEP_2.1_Scan_013
Apartment_MEP_2_002
Apartment_MEP_2_000
Apartment_MEP_2.1_Scan_006
Apartment_MEP_2.1_Scan_015

FIG. 8E

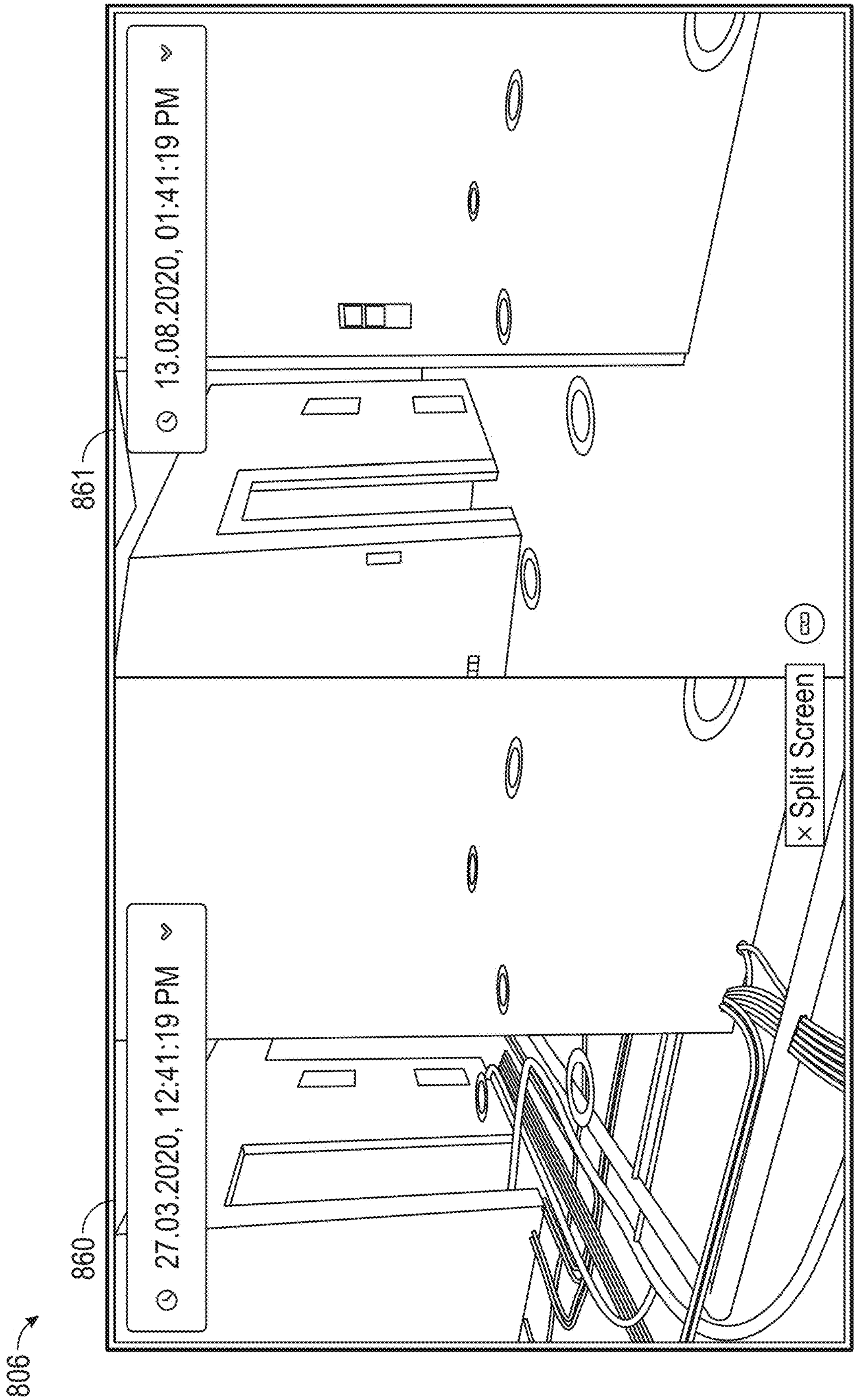

806
860
27.03.2020, 12:41:19 PM
861
13.08.2020, 01:41:19 PM
× Split Screen

FIG. 8F

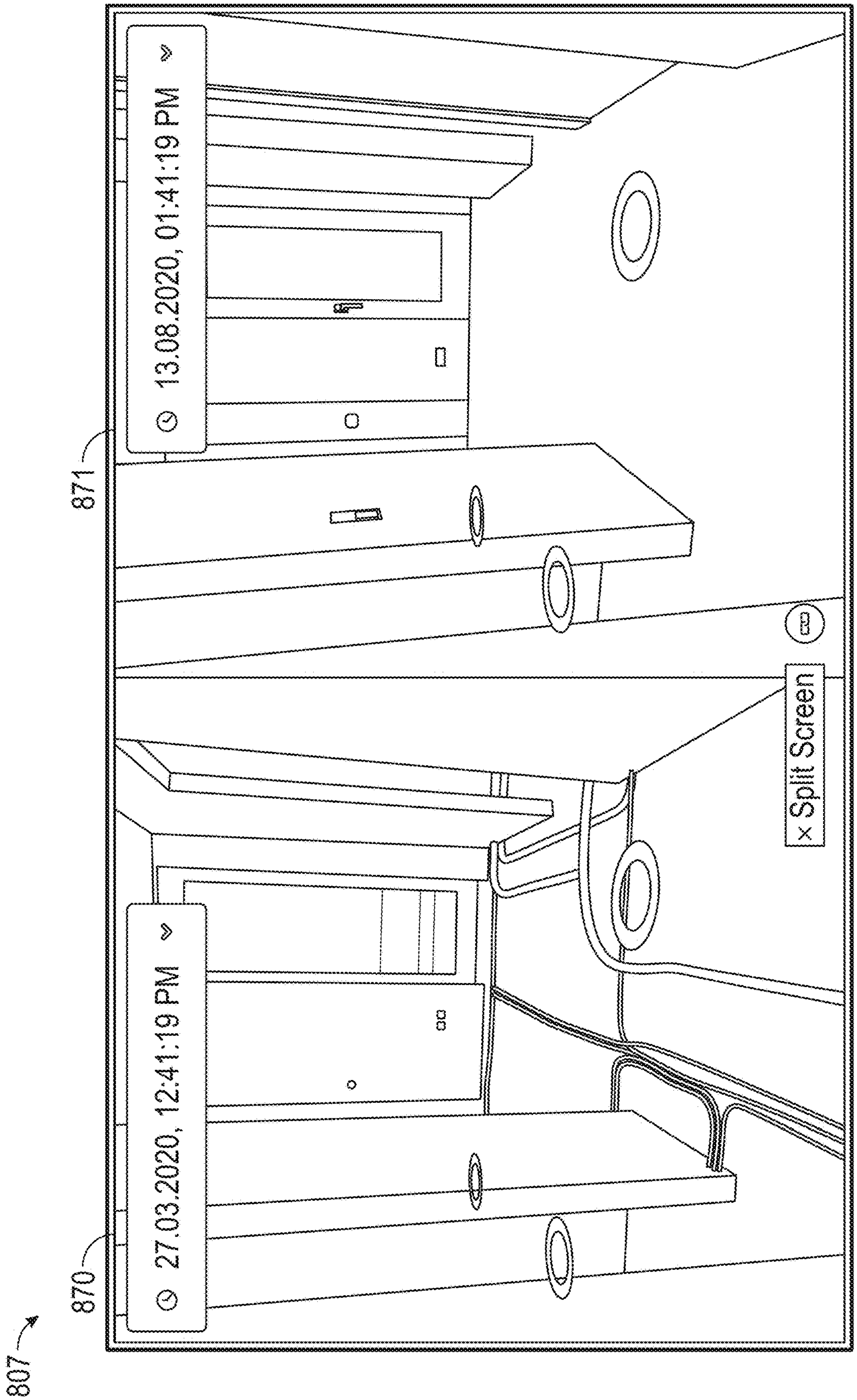

807
870
871
27.03.2020, 12:41:19 PM
13.08.2020, 01:41:19 PM
× Split Screen

FIG. 8G

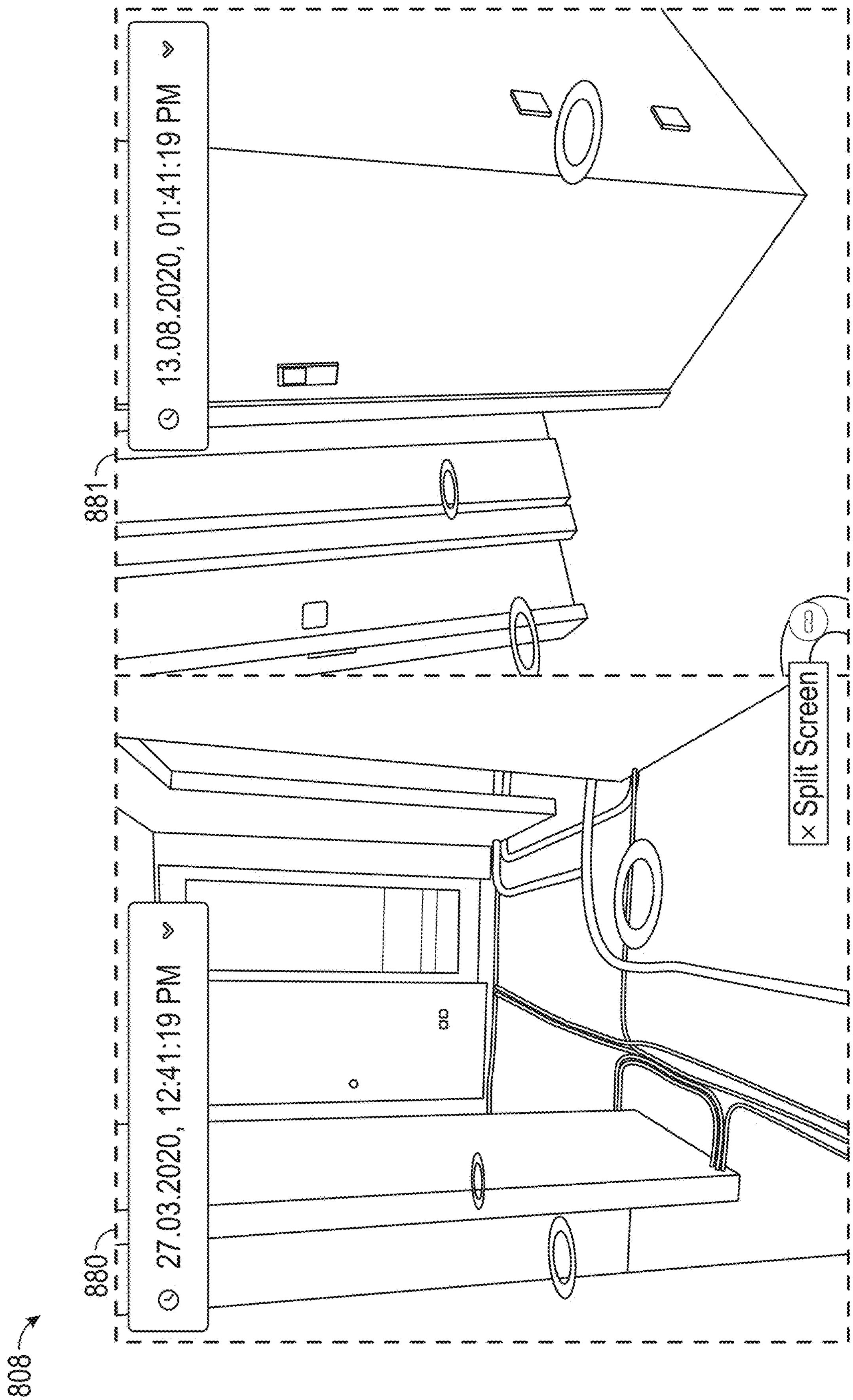

