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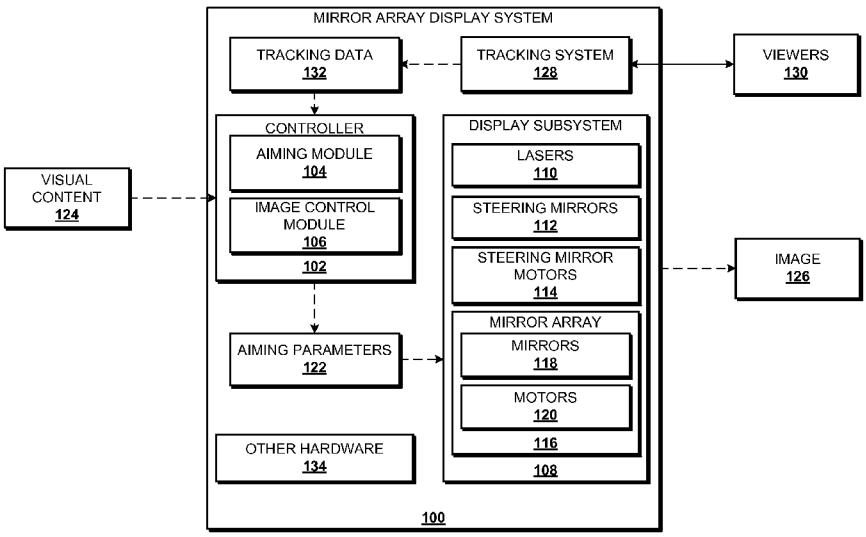


FIGURE 1

(57) Abstract: Technologies are generally described herein for a mirror array display system. In some examples, a controller can be configured to execute various methods for displaying content using a mirror array display having a mirror array including a number of mirrors and a light source. The controller can obtain content for display. The controller can also determine at least one aiming parameter associated with the number of mirrors and the light source. The controller can also emit light using the light source and aim the light emitted by the light source to a convergence point to generate a three-dimensional representation of the content, wherein the light is aimed in accordance with the at least one aiming parameter.

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MIRROR ARRAY DISPLAY SYSTEM

BACKGROUND

[0001] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0002] Users sometimes interact with two-dimensional ("2D") information presented by way of 2D display devices. With the proliferation of smaller and more compact display devices and an increase in the amount of available content for display on the display devices, users sometimes are limited in their interactions with displayed information. In particular, the display real estate can be limited, and interactions with the information displayed on the display devices can be limited to various interactions such as drag-and-drop mouse commands, swipe gestures on touch interfaces, and the like.

[0003] Additionally, many users are increasingly performing a greater percentage of computing tasks on mobile devices having small displays that are not necessarily well-suited to presenting large amounts of information. Thus, websites, for example, may provide mobile versions of websites that lack detail included on full versions of the sites to avoid crowding the limited display space of the mobile devices. As such, users may sacrifice detail in displayed content for display space and/or may sacrifice detail and/or display space due to a compressed size of a mobile device. Similarly, with an increased reliance upon small compact computing devices such as smart phones, the importance of power conservation has increased in conjunction with the increased reliance upon these devices. As such, users also often trade bright and/or large displays for energy efficiency.

[0004] Three dimensional ("3D") technologies are starting to become popular. One limitation of 3D technologies that continues to hamper growth is the requirement, in most solutions, of added gear such as glasses, special screens, or the like, to view 3D content. Users therefore may be unable to view 3D content if they do not currently have in their possession the required 3D gear or equipment.

SUMMARY

[0005] The present disclosure generally describes concepts and technologies for displaying content using a mirror array. According to various embodiments of the

concepts and technologies disclosed herein, an array of aimed or steerable mirrors is controlled by a controller or other processing device to create real images in an interaction space or virtual images outside the interaction space. A laser beam emitted from a laser is used to project one or more points corresponding to surfaces of an object represented by a displayed image. Each of the points can correspond to light projected by the laser from one or more angles. As such, light rays or light beams can emanate from the mirror array and illuminate each point of the object, forming a real image. The real image can correspond to a three-dimensional object. The user can interact with the three-dimensional objects by using gestures tracked by cameras, voice commands, or other commands that are interpreted by the controller and/or otherwise detected by the controller. The controller can modify the image created by the mirror array display system in response to the commands or gestures.