808
880
27.03.2020, 12:41:19 PM
881
13.08.2020, 01:41:19 PM
× Split Screen

FIG. 8H

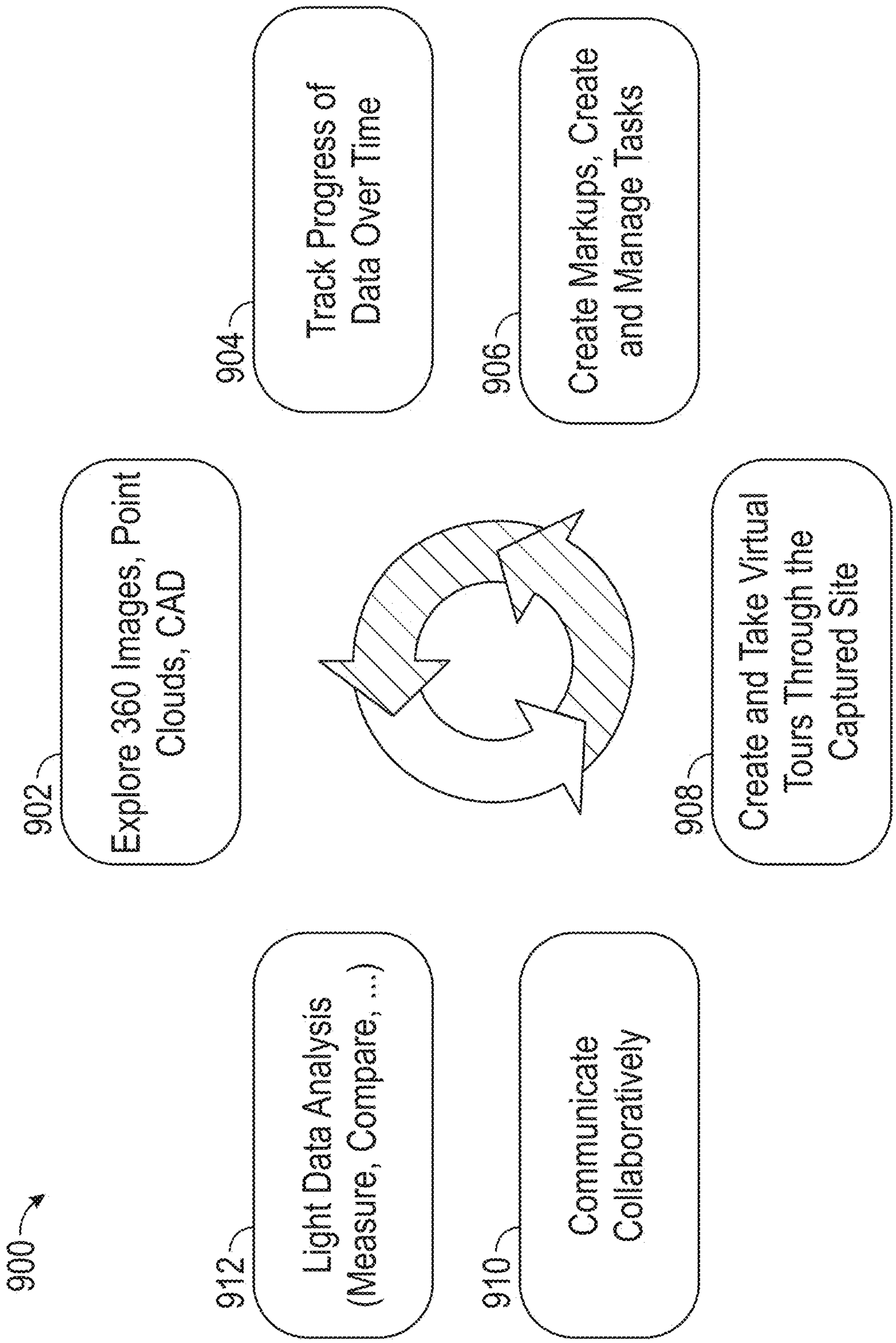

900
902
Explore 360 Images, Point Clouds, CAD
904
Track Progress of Data Over Time
906
Create Markups, Create and Manage Tasks
908
Create and Take Virtual Tours Through the Captured Site
910
Communicate Collaboratively
912
Light Data Analysis (Measure, Compare, ...)

FIG. 9

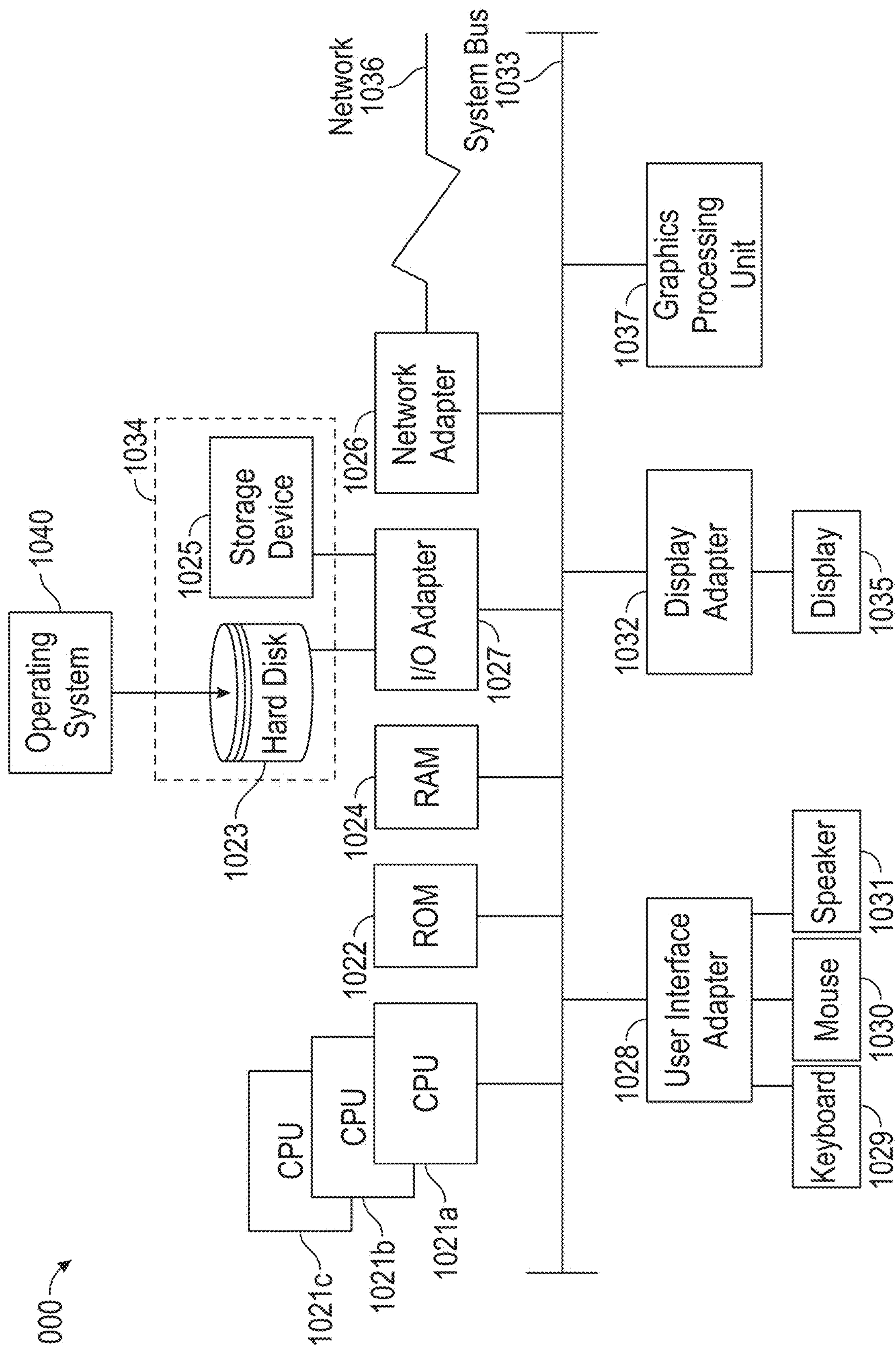

1000
CPU
CPU
CPU
1021c
1021b
1021a
ROM
1022
RAM
1024
Operating System
1040
Hard Disk
1023
Storage Device
1025
1034
I/O Adapter
1027
Network Adapter
1026
Network
1036
System Bus
1033
User Interface Adapter
1028
Keyboard
1029
Mouse
1030
Speaker
1031
Display Adapter
1032
Display
1035
Graphics Processing Unit
1037

FIG. 10

GENERATING GRAPHICAL REPRESENTATIONS FOR VIEWING 3D DATA AND/OR IMAGE DATA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of PCT Application Serial Number PCT/US23/33599, filed Sep. 25, 2023, the contents of which are incorporated by reference herein in its entirety, and claims the benefit of U.S. Provisional Patent Application Ser. No. 63/410,010, filed Sep. 26, 2022, the contents of which are incorporated by reference herein in its entirety.

BACKGROUND

[0002] The subject matter disclosed herein relates to use of a three-dimensional (3D) laser scanner time-of-flight (TOF) coordinate measurement device. A coordinate measurement device of this type steers a beam of light to a non-cooperative target such as a diffusely scattering surface of an object. A distance meter in the device measures a distance to the object, and angular encoders measure the angles of rotation of two axles in the device. The measured distance and two angles enable a processor in the device to determine the 3D coordinates of the target.

[0003] A laser scanner TOF coordinate measurement device (or simply "laser scanner") is a scanner in which the distance to a target point is determined based on the speed of light in air between the scanner and a target point. Laser scanners are typically used for scanning closed or open spaces such as interior areas of buildings, industrial installations and tunnels. They may also be used, for example, in industrial applications and accident reconstruction applications. A laser scanner optically scans and measures objects in a volume around the scanner through the acquisition of data points representing object surfaces within the volume. Such data points are obtained by transmitting a beam of light onto the objects and collecting the reflected or scattered light to determine the distance, two-angles (i.e., an azimuth and a zenith angle), and optionally a gray-scale value. This raw scan data is collected, stored and sent to a processor or processors to generate a 3D image representing the scanned area or object.

[0004] Accordingly, while existing coordinate measurement devices are suitable for their intended purposes, what is needed is a coordinate measurement device having certain features of embodiments described herein.

BRIEF DESCRIPTION

[0005] In one exemplary embodiment, a method is provided. The method includes receiving three-dimensional (3D) data associated with an environment. The method further includes receiving image data associated with the environment. The method further includes generating a graphical representation based at least in part on at least one of the 3D data and the image data, the graphical representation including a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode. Responsive to the single-sub-region mode being enabled, the first region displays at least one of at least a first portion of the 3D data and at least a first portion of the image data. Responsive to the multi-sub-region mode being enabled, the first region includes at least a first sub-region and a second sub-region. The first sub-region displays at least one of at least a second portion of the 3D data and at least a second portion of the image data, and the second sub-region displays at least one of at least a third portion of the 3D data or at least a third portion of the image data.

[0006] According to an embodiment, a system is provided that includes a memory comprising computer readable instructions and a processing device for executing the computer readable instructions, the computer readable instructions controlling the processing device to perform operations. The operations include receiving three-dimensional (3D) data associated with an environment. The operations further include receiving image data associated with the environment. The operations further include generating a graphical representation based at least in part on at least one of the 3D data and the image data, the graphical representation comprising a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode. Responsive to the single-sub-region mode being enabled, the first region displays at least one of at least a first portion of the 3D data and at least a first portion of the image data. Responsive to the multi-sub-region mode being enabled, the first region comprises at least a first sub-region and a second sub-region, the first sub-region displaying at least one of at least a second portion of the 3D data and at least a second portion of the image data, and the second sub-region displaying at least one of at least a third portion of the 3D data and at least a third portion of the image data.

[0007] Other embodiments described herein implement features of the above-described method in computer systems and computer program products.

[0008] The above features and advantages, and other features and advantages, of the disclosure are readily apparent from the following detailed description when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0009] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0010] The subject matter, which is regarded as the disclosure, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0011] FIG. **1** is a perspective view of a laser scanner according to one or more embodiments described herein;

[0012] FIG. **2** is a side view of the laser scanner illustrating a method of measurement according to one or more embodiments described herein;

[0013] FIG. **3** is a schematic illustration of the optical, mechanical, and electrical components of the laser scanner according to one or more embodiments described herein;

[0014] FIG. **4** is a schematic illustration of the laser scanner of FIG. **1** according to one or more embodiments described herein;

[0015] FIGS. **5**A-**5**C depict a system for collecting and/or displaying images of an environment according to one or more embodiments described herein;

[0016] FIGS. **5**D-**5**F depict images associated with the system of FIGS. **5**A-**5**C;

[0017] FIG. **6** is a schematic illustration of a processing system for generating graphical representations for viewing 3D data and or image data according to one or more embodiments described herein;

[0018] FIG. **7** depicts a flow diagram of a method for graphical representation generation using 3D data and/or image data according to one or more embodiments described herein;

[0019] FIGS. **8**A-**8**H depict graphical representations according to one or more embodiments described herein;

[0020] FIG. **9** depicts a block diagram of functional blocks of the processing system of FIG. **6** according to one or more embodiments described herein; and

[0021] FIG. **10** is a schematic illustration of a processing system for implementing the presently described techniques according to one or more embodiments described herein.

[0022] The detailed description explains embodiments of the disclosure, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION

[0023] Optical measurement devices use light to measure coordinates on surfaces in the environment. The raw scan data may be collected, stored and sent to a processor or processors to generate a 3D image representing the scanned area or object. Generating an image requires at least three values for each data point. These three values may include the distance and two angles, or may be transformed values, such as the x, y, z coordinates. In an embodiment, an image is also based on a fourth gray-scale value, which is a value related to irradiance of scattered light returning to the scanner.

[0024] Most laser scanner TOF coordinate measurement devices direct the beam of light within the measurement volume by steering the light with a beam steering mechanism. The beam steering mechanism includes a first motor that steers the beam of light about a first axis by a first angle that is measured by a first angular encoder (or another angle transducer). The beam steering mechanism also includes a second motor that steers the beam of light about a second axis by a second angle that is measured by a second angular encoder (or another angle transducer).

[0025] Many contemporary laser scanners include a camera mounted on the laser scanner for gathering camera digital images of the environment and for presenting the camera digital images to an operator of the laser scanner. By viewing the camera images, the operator of the scanner can determine the field of view of the measured volume and adjust settings on the laser scanner to measure over a larger or smaller region of space. In addition, the camera digital images may be transmitted to a processor to add color to the scanner image. To generate a color scanner image, at least three positional coordinates (such as x, y, z) and three color values (such as red, green, blue "RGB") are collected for each data point.