[0006] According to one aspect, a computer-implemented method for displaying content using a mirror array display is provided. The mirror array display includes a controller, a mirror array having one or more mirrors, and a light source, and the method includes computer-implemented operations for obtaining, by the controller, the content, determining, by the controller, at least one aiming parameter associated with the one or more mirrors and the light source, emitting light, using the light source, and aiming the light emitted by the light source to a convergence point to generate a three-dimensional representation of the content. The light can be aimed in accordance with the at least one aiming parameter.

[0007] According to some embodiments, the convergence point includes a first convergence point and a second convergence point, and the content includes a first content component visible at the first convergence point and a second content component visible at the second convergence point. The method can also include determining, using a tracking system associated with the mirror array display, a first location, relative to the mirror array display, of a first viewer; determining, using the tracking system, a second location, relative to the mirror array display, of a second viewer; determining the first convergence point based, at least partially, upon the first location; and determining the second convergence point based, at least partially, upon the second location. According to various implementations, aiming the light includes aiming a first portion of the light emitted by the light source to the first convergence point and aiming a second portion of the light emitted by the light source to the second convergence point.

[0008] In some embodiments, determining the aiming parameter includes executing an aiming algorithm at the controller based, at least partially, upon the convergence point. Determining the aiming parameter can include determining, using the aiming algorithm, a modulation rate for the light source and a rotation angle, relative to the light source, of at least one of the one or more mirrors. In some embodiments, the light source includes a laser and determining the aiming parameter includes determining, using the aiming algorithm, a modulation rate of a laser beam emitted by the laser and a rotation angle, relative to the light source, of at least one of the one or more mirrors. The mirror array display further can include a secondary mirror for aiming the laser beam emitted by the laser, and determining the aiming parameter further can include determining the rotation angle, relative to the light source, of the secondary mirror.

[0009] In some embodiments, the method also includes determining, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewer and determining the convergence point based, at least partially, upon the location of the viewer. The method can also include determining that the viewer has moved relative to the convergence point; in response to determining that the viewer has moved, determining at least one modified aiming parameter and a modified convergence point; and aiming the light emitted by the light source to the modified convergence point, wherein the light is aimed in accordance with the at least one modified aiming parameter.

[0010] The method can also include determining, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewing area; determining the convergence point based, at least partially, upon the location of the viewing area; and determining that the viewing area has moved relative to the convergence point. In response to determining that the viewing area has moved, the method further can include determining a rotation angle, relative to a rotation axis associated with the mirror array display, of a movement of the viewing area, modifying the content in accordance with the rotation angle to obtain modified content, determining a modified convergence point, in accordance with the rotation angle, and aiming the light emitted by the light source to the modified convergence point. In some embodiments, the method further includes detecting, with a tracking system in communication with the controller, a movement of a user

corresponding to an interaction with the three-dimensional representation. The method can also include modifying the content in response to the interaction.

[0011] According to another aspect, a computer readable medium for displaying content using a mirror array display is disclosed. The computer readable medium includes including computer executable instructions that, when executed by a computer, cause the computer to obtain content for display at a mirror array display including a mirror array having one or more mirrors and a light source; determine at least one aiming parameter for at least one of the one or more mirrors and a modulation rate of light emitted by the light source; and emit light, using the light source; and aim the light emitted by the light source to a convergence point to generate a three-dimensional representation of the content. According to some embodiments, the light is aimed by moving the at least one of the one or more mirrors in accordance with the at least one aiming parameter and emitting the light in accordance with the modulation rate.

[0012] According to some embodiments, the computer readable medium further includes instructions that, when executed by the computer, cause the computer to determine, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewing area associated with a viewer; and determine the convergence point based, at least partially, upon the location of the viewing area. The computer readable medium further can include instructions that, when executed by the computer, cause the computer to determine that the viewer has moved relative to the convergence point; when a determination is made that the viewer has moved, determine at least one modified aiming parameter and a modified convergence point; and aim the light emitted by the light source to the modified convergence point. In some embodiments, the light is aimed in accordance with the at least one modified aiming parameter. The computer readable medium further can include instructions that, when executed by the computer, cause the computer to determine that the viewing area has moved relative to the convergence point; when a determination is made that the viewing area has moved, determine a rotation angle, relative to a rotation axis associated with the mirror array display, of a movement of the viewing area, modify the content in accordance with the rotation angle to obtain modified content, determine a modified convergence point, in accordance with the rotation angle, and aim the light emitted by the light source to the modified convergence point.