[0026] One application where coordinate measurement devices such as laser scanners are used is to scan an environment. Another application where coordinate measurement devices such as laser scanners are used is to scan an object.

[0027] One or more embodiments described herein relate generating graphical representations for viewing 3D data and/or image data.

[0028] Referring now to FIGS. **1**-**3**, a 3D coordinate measurement device, such as a laser scanner **20**, is shown for optically scanning and measuring the environment surrounding the laser scanner **20** according to one or more embodiments described herein. The laser scanner **20** has a measuring head **22** and a base **24**. The measuring head **22** is mounted on the base **24** such that the laser scanner **20** may be rotated about a vertical axis **23**. In one embodiment, the measuring head **22** includes a gimbal point **27** that is a center of rotation about the vertical axis **23** and a horizontal axis **25**. The measuring head **22** has a rotary mirror **26**, which may be rotated about the horizontal axis **25**. The rotation about the vertical axis may be about the center of the base **24**. The terms vertical axis and horizontal axis refer to the scanner in its normal upright position. It is possible to operate a 3D coordinate measurement device on its side or upside down, and so to avoid confusion, the terms azimuth axis and zenith axis may be substituted for the terms vertical axis and horizontal axis, respectively. The term pan axis or standing axis may also be used as an alternative to vertical axis.

[0029] The measuring head **22** is further provided with an electromagnetic radiation emitter, such as light emitter **28**, for example, that emits an emitted light beam **30**. In one embodiment, the emitted light beam **30** is a coherent light beam such as a laser beam. The laser beam may have a wavelength range of approximately 300 to 1600 nanometers, for example 790 nanometers, 905 nanometers, 1550 nm, or less than 400 nanometers. It should be appreciated that other electromagnetic radiation beams having greater or smaller wavelengths may also be used. The emitted light beam **30** is amplitude or intensity modulated, for example, with a sinusoidal waveform or with a rectangular waveform. The emitted light beam **30** is emitted by the light emitter **28** onto a beam steering unit, such as mirror **26**, where it is deflected to the environment. A reflected light beam **32** is reflected from the environment by an object **34**. The reflected or scattered light is intercepted by the rotary mirror **26** and directed into a light receiver **36**. The directions of the emitted light beam **30** and the reflected light beam **32** result from the angular positions of the rotary mirror **26** and the measuring head **22** about the axes **25** and **23**, respectively. These angular positions in turn depend on the corresponding rotary drives or motors.

[0030] Coupled to the light emitter **28** and the light receiver **36** is a controller **38**. The controller **38** determines, for a multitude of measuring points X, a corresponding number of distances d between the laser scanner **20** and the points X on object **34**. The distance to a particular point X is determined based at least in part on the speed of light in air through which electromagnetic radiation propagates from the device to the object point X. In one embodiment the phase shift of modulation in light emitted by the laser scanner **20** and the point X is determined and evaluated to obtain a measured distance d.

[0031] The speed of light in air depends on the properties of the air such as the air temperature, barometric pressure, relative humidity, and concentration of carbon dioxide. Such air properties influence the index of refraction n of the air. The speed of light in air is equal to the speed of light in vacuum c divided by the index of refraction. In other words, $C_{air}=c/n$. A laser scanner of the type discussed herein is based on the time-of-flight (TOF) of the light in the air (the round-trip time for the light to travel from the device to the object and back to the device). Examples of TOF scanners include scanners that measure round trip time using the time interval between emitted and returning pulses (pulsed TOF scanners), scanners that modulate light sinusoidally and measure phase shift of the returning light (phase-based scanners), as well as many other types. A method of measuring distance based on the time-of-flight of light depends on the speed of light in air and is therefore easily distinguished from methods of measuring distance based on triangulation. Triangulation-based methods involve projecting light from a light source along a particular direction and then intercepting the light on a camera pixel along a particular direction. By knowing the distance between the camera and the projector and by matching a projected angle with a received angle, the method of triangulation enables the distance to the object to be determined based on one known length and two known angles of a triangle. The method of triangulation, therefore, does not directly depend on the speed of light in air.

[0032] In one mode of operation, the scanning of the volume around the laser scanner **20** takes place by rotating the rotary mirror **26** relatively quickly about axis **25** while rotating the measuring head **22** relatively slowly about axis **23**, thereby moving the assembly in a spiral pattern. In an exemplary embodiment, the rotary mirror rotates at a maximum speed of 5820 revolutions per minute. For such a scan, the gimbal point **27** defines the origin of the local stationary reference system. The base **24** rests in this local stationary reference system.

[0033] In addition to measuring a distance d from the gimbal point **27** to an object point X, the laser scanner **20** may also collect gray-scale information related to the received optical power (equivalent to the term "brightness.") The gray-scale value may be determined at least in part, for example, by integration of the bandpass-filtered and amplified signal in the light receiver **36** over a measuring period attributed to the object point X.

[0034] The measuring head **22** may include a display device **40** integrated into the laser scanner **20**. The display device **40** may include a graphical touch screen **41**, as shown in FIG. **1**, which allows the operator to set the parameters or initiate the operation of the laser scanner **20**. For example, the screen **41** may have a user interface that allows the operator to provide measurement instructions to the device, and the screen may also display measurement results.

[0035] The laser scanner **20** includes a carrying structure **42** that provides a frame for the measuring head **22** and a platform for attaching the components of the laser scanner **20**. In one embodiment, the carrying structure **42** is made from a metal such as aluminum. The carrying structure **42** includes a traverse member **44** having a pair of walls **46**, **48** on opposing ends. The walls **46**, **48** are parallel to each other and extend in a direction opposite the base **24**. Shells **50**, **52** are coupled to the walls **46**, **48** and cover the components of the laser scanner **20**. In the exemplary embodiment, the shells **50**, **52** are made from a plastic material, such as polycarbonate or polyethylene for example. The shells **50**, **52** cooperate with the walls **46**, **48** to form a housing for the laser scanner **20**.

[0036] On an end of the shells **50**, **52** opposite the walls **46**, **48** a pair of yokes **54**, **56** are arranged to partially cover the respective shells **50**, **52**. In the exemplary embodiment, the yokes **54**, **56** are made from a suitably durable material, such as aluminum for example, that assists in protecting the shells **50**, **52** during transport and operation. The yokes **54**, **56** each includes a first arm portion **58** that is coupled, such as with a fastener for example, to the traverse **44** adjacent the base **24**. The arm portion **58** for each yoke **54**, **56** extends from the traverse **44** obliquely to an outer corner of the respective shell **50**, **52**. From the outer corner of the shell, the yokes **54**, **56** extend along the side edge of the shell to an opposite outer corner of the shell. Each yoke **54**, **56** further includes a second arm portion that extends obliquely to the walls **46**, **48**. It should be appreciated that the yokes **54**, **56** may be coupled to the traverse **42**, the walls **46**, **48** and the shells **50**, **54** at multiple locations.

[0037] The pair of yokes **54**, **56** cooperate to circumscribe a convex space within which the two shells **50**, **52** are arranged. In the exemplary embodiment, the yokes **54**, **56** cooperate to cover all of the outer edges of the shells **50**, **54**, while the top and bottom arm portions project over at least a portion of the top and bottom edges of the shells **50**, **52**. This provides advantages in protecting the shells **50**, **52** and the measuring head **22** from damage during transportation and operation. In other embodiments, the yokes **54**, **56** may include additional features, such as handles to facilitate the carrying of the laser scanner **20** or attachment points for accessories for example.

[0038] On top of the traverse **44**, a prism **60** is provided. The prism extends parallel to the walls **46**, **48**. In the exemplary embodiment, the prism **60** is integrally formed as part of the carrying structure **42**. In other embodiments, the prism **60** is a separate component that is coupled to the traverse **44**. When the mirror **26** rotates, during each rotation the mirror **26** directs the emitted light beam **30** onto the traverse **44** and the prism **60**. Due to non-linearities in the electronic components, for example in the light receiver **36**, the measured distances d may depend on signal strength, which may be measured in optical power entering the scanner or optical power entering optical detectors within the light receiver **36**, for example. In an embodiment, a distance correction is stored in the scanner as a function (possibly a nonlinear function) of distance to a measured point and optical power (generally unscaled quantity of light power sometimes referred to as "brightness") returned from the measured point and sent to an optical detector in the light receiver **36**. Since the prism **60** is at a known distance from the gimbal point **27**, the measured optical power level of light reflected by the prism **60** may be used to correct distance measurements for other measured points, thereby allowing for compensation to correct for the effects of environmental variables such as temperature. In the exemplary embodiment, the resulting correction of distance is performed by the controller **38**.

[0039] In an embodiment, the base **24** is coupled to a swivel assembly (not shown) such as that described in commonly owned U.S. Pat. No. 8,705,012 ('012), which is incorporated by reference herein. The swivel assembly is housed within the carrying structure **42** and includes a motor **138** that is configured to rotate the measuring head **22** about the axis **23**. In an embodiment, the angular/rotational position of the measuring head **22** about the axis **23** is measured by angular encoder **134**.