[0013] According to some embodiments, the computer readable medium further includes instructions that, when executed by the computer, cause the computer to determine a rotation point associated with the mirror array display; track movement, using the tracking system, of the viewing area relative to the rotation point; and calculate the rotation angle based, at least partially, the movement. In some embodiments the tracking system includes an image capture device for tracking movement of the viewer. In some embodiments, the tracking system includes an orientation sensor of a device, and to determine the rotation angle, the computer executable instructions, when executed by the computer, further cause the computer to determine, using the orientation sensor a rotation point associated with the mirror array display, an amount the device is moved, relative to the rotation point, and the rotation angle based, at least partially, upon the movement. In some embodiments, the computer readable medium further includes computer executable instructions that, when executed by the computer, cause the computer to detect, via receiving tracking data generated by a tracking system in communication with the computer, a movement of a user corresponding to an interaction with the three-dimensional representation; and modify the content in response to the interaction.

[0014] According to another aspect, a mirror array display for generating a three-dimensional representation of content is disclosed. The mirror array display can include a mirror array having one or more mirrors, a light source configured to emit light for projection by the one or more mirrors, and a controller configured to execute computer executable instructions to determine at least one aiming parameter for at least one of the one or more mirrors, determine a modulation rate of light emitted by the light source, control the light source to emit light in accordance with the modulation rate, and control an orientation of at least one of the one or more mirrors to project the light toward a convergence point. In some embodiments, the controller controls the orientation of the at least one of the one or more mirrors in accordance with the at least one aiming parameter.

[0015] According to some embodiments, the mirror array display further includes a secondary mirror configured to direct light emitted by the light source toward at least one of the one or more mirrors. The controller can be further configured to control an orientation of the secondary mirror and the light source can include a laser. The controller can also be further configured to execute computer executable instructions to determine, using a tracking system associated with the

mirror array display, a location, relative to the mirror array display, of a viewing area associated with a viewer, and determine the convergence point based, at least partially, upon the location of the viewing area. In some embodiments, the controller is further configured to execute computer executable instructions to determine that the viewer has moved relative to the convergence point, when a determination is made that the viewer has moved, determine at least one modified aiming parameter and a modified convergence point, and aim the light emitted by the light source to the modified convergence point, wherein the light is aimed in accordance with the at least one modified aiming parameter.

[0016] According to some embodiments, the controller is further configured to execute computer executable instructions to determine that the viewing area has moved relative to the convergence point, when a determination is made that the viewing area has moved, determine a rotation angle, relative to a rotation axis associated with the mirror array display, of a movement of the viewing area, modify the content in accordance with the rotation angle to obtain modified content, determine a modified convergence point, in accordance with the rotation angle, and aim the light emitted by the light source to the modified convergence point. In some embodiments, the mirror array has a first side and a second side, and the light source is located at the first side and the convergence point is located at the second side. In some embodiments, the mirror array has a first side and a second side, and the light source and the convergence point are located at the first side of the mirror array. In some embodiments, the controller is further configured to execute computer executable instructions to detect, via receiving tracking data generated by a tracking system in communication with the controller, a movement of a user corresponding to an interaction with the three-dimensional representation, and modify the content in response to the interaction.

[0017] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0018] The foregoing and other features of this disclosure will become more fully apparent from the following description and appended claims, taken in

conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings, in which:

FIGURE **1** is a block diagram illustrating a mirror array display system for displaying content using a mirror array;

FIGURE **2** is a line drawing illustrating additional aspects of the mirror array display system;

FIGURE **3** is a line drawing illustrating additional aspects of the mirror array display system;

FIGURE **4** is a line drawing illustrating additional aspects of the mirror array display system;

FIGURE **5** is a line drawing illustrating an example of using the mirror array display system;

FIGURES **6A-6B** are line drawings illustrating illustrative displays generated by the mirror array display system;

FIGURE **7** is line drawing illustrating another example of using the mirror array display system;

FIGURES **8A-8B** are line drawings illustrating illustrative displays generated by the mirror array display system;

FIGURE **9** is a line drawing illustrating additional aspects of the mirror array display system;

FIGURE **10** is a line drawing illustrating additional aspects of the mirror array display system;

FIGURE **11** is a flow diagram illustrating an example process for displaying content using a mirror array display system;

FIGURE **12** is a flow diagram illustrating another example process for displaying content using the mirror array display system;

FIGURE **13** is a block diagram illustrating an example computer capable of displaying content using a mirror array display system; and

FIGURE **14** is a schematic diagram illustrating computer program products for displaying content using a mirror array display system,

all arranged according to at least some embodiments presented herein.

DETAILED DESCRIPTION

[0019] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the FIGURES, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0020] This disclosure is generally drawn, *inter alia*, to technologies for displaying content using a mirror array. In an illustrative example, a mirror array display system can include a controller and a display subsystem that can include a mirror array having a number of mirrors. The display system can also include a laser and a steering mirror for aiming light emitted by the laser. The controller can be configured to control the mirrors and the laser to emit light toward a viewing area to generate a real image in free space. The mirror array display system can further include a tracking system for tracking movements of viewers and/or interactions of viewers with the displayed images in free space.

[0021] The controller can obtain visual content and determine a location at which to project an image corresponding to the visual content. The location can include a viewing area and/or a convergence point associated with a viewing area and/or viewer. The viewing area and the convergence point may or may not coincide with one another. The controller can determine aiming parameters for controlling a light source such as a laser, a steering mirror if used, or one or more mirrors in the mirror array. One or more of the mirrors can be controlled by a motor via the aiming parameters generated by the controller. As will be explained in more detail herein, the mirror array display system can be used to create real images in free space such as an interaction space. As is known, one type of image in optics is a real image. In a real image there can be a one-to-one correspondence, for example, a complete mapping, from one or more points on a real world object to corresponding one or more points in the real image. In accordance with various embodiments of the concepts and technologies disclosed herein, a three-dimensional object, which in appearance is

identical to a real-world object, can be created by converging rays or light beams emitted by the lasers.

[0022] In some implementations, the mirror array display system can support viewing by multiple viewers, where the viewers may see the same image albeit from different angles. In some other embodiments, the mirror array display system can display multiple copies of the same image, one for each viewer (for example, one copy of the image directly in front of each viewer). In other embodiments, each of the viewers may see a different image generated based upon various instances of visual content. The controller can calculate a convergence cone that ends at a convergence point in front of a face or eyes of the viewer, the convergence point corresponding to one point of a displayed real image that can be seen by a viewer.

[0023] The controller can also calculate a line that extends from the convergence point to a mirror on the mirror array that is to display light for the convergence point. The controller can calculate convergence points corresponding to one or more contours or surfaces of the displayed image and can display the image by projecting or emitting light corresponding to the convergence points toward the viewing area. Thus, the mirror array display system can display an image by emitting or projecting light toward a viewing area to a convergence point to generate the image. In some embodiments, the rays may diverge and enter the eyes of the viewer. As such, the viewer can see a real image that appears to the viewer to float in free space in between the mirror array and the viewer. Thus, viewers can see 3D images in free space and can interact with the images, in accordance with the various embodiments disclosed herein. These and other aspects of systems and methods for displaying content using a mirror array display will be described in more detail herein.

[0024] Referring now to FIGURE **1**, a block diagram illustrating a mirror array display system **100** for displaying content using a mirror array arranged according to at least some embodiments presented herein will be described. (The optical nature of the display is best illustrated in FIGURE 9, discussed below.) As will be explained in more detail herein, the mirror array display system **100** can be embodied as part of a computer display, a monitor, a television set, a laptop or other mobile computing device, a mobile telephone or smartphone, a projector system, or the like. The mirror array display system **100** can also be embodied as a ubiquitous display that is integrated within a wall, table, counter, building, signage, furniture,

and/or other surfaces of other structures. In some other embodiments, one or more components of the mirror array display system **100** can be embodied in a display device, while one or more other components of the mirror array display system **100** can be communicatively coupled to one another via a network connection or one or more other types of connections.