[0040] An auxiliary image acquisition device **66** may be a device that captures and measures a parameter associated with the scanned area or the scanned object and provides a signal representing the measured quantities over an image acquisition area. The auxiliary image acquisition device **66** may be, but is not limited to, a pyrometer, a thermal imager, an ionizing radiation detector, or a millimeter-wave detector. In an embodiment, the auxiliary image acquisition device **66** is a color camera.

[0041] In an embodiment, a central color camera (first image acquisition device) **112** is located internally to the scanner and may have the same optical axis as the 3D scanner device. In this embodiment, the first image acquisition device **112** is integrated into the measuring head **22** and arranged to acquire images along the same optical pathway as emitted light beam **30** and reflected light beam **32**. In this embodiment, the light from the light emitter **28** reflects off a fixed mirror **116** and travels to dichroic beam-splitter **118** that reflects the light **117** from the light emitter **28** onto the rotary mirror **26**. In an embodiment, the mirror **26** is rotated by a motor **136** and the angular/rotational position of the mirror is measured by angular encoder **134**. The dichroic beam-splitter **118** allows light to pass through at wavelengths different than the wavelength of light **117**. For example, the light emitter **28** may be a near infrared laser light (for example, light at wavelengths of 780 nm or 1250 nm), with the dichroic beam-splitter **118** configured to reflect the infrared laser light while allowing visible light (e.g., wavelengths of 400 to 700 nm) to transmit through. In other embodiments, the determination of whether the light passes through the beam-splitter **118** or is reflected depends on the polarization of the light. The digital camera **112** obtains 2D images of the scanned area to capture color data to add to the scanned image. In the case of a built-in color camera having an optical axis coincident with that of the 3D scanning device, the direction of the camera view may be easily obtained by simply adjusting the steering mechanisms of the scanner—for example, by adjusting the azimuth angle about the axis **23** and by steering the mirror **26** about the axis **25**.

[0042] Referring now to FIG. **4** with continuing reference to FIGS. **1-3**, elements are shown of the laser scanner **20**. Controller **38** is a suitable electronic device capable of accepting data and instructions, executing the instructions to process the data, and presenting the results. The controller **38** includes one or more processing elements **122**. The processors may be microprocessors, field programmable gate arrays (FPGAs), digital signal processors (DSPs), and generally any device capable of performing computing functions. The one or more processors **122** have access to memory **124** for storing information.

[0043] Controller **38** is capable of converting the analog voltage or current level provided by light receiver **36** into a digital signal to determine a distance from the laser scanner **20** to an object in the environment. Controller **38** uses the digital signals that act as input to various processes for controlling the laser scanner **20**. The digital signals represent one or more laser scanner **20** data including but not limited to distance to an object, images of the environment, images acquired by panoramic camera **126**, angular/rotational measurements by a first or azimuth encoder **132**, and angular/rotational measurements by a second axis or zenith encoder **134**.

[0044] In general, controller **38** accepts data from encoders **132**, **134**, light receiver **36**, light source **28**, and panoramic camera **126** and is given certain instructions for the purpose of generating a 3D point cloud of a scanned environment. Controller **38** provides operating signals to the light source **28**, light receiver **36**, panoramic camera **126**, zenith motor **136** and azimuth motor **138**. The controller **38** compares the operational parameters to predetermined variances and if the predetermined variance is exceeded, generates a signal that alerts an operator to a condition. The data received by the controller **38** may be displayed on a user interface **40** coupled to controller **38**. The user interface **40** may be one or more LEDs (light-emitting diodes) **82**, an LCD (liquid-crystal diode) display, a CRT (cathode ray tube) display, a touch-screen display or the like. A keypad may also be coupled to the user interface for providing data input to controller **38**. In one embodiment, the user interface is arranged or executed on a mobile computing device that is coupled for communication, such as via a wired or wireless communications medium (e.g. Ethernet, serial, USB, Bluetooth™ or WiFi) for example, to the laser scanner **20**.

[0045] The controller **38** may also be coupled to external computer networks such as a local area network (LAN) and the Internet. A LAN interconnects one or more remote computers, which are configured to communicate with controller **38** using a well-known computer communications protocol such as TCP/IP (Transmission Control Protocol/Internet (^) Protocol), RS-232, ModBus, and the like. Additional laser scanners **20** may also be connected to LAN with the controllers **38** in each of these laser scanners **20** being configured to send and receive data to and from remote computers and other laser scanners **20**. The LAN may be connected to the Internet. This connection allows controller **38** to communicate with one or more remote computers connected to the Internet.

[0046] The processors **122** are coupled to memory **124**. The memory **124** may include random access memory (RAM) device **140**, a non-volatile memory (NVM) device **142**, and a read-only memory (ROM) device **144**. In addition, the processors **122** may be connected to one or more input/output (I/O) controllers **146** and a communications circuit **148**. In an embodiment, the communications circuit **92** provides an interface that allows wireless or wired communication with one or more external devices or networks, such as the LAN discussed above.

[0047] Controller **38** includes operation control methods embodied in application code (e.g., program instructions executable by a processor to cause the processor to perform operations). These methods are embodied in computer instructions written to be executed by processors **122**, typically in the form of software. The software can be encoded in any language, including, but not limited to, assembly language, VHDL (Verilog Hardware Description Language), VHSIC HDL (Very High Speed IC Hardware Description Language), Fortran (formula translation), C, C++, C#, Objective-C, Visual C++, Java, ALGOL (algorithmic language), BASIC (beginners all-purpose symbolic instruction code), visual BASIC, ActiveX, HTML (HyperText Markup Language), Python, Ruby and any combination or derivative of at least one of the foregoing.

[0048] It should be appreciated that while embodiments herein describe the 3D coordinate measurement device as being a laser scanner, this is for example purposes and the claims should not be so limited. In other embodiments, the 3D coordinate measurement device may be another type of system that measures a plurality of points on surfaces (i.e., generates a point cloud), such as but not limited to a triangulation scanner, a structured light scanner, or a photogrammetry device for example.

[0049] Referring now to FIGS. **5A-5C**, an embodiment is shown of a system **500** for collecting and/or displaying images of an environment according to one or more embodiments described herein. Particularly, FIG. **5**A depicts the system **500** to collect and/or display images of an environment or object, the system **500** having a camera **504** and a processing system **502**.

[0050] The processing system **502** can be any suitable processing system, such as a smartphone, tablet computer, laptop or notebook computer, node(s) of a cloud computing system, etc. Although not shown, the processing system **502** can include one or more additional components, such as a processor for executing instructions, a memory for storing instructions and/or data, a display for displaying user interfaces, an input device for receiving inputs, an output device for generating outputs, a communications adapter for facilitating communications with other devices (e.g., the camera **504**), and/or the like including combinations and/or multiples thereof.

[0051] The camera **504** captures one or more images, such as a panoramic image, of an environment. In examples, the camera **504** can be an ultra-wide angle camera. As an example, the camera **504** can be an omnidirectional camera, such as the RICO THETA camera. In an embodiment, the camera **504** includes a sensor **510** (FIG. **5**B), that includes an array of photosensitive pixels. The sensor **510** is arranged to receive light from a lens **512**. In the illustrated embodiment, the lens **512** is an ultra-wide angle lens that provides (in combination with the sensor **510**) a field of view θ between 100 and 270 degrees, for example. In an embodiment, the field of view θ is greater than 180 degrees and less than 270 degrees about a vertical axis (e.g., substantially perpendicular to the floor or surface that the measurement device is located). It should be appreciated that while embodiments herein describe the lens **512** as a single lens, this is for example purposes and the lens **512** may be a comprised of a plurality of optical elements.

[0052] In an embodiment, the camera **504** includes a pair of sensors **510**A, **510**B that are arranged to receive light from ultra-wide angle lenses **512**A, **512**B respectively (FIG. **5**C). In this example, the camera **104** can be referred to as a dual camera because it has a pair of sensors **510**A, **510**B and lenses **512**A, **512**B as shown. The sensor **510**A and lens **512**A are arranged to acquire images in a first direction, and the sensor **510**B and lens **512**B are arranged to acquire images in a second direction. In the illustrated embodiment, the second direction is opposite the first direction (e.g., 180 degrees apart). A camera having opposingly arranged sensors and lenses with at least 180 degree field of view are sometimes referred to as an omnidirectional camera, a 360 degree camera, or a panoramic camera as it acquires an image in a 360 degree volume about the camera.

[0053] FIGS. **5**D and **5**E depict images acquired by the dual camera of FIG. **5**C, for example, and FIGS. **5**D' and **5**E' depict images acquired the dual camera of FIG. **5**C where each of the images has a field of view greater than 180 degrees. It should be appreciated that when the field of view is greater than 180 degrees, there will be an overlap **120**, **122** between the acquired images **124**, **126** as shown in FIG. **5**D' and FIG. **5**E'. In some embodiments, the images may be combined to form a single image **528** of at least a substantial portion of the spherical volume about the camera **504** as shown in FIG. **5**F.

[0054] FIG. **6** is a schematic illustration of a processing system **600** for generating graphical representations for viewing 3D data and or image data according to one or more embodiments described herein. The processing system **600** includes a processing device **602** (e.g., one or more of the processing devices **1021** of FIG. **10**), a system memory **604** (e.g., the RAM **1024** and/or the ROM **1022** of FIG. **10**), a network adapter **606** (e.g., the network adapter **1026** of FIG. **10**), a data store **608**, a display **610**, a data processing engine **612**, a graphical representation generation engine **614**, and manipulation engine **616**. According to one or more embodiments described herein, the processing system **600** is an example of the processing system **502** of FIG. **5**A. The processing system **600** can be any suitable processing system, such as a smartphone, tablet computer, laptop or notebook computer, node(s) of a cloud computing system, etc.

[0055] The various components, modules, engines, etc. described regarding FIG. **6** (e.g., the data processing engine **612**, the graphical representation generation engine **614**, and the manipulation engine **616**) can be implemented as instructions stored on a computer-readable storage medium, as hardware modules, as special-purpose hardware (e.g., application specific hardware, application specific integrated circuits (ASICs), application specific special processors (ASSPs), field programmable gate arrays (FPGAs), as embedded controllers, hardwired circuitry, etc.), or as some combination or combinations of these. According to aspects of the present disclosure, the engine(s) described herein can be a combination of hardware and programming. The programming can be processor executable instructions stored on a tangible memory, and the hardware can include the processing device **602** for executing those instructions. Thus, the system memory **604** can store program instructions that when executed by the processing device **602** implement the engines described herein. Other engines can also be utilized to include other features and functionality described in other examples herein.

[0056] The network adapter **606** enables the processing system **600** to transmit data to and/or receive data from other sources, such as the scanner **620** and/or the camera **621**. For example, the processing system **600** receives data (e.g., a data set that includes a plurality of three-dimensional coordinates of an environment **622**) from the scanner **620** directly and/or via a network **607**. The data from the scanner **620** can be stored in the data store **608** of the processing system **600** as 3D data **609***a*, which can be used to display a point cloud or other graphical representation on the display **610**. The scanner **620** can be the same or similar to the scanner **20** of FIGS. **1-4** according to one or more embodiments described herein. According to one or more embodiments described herein, the camera **621** can capture images of the environment **622**, which may be presented on the display **610** as a video stream of the environment **622**, as a panoramic and/or 360 degree view of the environment **622**, and/or the like, including combinations and/or multiples thereof. The images of the environment **622** captured by the camera **621** can be transmitted from the camera **621** to the processing system **600** directly and/or via the network **607** and can be stored in the data store **608** as image data **609***b*. The camera **621** can be the same or similar to the camera **504** of FIGS. **5A-5**C according to one or more embodiments described herein.

[0057] The network **607** represents any one or a combination of different types of suitable communications networks such as, for example, cable networks, public networks (e.g., the Internet), private networks, wireless networks, cellular networks, or any other suitable private and/or public networks. Further, the network **607** can have any suitable communication range associated therewith and may include, for example, global networks (e.g., the Internet), metropolitan area networks (MANs), wide area networks (WANs), local area networks (LANs), or personal area networks (PANs). In addition, the network **607** can include any type of medium over which network traffic may be carried including, but not limited to, coaxial cable, twisted-pair wire, optical fiber, a hybrid fiber coaxial (HFC) medium, microwave terrestrial transceivers, radio frequency communication mediums, satellite communication mediums, or any combination thereof.

[0058] The scanner **620** (e.g., a laser scanner) can be arranged on, in, and/or around the environment **622** to scan the environment **622**. It should be appreciated that while embodiments herein refer to a 3D coordinate measurement device as a laser scanner (e.g., the scanner **620**), this is for example purposes and the claims should not be so limited. In other embodiments, other types of optical measurement devices may be used, such as but not limited to triangulation scanners and structured light scanners for example.

[0059] According to one or more embodiments described herein, the scanner **620** can include a scanner processing system including a scanner controller, a housing, and a three-dimensional (3D) scanner. The 3D scanner can be disposed within the housing and operably coupled to the scanner processing system. The 3D scanner includes a light source, a beam steering unit, a first angle measuring device, a second angle measuring device, and a light receiver. The beam steering unit cooperates with the light source and the light receiver to define a scan area. The light source and the light receiver are configured to cooperate with the scanner processing system to determine a first distance to a first object point based at least in part on a transmitting of a light by the light source and a receiving of a reflected light by the light receiver. The 3D scanner is further configured to cooperate with the scanner processing system to determine 3D coordinates of the first object point based at least in part on the first distance, a first angle of rotation, and a second angle of rotation.

[0060] The scanner **620** performs at least one scan to generate a data set (e.g., the 3D data **609***a*) that includes a plurality of three-dimensional coordinates of the environment **622**. It should be appreciated that other numbers of scanners (e.g., one scanner, three scanners, four scanners, six scanners, eight scanners, etc.) can be used. According to one or more embodiments described herein, one or more scanners can be used to take multiple scans. For example, the scanner **620** can capture first scan data of the environment **622** at a first location and then be moved to a second location, where the scanner **620** captures second scan data of the environment **622**.

[0061] Using the data received from the scanner **620**, the processing system **600** can generate a graphical representation based on the 3D data **609***a* and/or the image data **609***b* (e.g. point data) using one or more of the data processing engine **612**, the graphical representation generation engine **614**, and/or the manipulation engine **616**. For example, the data processing engine **612** performs processing on the data **609***a* and/or the data **609***b*. Examples of data processing include removing/reducing noise within the data, extracting features from the data, identifying changes in the data over time, adding annotations to data, measuring aspects of the data (e.g., a distance between two points), comparing aspects of the data, and/or the like, including combinations and/or multiples thereof. The graphical representation generation engine **614** generates a graphical representation of the data **609***a* and/or the data **609***b* for display on the display **610** and/or on a display of another device/system. For example, in an embodiment where the processing system **600** is a node of a cloud computing system, the graphical representation generation engine **614** can generate a graphical representation to be displayed on a user computing device **630** (e.g., such as a smartphone, tablet computer, laptop or notebook computer, a wearable device such as a head-up display or smartwatch, and/or the like, including combinations and/or multiples thereof).

[0062] According to one or more embodiments described herein, the graphical representation generation engine **614** can generate a split-screen view of the data **609***a*, **609***b*. For example, the graphical representation generation engine **614** can generate a graphical display that displays at least a portion of the data **609***a* and/or the data **609***b* separately as is further described herein. Particularly, the features and functions of the engines **612**, **614**, **616** are now described in more detail with reference to FIGS. **7** and **8**A-**8**H as examples.

[0063] Turning now to FIG. **7**, a flow diagram of a method **700** for graphical representation generation using 3D data and/or image data according to one or more embodiments described herein. The method **700** can be performed by any suitable system or device, such as the processing system **503** of FIG. **5**, the processing system **600** of FIG. **6**, and/or the processing system **1000** of FIG. **10**. The method **700** is now described with further reference to FIGS. **8**A-**8**H.

[0064] At block **702**, a processing system (e.g., the processing system **600**) receives 3D data (e.g., 3D data **609***a*) associated with an environment (e.g., the environment **622**). The 3D data **609***a* can be captured by any suitable 3D coordinate measurement device, such as the scanner **20** of FIGS. **1-4**, the scanner **620** of FIG. **6**, and/or the like, including combinations and/or multiples thereof. According to an embodiment, the 3D data **609***a* includes one or more point clouds, which are collections of points having 3D coordinates (e.g., "x,y,z") associated with the environment.

[0065] At block **704**, the processing system (e.g., the processing system **600**) receives image data (e.g., image data **609**b) associated with the environment (e.g., the environment **622**). The image data **609***b* can be captured by any suitable camera device, such as the camera **504** of FIG. **5**, the camera **621** of FIG. **6**, and/or the like, including combinations and/or multiples thereof. According to an embodiment, the image data **609***b* includes one or more images. According to one or more embodiments described herein, the one or more images can be one or more 360 degree images, panoramic images, and/or the like, including combinations and/or multiples thereof, which are associated with the environment.

[0066] At block **706**, the processing system (e.g., using the graphical representation generation engine **614**) generates a graphical representation. The graphical representation can be based at least in part on the 3D data, the image data, a combination of the 3D data and the image data, and/or the like, including combinations and/or multiples thereof. FIGS. **8**A-**8**E depict example graphical representation **801-805** according to one or more embodiments described herein.