[0025] For purposes of explaining the various components of the mirror array display system **100**, the mirror array display system **100** is described herein as being embodied in a display screen of a computer display, a wall of mirrors such as a stationary mirror array, or a mobile telephone display. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way. Although not illustrated in FIGURE **1**, it should be understood that the mirror array display system **100** can operate as part of, or in communication with, a communications network (not shown in FIGURE **1**). As such, various entities may communicate with the mirror array display system **100** via direct connections and/or via network connections.

[0026] The mirror array display system **100** includes a controller **102**. The functionality of the controller **102** can be provided by hardware and/or software. In the illustrated embodiment, the controller **102** includes one or more application programs such as, for example, an aiming module **104** and an image control module **106**. While the aiming module **104** and the image control module **106** are illustrated as separate entities (components) in FIGURE **1**, it should be understood that a single application program can provide some or all of the functionality described herein with respect to the aiming module **104** and/or the image control module **106**. Furthermore, although the aiming module **104** and the image control module **106** are illustrated as components of the controller **102**, it should be understood that these and/or other modules (not shown in FIGURE **1**) may be embodied as one or more stand-alone devices or components.

[0027] The aiming module **104** can be configured to control alignments, orientations, modulation rates, and/or performance and/or other operating characteristics of various hardware and/or software components used to provide a display subsystem **108** of the mirror array display system **100**. In particular, as will be described in more detail herein, the display subsystem **108** can include one or more lasers **110**, one or more steering mirrors **112**, one or more steering mirror motors **114**, and one or more mirror arrays **116.** A mirror array **116** can include a number of

mirrors **118** and a number of motors **120**. According to various embodiments, each of the mirrors **118** may be controlled by one of the motors **120**, and the motors **120** can be operated by instructions or signals generated by the aiming module **104**. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0028] In some embodiments, the aiming module **104** can generate aiming parameters **122** for controlling the various components of the display subsystem **108**. Thus, the aiming module **104** can be configured to output the aiming parameters **122**, and various hardware components of the display subsystem **108** can be controlled by the aiming parameters **122**. The aiming parameters **122** can include analog and/or digital control signals for modulating a beam emitted by one or more of the lasers **110**, for driving one or more of the steering mirror motors **114** to orient one or more of the steering mirrors **112**, and/or for driving one or more of the motors **120** to aim one or more of the mirrors **118**. It should be understood that the aiming parameters **122** can be, but are not necessarily static quantities. As such, the aiming parameters **122** can include dynamic signals or other values that can change at any time. Because the aiming parameters **122** can control other performance aspects of the mirror array display system **100**, it should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0029] The functionality of the lasers **110** can be provided by various light emitting devices including, but not limited to, lasers. The lasers **110** can emit amplified light in various wavelengths and/or frequencies, as is generally understood. The lasers **110** can be modulated and/or can be pulsed. According to various embodiments, the lasers **110** can be modulated for brightness and/or to combine various colors of laser beams into a multi-colored image of a multi-colored object. The lasers **110** can also be modulated to illuminate objects and/or to form imagery in an interaction space associated with the mirror array display system **100**.

[0030] According to various embodiments, the lasers **110** can be pulsed, switched, or optically chopped to emit, or appear to emit, bursts of light. The bursts of light from the laser **110** can be aimed at, or directed via the steering mirror or mirrors **112** to, the mirrors **118** of the mirror array **116**. In some embodiments, the steering mirror or mirrors **112** can be omitted and each mirror **118** in the mirror array **116** can have a dedicated respective laser **110**. In some embodiments, the lasers **100** themselves can be aimed. The steering mirror **112** and the mirrors **118** are described

in more detail below. In some of these embodiments, the various mirrors described herein (the steering mirror **112** and the mirrors **118**) can be sized such that an angular change during an interval when the beam is impinging on a mirror is short (and therefore reduces brightness relative to longer angular changes during the interval when the beam is impinging on the mirror). This can be accomplished by reducing the size of the mirrors **118** such that the beam impinges on the mirrors **118** for a short duration of time, relative to a duration of time during which the beam impinges on the mirrors **118** if sized larger. According to various embodiments, the lasers **110** can be pulsed or switched at rates of about a megahertz or more, thus enabling the lasers **110** to emit about one million real-image points, corresponding to convergence points, in a second.

[0031] The lasers **110** can be pulsed fast enough to light each mirror **118** in the mirror array **116** multiple times each second. The lasers **110** can be powered to overcome daylight and/or can be powered down to zero. Furthermore, the Helmholtz-Kohlrausch effect can cause saturated colors in narrow wavelengths to be perceived as up to fifty percent brighter than broad wavelengths of light such as, for example, light emitted by cathode ray tube ("CRT") displays, liquid crystal device ("LCD") displays, or the like. As such, the lasers **110** can produce bright vivid colors with little to no increase in power requirements relative to other lighting technologies. Because the lasers **110** can be configured to emit rays, embodiments of the mirror array display system **100** can be focus-free and the image field can extend almost any distance, limited only by the precision of beam aiming. Furthermore, in some embodiments, a laser, such as the laser **110**, may not draw dark portions of an image, thereby providing a potential power savings.

[0032] The steering mirrors **112** can be used to aim light emitted by a light source, for example, laser beams emitted by the lasers **110**. The aiming or steering of the light beams will be more clearly understood with reference to FIGURES **2-12** below but is briefly described here for clarity. An example of a laser beam emitted by the laser **110** is used for illustration, but should not be understood as being limiting. The laser **110** emits a laser beam toward the steering mirror **112**. In some embodiments, the steering mirror **112** can be configured to oscillate in one axis and to be rotated or oriented along another axis by the steering mirror motor **114**. The orientation of the steering mirror **112** can be precisely controlled and/or tracked by the controller **102**. Furthermore, as explained herein, the aiming parameters **122** can

include hardware controls for manipulating the steering mirror **112** via control of the steering mirror motor **114**.

[0033] The steering mirror **112** may reflect, deflect, steer, and/or otherwise aim the light toward the mirror array **116** and, more specifically, toward some, none, or each of the mirrors **118** in the mirror array **116**. According to various embodiments of the concepts and technologies disclosed herein, functionality of the steering mirror **112** and/or the mirrors **118** may be provided by metal-on-silicon resonant mirrors or microelectromechanical systems ("MEMS") mirrors. In some embodiments, the mirrors **118** may be designed to be closely packed together to reduce space between the reflective surfaces of the mirrors **118**. In some embodiments, a number of the mirrors **118** may be packaged together or disposed onto a single substrate.

[0034] In some embodiments, the mirrors **118** can be sized from about 0.5 mm square or 0.5 mm diameter round to almost any dimensions up to several centimeters. The size of the mirrors **118** can limit the mirror spacing. As such, depending upon a distance of the viewer from the mirror array **116**, the mirror size can affect the fineness of the real image, which can correspond to the pixel size in a conventional 2D display. Because image quality can be varied by varying sizes of the mirrors **118** and/or spaces between the mirrors **118**, these embodiments are illustrative. Some embodiments of the steering mirrors **112** and the mirrors **118** have a resonant scan of sixty degrees at 250 Hz and/or can be controlled in a non-resonant axis at a rate of up to 100 Hz. One commercial example of a mirror/motor that can be used to provide the functionality of the mirror **118** and the motor **120** is available from Meric Technology. Furthermore, the resonant or non-resonant motions of the mirrors **118** and/or the steering mirror **112** can be synchronized with the pulsing or modulation of the laser **110**. As such, some embodiments of the concepts and technologies disclosed herein allow images to be scanned by multiple mirrors **118** that can be synchronized to scan in unison, in time with modulation or pulsing of the laser **110**. As used herein, a "scan" refers to a process whereby light emitted by the lasers **110** is directed to each designated subset mirror **118** in the mirror array **116** that is to be illuminated to project and/or drawn an object or other imagery.