[0067] In these examples, the graphical representations **801-805** include a first region **811** that can be used to display 3D data (e.g., the 3D data **609***a*) and/or image data (e.g., the image data **609***b*). According to one or more embodiments described herein, the field of view of the 3D data and/or the image data displayed in the first region **811** can be defined by a user and can be adjusted while the user is viewing the graphical representations **801-805**. As the user adjusts a field of view, the 3D data and/or the image data displayed in the first region **811** can correspondingly adjust in some embodiments or can be fixed in some embodiments.

[0068] According to one or more embodiments described herein, the first region **811** is selectively switchable between a single-sub-region mode and a multi-sub-region mode. For example, a user can select a "split screen" option to divide the first region **811** into multiple sub-regions.

[0069] FIGS. **8**A and **8**B depict the single-sub-region mode and FIGS. **8**C-**8**E depict the multi-sub-region mode. In FIG. **8**A, the first region **811** of the graphical representation **801** represents a single-sub region and displays 3D data in the form of a point cloud. In FIG. **8**B, the first region **811** of the graphical representation **802** also represents a single-sub region, but in this example, the first region **811** displays image data as a portion of a 360 degree image.

[0070] In the examples of FIGS. **8**C-**8**E, the first region **811** is switched to a multi-sub-region mode having two sub-regions. It should be appreciated that the first region **811** can have additional sub-regions in other embodiments and is not limited to the two illustrated sub-regions. In FIGS. **8**C-**8**E, the first region **811** is divided into a first sub-region **821** and a second sub-region **822**. In FIG. **8**C, the first sub-region **821** displays image data and the second sub-region **822** displays 3D data in the form of a point cloud. In this example, the first and second sub-regions **821**, **822** show the respective image and 3D data that were captured at substantially the same time as shown. However, in other examples, different times can be selected to show how the environment changed over time. For example, in FIG. **8**D, the first sub-region **821** displays image data captured at a first point in time and the second sub-region **822** displays image data captured at a second point in time. A comparison between the images shows differences in the environment that occurred over time. In FIG. **8**D, the first sub-region **821** displays 3D data in the form of a point cloud captured at a first point in time and the second sub-region **822** displays 3D data in the form of a point cloud captured at a second point in time. Again, differences in the environment between the two points in time can be observed.

[0071] According to one or more embodiments described herein, the graphical representations **801-805** can also include a second region **812**. According to one or more embodiments described herein, the second region **812** displays information associated with the 3D data and/or the image data, such as a location of the environment at which the 3D data and/or the image data were captured, a timestamp associated with when the 3D data and/or the image data were captured, and/or the like, including combinations and/or multiples thereof.

[0072] FIGS. **8**F-**8**H depict additional example graphical representations **806-808**. Regarding FIG. **8**F, the graphical representation **806** depicts an image **860** captured at a first point in time and an image **861** captured at a second point in time. A user, using the manipulation engine **616**, can manipulate the images **860**, **861**. For example, a user may want to compare change to the environment relative to the first and second points in time. When the user moves the field of view of the image **860**, the field of view for the image **861** also moves. This is referred to as a dependent linking mode. For example, when the user manipulates one of the images **860**, **861**, the field of view of the other image also moves, as shown in the graphical representation **807** of FIG. **8**G. That is, when the user manipulates one of the images **860**, **861** of the graphical representation **806** by changing the field of view, the graphical representation **806** is generated, showing images **870**, **871**. Particularly, the graphical representation **807** depicts an image **870** captured at the first point in time and the image **871** captured at the second point in time.

[0073] According to an embodiment, the user may desire to inspect details from multiple locations or points of view. In such cases, the fields of view of the images **870**, **871** can move independently in an independent linking mode. To select between dependent moving and independent moving, the user can select a "linking" option on the graphical representation. When independent moving is selected, the user can move the fields of view of each of the images **870**, **871** independently to generate the graphical representation **808** shown in FIG. **8**H.

[0074] According to an embodiment, a hybrid linking approach may be implemented, which is now described with reference to FIG. **8**H. Particularly, the graphical representation **808** of FIG. **8**H depicts an image **880** captured at the first point in time and the image **881** captured at the second point in time. In this example, the image **880** is a "main" view where adjusting a field of view of the image **880** also adjusts the field of view of the image **881**. However, the field of view of the image **881** can be moved independently such that when the user adjusts the field of view of the image **881**, the field of view of the image **880** does not move.

[0075] According to one or more embodiments described herein, each of the images **880**, **881** of two split screens of FIG. **8**H shows a spherical view of the **360**/panorama image. Also, each of the images **880**, **881** contains capture location markers (e.g., shown on the "floor" of the environment in the images) that indicate other capture locations. Clicking, by a user, on one of the capture location markers does causes one or more of the following to occur. If clicked on a marker in the left split screen (e.g., the image **880**), the virtual user walks in both split screens, satisfying the use case of time comparisons of adjacent locations. If clicked on a marker in the right split screen (e.g., the image **881**), the virtual user only walks in the right split screen. This provides for users to compare the same objects from different camera angles, either in the same time point or at different time points.

[0076] Adjusting the field of view of an image, as described herein, can include one or more of panning the image, tilting the image, rotating the image, moving "through" the environment digitally, zooming in/out, and/or the like, including combinations and/or multiples thereof.

[0077] One or more embodiments described herein provide for independently rotating the two views. One or more embodiments described herein provides for independently translating one view relative to the other. For example, clicking on an icon in the left view causes the two views to rotate together while clicking on the right icon causes the right view to be moved and rotated independently of the first. Clicking on the left icon again causes to two images to rotate synchronously, but now seen from different perspectives. In this way, a user may view two different sides of an environment or view two different environments in the split screen.

[0078] It should be understood that the process depicted in FIG. **7** represents an illustration, and that other processes may be added or existing processes may be removed, modified, or rearranged without departing from the scope of the present disclosure.

[0079] FIG. **9** depicts a block diagram of functional blocks **900** of the processing system **600** of FIG. **6** according to one or more embodiments described herein. One or more of the functional blocks **900** can be performed by the processing system **600**, such as using the data processing engine **612**, or another suitable system, device, or engine. At functional block **902**, the data processing engine **612** can provide for a user to explore 360 images, point clouds, computer-aided design (CAD) models, building information modeling (BIM) models, and/or the like, including combinations and/or multiples thereof, such as using one or more of the graphical representations **801-808** in FIGS. **8**A-**8**H.

[0080] At functional block **904**, the data processing engine **612** can track the progress of data over time. For example, the data **609***a*, **609***b* can have associated timestamps when the data is captured, and the data processing engine **612** can process changes to the data, and thus the environment, over time.

[0081] At functional block **906**, the data processing engine **612** can provide for annotating the data **609***a*, **609***b*. For example, the data can be annotated by creating markups, creating and managing tasks, and/or the like, including combinations and/or multiples thereof.

[0082] At functional block **908**, the data processing engine **612**, in conjunction with the graphical representation generation engine **614**, can provide for a user to create and take virtual tours through an environment (e.g., captured site) associated with the data **609***a*, **609***b*.

[0083] At functional block **910**, the data processing engine **612** can provide for the user to communicate collaboratively with another user(s), such as by sharing some or all of the data **690***a*, **609***b*, sharing a virtual tour from functional block **908**, sharing annotations from block **906**, and/or the like, including combinations and/or multiples thereof.

[0084] At functional block **912**, the data processing engine **612** perform data analysis, such as performing measuring, comparing, and/or the like, including combinations and/or multiples thereof, as described herein.

[0085] It should be appreciated that the functional blocks **900** are merely examples of functions that the processing system **600** can perform, and the processing system **600** is not limited to these functions as other functions can be added in different embodiments.

[0086] It is understood that one or more embodiments described herein is capable of being implemented in conjunction with any other type of computing environment now known or later developed. For example, FIG. **10** depicts a block diagram of a processing system **1000** for implementing the techniques described herein. In accordance with one or more embodiments described herein, the processing system **1000** is an example of a cloud computing node of a cloud computing environment. In examples, processing system **1000** has one or more central processing units ("processors" or "processing resources" or "processing devices") **1021***a*, **1021***b*, **1021***c*, etc. (collectively or generically referred to as processor(s) **1021** and/or as processing device(s)). In aspects of the present disclosure, each processor **1021** can include a reduced instruction set computer (RISC) microprocessor. Processors **1021** are coupled to system memory (e.g., random access memory (RAM) **1024**) and various other components via a system bus **1033**. Read only memory (ROM) **1022** is coupled to system bus **1033** and may include a basic input/output system (BIOS), which controls certain basic functions of processing system **1000**.

[0087] Further depicted are an input/output (I/O) adapter **1027** and a network adapter **1026** coupled to system bus **1033**. I/O adapter **1027** may be a small computer system interface (SCSI) adapter that communicates with a hard disk **1023** and/or a storage device **1025** or any other similar component. I/O adapter **1027**, hard disk **1023**, and storage device **1025** are collectively referred to herein as mass storage **1034**. Operating system **1040** for execution on processing system **1000** may be stored in mass storage **1034**. The network adapter **1026** interconnects system bus **1033** with an outside network **1036** enabling processing system **1000** to communicate with other such systems.

[0088] A display (e.g., a display monitor) **1035** is connected to system bus **1033** by display adapter **1032**, which may include a graphics adapter to improve the performance of graphics intensive applications and a video controller. In one aspect of the present disclosure, adapters **1026**, **1027**, and/or **1032** may be connected to one or more I/O busses that are connected to system bus **1033** via an intermediate bus bridge (not shown). Suitable I/O buses for connecting peripheral devices such as hard disk controllers, network adapters, and graphics adapters typically include common protocols, such as the Peripheral Component Interconnect (PCI). Additional input/output devices are shown as connected to system bus **1033** via user interface adapter **1028** and display adapter **1032**. A keyboard **1029**, mouse **1030**, and speaker **1031** may be interconnected to system bus **1033** via user interface adapter **1028**, which may include, for example, a Super I/O chip integrating multiple device adapters into a single integrated circuit.

[0089] In some aspects of the present disclosure, processing system **1000** includes a graphics processing unit **1037**. Graphics processing unit **1037** is a specialized electronic circuit designed to manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display. In general, graphics processing unit **1037** is very efficient at manipulating computer graphics and image processing, and has a highly parallel structure that makes it more effective than general-purpose CPUs for algorithms where processing of large blocks of data is done in parallel.

[0090] Thus, as configured herein, processing system **1000** includes processing capability in the form of processors **1021**, storage capability including system memory (e.g., RAM **1024**), and mass storage **1034**, input means such as keyboard **1029** and mouse **1030**, and output capability including speaker **1031** and display **1035**. In some aspects of the present disclosure, a portion of system memory (e.g., RAM **1024**) and mass storage **1034** collectively store the operating system **1040** to coordinate the functions of the various components shown in processing system **1000**.

[0091] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that the graphical representation further includes a second region, wherein the second region displays information associated with the 3D data and the image data.

[0092] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that the 3D data and the image data are temporally linked.

[0093] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that, in an independent linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region.

[0094] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that, in a dependent linking mode, a field of view of the first sub-region changes according to a change to a field of view of the second sub-region.

[0095] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that, in a hybrid linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region and the field of view of the second sub-region changes according to a change to the field of view of the first sub-region.

[0096] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that the 3D data includes a point cloud.

[0097] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that the image data includes a 360 degree image.

[0098] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that the first portion of the 3D data was captured at a first point in time and the at least the first portion of the image data was captured at a second point in time.

[0099] In addition to one or more of the features described herein, or as an alternative, further embodiments of the method may include that the at least the second portion of the 3D data or the least the second portion of the image data were captured at a first point in time, and wherein the at least the third portion of the 3D data or the least the third portion of the image data were captured at a second point in time.

[0100] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that the graphical representation further comprises a second region, wherein the second region displays information associated with the 3D data and the image data.

[0101] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that the 3D data and the image data are temporally linked.

[0102] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that, in an independent linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region.

[0103] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that, in a dependent linking mode, a field of view of the first sub-region changes according to a change to a field of view of the second sub-region.

[0104] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that, in a hybrid linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region and the field of view of the second sub-region changes according to a change to the field of view of the first sub-region.

[0105] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that the 3D data comprises a point cloud.

[0106] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that the image data comprises a 360 degree image.

[0107] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that the first portion of the 3D data was captured at a first point in time and the at least the first portion of the image data was captured at a second point in time.

[0108] In addition to one or more of the features described herein, or as an alternative, further embodiments of the system may include that the at least the second portion of the 3D data or the least the second portion of the image data were captured at a first point in time, and wherein the at least the third portion of the 3D data or the least the third portion of the image data were captured at a second point in time.

[0109] It will be appreciated that one or more embodiments described herein may be embodied as a system, method, or computer program product and may take the form of a hardware embodiment, a software embodiment (including firmware, resident software, micro-code, etc.), or a combination thereof. Furthermore, one or more embodiments described herein may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[0110] The term "about" is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, "about" can include a range of ±8% or 5%, or 2% of a given value.

[0111] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0112] While the disclosure is provided in detail in connection with only a limited number of embodiments, it should be readily understood that the disclosure is not limited to such disclosed embodiments. Rather, the disclosure can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the disclosure. Additionally, while various embodiments of the disclosure have been described, it is to be understood that the exemplary embodiment(s) may include only some of the described exemplary aspects. Accordingly, the disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

What is claimed is:

1. A method comprising:

receiving three-dimensional (3D) data associated with an environment;

receiving image data associated with the environment; and

generating a graphical representation based at least in part on at least one of the 3D data and the image data, the graphical representation comprising a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode,

wherein, responsive to the single-sub-region mode being enabled, the first region displays at least one of at least a first portion of the 3D data and at least a first portion of the image data, and

wherein, responsive to the multi-sub-region mode being enabled, the first region comprises at least a first sub-region and a second sub-region, the first sub-region displaying at least one of at least a second portion of the 3D data and at least a second portion of the image data, and the second sub-region displaying at least one of at least a third portion of the 3D data and at least a third portion of the image data.

2. The method of claim **1**, wherein the graphical representation further comprises a second region, wherein the second region displays information associated with the 3D data and the image data.

3. The method of claim **1**, wherein the 3D data and the image data are temporally linked.

4. The method of claim **1**, wherein, in an independent linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region.

5. The method of claim **1**, wherein, in a dependent linking mode, a field of view of the first sub-region changes according to a change to a field of view of the second sub-region.

6. The method of claim **1**, wherein, in a hybrid linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region and the field of view of the second sub-region changes according to a change to the field of view of the first sub-region.

7. The method of claim **1**, wherein the 3D data comprises a point cloud.

8. The method of claim **1**, wherein the image data comprises a 360 degree image.

9. The method of claim **1**, wherein the first portion of the 3D data is captured at a first point in time and the at least the first portion of the image data is captured at a second point in time.

10. The method of claim **1**, wherein the at least one of the at least the second portion of the 3D data and the least the second portion of the image data are captured at a first point in time, and wherein the at least one of the at least the third portion of the 3D data and the least the third portion of the image data are captured at a second point in time.

11. A system, comprising:

a memory comprising computer readable instructions; and

a processing device for executing the computer readable instructions, the computer readable instructions controlling the processing device to perform operations comprising:

receiving three-dimensional (3D) data associated with an environment;

receiving image data associated with the environment; and

generating a graphical representation based at least in part on at least one of the 3D data and the image data, the graphical representation comprising a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode,

wherein, responsive to the single-sub-region mode being enabled, the first region displays at least one of at least a first portion of the 3D data and at least a first portion of the image data, and

wherein, responsive to the multi-sub-region mode being enabled, the first region comprises at least a first sub-region and a second sub-region, the first sub-region displaying at least one of at least a second portion of the 3D data and at least a second portion of the image data, and the second sub-region displaying at least one of at least a third portion of the 3D data and at least a third portion of the image data.

12. The system of claim **11**, wherein the graphical representation further comprises a second region, wherein the second region displays information associated with the 3D data and the image data.

13. The system of claim **11**, wherein the 3D data and the image data are temporally linked.

14. The system of claim **11**, wherein, in an independent linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region.

15. The system of claim **11**, wherein, in a dependent linking mode, a field of view of the first sub-region changes according to a change to a field of view of the second sub-region.

16. The system of claim **11**, wherein, in a hybrid linking mode, a field of view of the first sub-region can be changed independently of a field of view of the second sub-region and the field of view of the second sub-region changes according to a change to the field of view of the first sub-region.

17. The system of claim **11**, wherein the 3D data comprises a point cloud, and wherein the image data comprises a 360 degree image.

18. The system of claim **11**, wherein the first portion of the 3D data is captured at a first point in time and the at least the first portion of the image data is captured at a second point in time.

19. The system of claim **11**, wherein the at least one of the at least the second portion of the 3D data and the least the second portion of the image data are captured at a first point in time, and wherein the at least one of the at least the third portion of the 3D data and the least the third portion of the image data are captured at a second point in time.

20. A system, comprising:

at least one camera that captures image data associated with an environment;

at least one scanner that captures three-dimensional (3D) data associated with the environment;

a data store for storing the image data associated with the environment captured with the at least one camera, and the 3D data associated with the environment captured with the at least one scanner;

a processing system that generates a graphical representation based at least in part on at least one of the 3D data and the image data, the graphical representation comprising a first region selectively switchable between a single-sub-region mode and a multi-sub-region mode,

wherein, responsive to the single-sub-region mode being enabled, the first region displays on a display of a user computing device at least one of at least a first portion of the 3D data and at least a first portion of the image data, and

wherein, responsive to the multi-sub-region mode being enabled, the first region comprises at least a first sub-region and a second sub-region, the first sub-region displaying on the display of the user computing device at least one of at least a second portion of the 3D data and at least a second portion of the image data, and the second sub-region displaying on the display of the user computing device at least one of at least a third portion of the 3D data and at least a third portion of the image data.

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