[0035] Some contemplated embodiments of the mirrors **118** includes a 2-axis (pitch and yaw) 20-mm-diameter steering mirror that swings through arcs of ∀24.0°

with a pointing accuracy of 1 milliradian (mrad), mounted in a housing that is 1.2 inches square. One example of such a mirror/motor combination is available from Meric Technology. The above embodiment of the mirrors **118** can steer a beam through an angle of 48° in less than 60 ms. For a relatively smaller 10° move, the settling time can be less than 15 ms. As such, this mirror can target about fifty points per second, in accordance with the various concepts and technologies disclosed herein. The mirror **118** can be controlled by an SPI or UART electrical interface and software command set, which can be provided by the controller **102**. The position of the mirror **118** can be optically encoded using a position sensor that provides feedback to the controller **102**. As such, the mirror **118** can be positioned with an accuracy of 1 mrad (about 0.06 degrees) and repeatedly returned to the same position with an accuracy better than 1 mrad.

[0036] The image control module **106** can be configured to process one or more instances of visual content **124** and to configure the aiming parameters **122** such that the display subsystem **108** displays light for producing an image **126** corresponding to the visual content **124** (see FIGURE **1**). The single or multiple instances of visual content **124** (e.g., one or multiple images seen by a viewer **130** can be displayed by the mirror array display system **100** in accordance with the various embodiments disclosed herein. As such, it will be more clearly understood with reference to the description herein below that the mirror array display system **100** can display a single instance of visual content **124** (an example of which is shown in FIGURE **4**) and/or can simultaneously or separately display multiple instances of visual content **124** (an example of which is shown in FIGURE **10**).

[0037] One or more instances of visual content **124** can include two dimensional ("2D") content, three-dimensional ("3D") content, animated content, video, icons, desktops, still images, text, photographs, slide shows, presentations, other content, combinations thereof, or the like. The visual content **124** can be received at the controller **102** from one or more sources (not illustrated). In some embodiments, the visual content **124** can be received from one or more sources or devices configured to transmit, stream, broadcast, multicast, output, and/or otherwise provide the visual content **124** to the controller **102**. Because the visual content **124** can include almost any kind of content, it should be understood that the above

embodiments of the visual content **124** are illustrative, and should not be construed as being limiting in any way.

[0038] Similarly, the visual content **124** can be received at the controller **102** via one or more wired and/or wireless connections to various sources. According to various embodiments, the sources include, but are not limited to, media playback devices, computer readable media (as defined herein), one or more data streams, and/or other sources. The visual content **124** can also be obtained from various signal sources including, but not limited to, satellite sources, a connection to the Internet or other network connections, cable television sources, digital or analog antenna sources, set-top boxes, other sources, combinations thereof, or the like. It should be understood that the sources can also include any combination of virtual machines and/or other resources within a cloud computing or other environment. Thus, it should be understood that the visual content **124** can be received at the controller **102** via any suitable source via any number of wireless and/or wired connections or networks.

[0039] According to various embodiments, the mirror array display system **100** can also include a tracking system **128** for tracking position, movement, identity, and/or orientation of one or more viewers or other users ("viewers") **130**. In some embodiments, the tracking system **128** can be configured to track position, movement, identity, and/or orientation of the viewer **130**. In some other embodiments, the tracking system **128** can be configured to track position, movement, and/or orientation of eyes, a face, or appendages of the viewer **130**. To provide these and other functions, the tracking system **128** can include and/or can access one or more or a combination of optical sensors, cameras, microphones or other sound sensors, radio frequency ("RF") devices, biometric sensors, pressure sensors, combinations thereof, or the like. The tracking system **128** can also use facial recognition, eye movement tracking, proximity sensing, and/or other software controls in association with various hardware to provide the functionality described herein. In some embodiments, optical sensors and/or cameras associated with the tracking system **128** can use light in visible and/or invisible spectrums to help enable tracking of bodies, eyes, and/or appendages of the viewer **130** in low-light conditions, to supplement other tracking technologies, and/or in other situations.

[0040] According to various embodiments, the tracking system **128** tracks positions, movements, identities, and/or orientations of the viewers **130** and generates

tracking data **132** corresponding to and/or indicating the tracked information. The tracking data **132** can be obtained by the controller **102**. The controller **102** uses the tracking data **132** to determine locations, orientations, and/or identities of viewers **130** and, based thereon, configures the aiming parameters **122** to direct the image **126** to the viewers **130**. Illustrative embodiments of tracking movements of viewers **130** and configuring aiming parameters based upon tracking data **132** are described in detail herein, particularly with reference to FIGURES **3-12**.

[0041] According to various embodiments, the mirror array display system **100** forms the image **126** as a real image in a space in front of a surface such as a wall to which the mirror array **116** is attached or other surface. According to various embodiments, the mirror array display system **100** forms the image **126** using laser beams directed by the steering mirror **112** and a number of the steerable mirrors **118** that can be arrayed in the surface. Some, none, or each of the mirrors **118** can be steered or orientated by various servomechanisms such as the motors **120** under the control of the controller **102** or other processor. In some arrangements, each laser beam can be aimed at the steering mirror **112**, which can direct the laser beam in rapid succession to a series of secondary mirrors, each of which in turn can scan the beam over a series of tertiary mirrors. The tertiary mirrors can be arranged in a line in such a way that the laser beam directed from the secondary mirror scans over a row of the tertiary mirrors, each of which can be individually tilted by the controller **102** to send the beam to a particular point in space to form the image **126**. In some embodiments, the line of tertiary mirrors can be a vertical column in a planar rectangular array of mirrors **118** such as the mirror array **116** illustrated in FIGURE **2**.

[0042] Because a laser beam can be thin and linear, the laser beam can act as a ray of geometrical optics. As such, the terms "beam" and "ray" are used herein interchangeably. The controller **102** can access a list of virtual-image point locations, *e.g.*, from a list stored in a memory, and can issue the aiming parameters **122** to steer or aim the mirrors **118** to direct laser beams, or pulses of the laser beams, toward each convergence point. As such, the mirror array display system **100** can create the image **126** such as a real image. A point of the image **126** can be seen at any place that is more distant from the mirror array **116** than a convergence point of the beams. The aimed beams can diverge from the convergence point and enter eyes of the viewer **130**. The viewer **130** can see a single point of light located at the convergence point

and this single point of light can correspond to a point on a surface of an object such as the image **126**.

[0043] Each point on the imaged object can emit light toward eyes of the viewer **130** from the convergence point. Each ray of light can arrive at a convergence point from different directions over a solid angle, which can correspond to different mirrors **118**. Diverging from the convergence point, the rays can mimic the light from a corresponding point on a real image corresponding to an actual object. Each point can be scanned sequentially and the viewer **130** therefore can see an entire object (real image) floating in space in front of the mirror array **116**. An example of this is shown in FIGURE **9**. In light of the above, it can be appreciated that a viewing area of a viewer **130** can be past a convergence point of light beams emitted by the mirror array display system **100**, as shown in the FIGURES. That is, the convergence point ***CP*** can lie between the mirrors **118** and the viewer **130**.

[0044] One aspect of image quality can be an angular extent of the image, which is limited to the angular extent of the array of mirrors **118** from the viewing area of the viewer **130**. Another aspect of image quality can be density of the converging rays. If the rays are not close together angularly (i.e., angularly dense), the image **126** can appear to have voids or holes between points of light. That is, if the mirrors **118** do not have a large enough area density, then the image will lack detail, especially when the viewer **130** is close to the array of mirrors **118**. In some embodiments, the mirrors **118** can be located close together to provide dense rays and in other embodiments, having sparse rays can be acceptable, for example, when the image **126** does not need to appear solid or realistic. An icon, for example, may not need to mimic a real object and therefore may not need fine detail as long as a surface of the icon is smooth enough that it has a definite shape. It should be understood that when the rays are angularly sparse, an object can still be imaged in detail by making the image larger, or, by moving the viewer **130** and/or the image **126** away from the mirror array **116**.

[0045] Thus, if for example viewers **130** are expected to approach the mirror array **116** to within about a few feet, for example about four feet, the mirrors **118** may be sized and spaced at various distances such as, for example, four millimeters, thereby providing a two-millimeter point-to-point resolution in the image **126** halfway between the viewer **130** and the mirror array **116**. The fineness of the image can be similar to that of an image on paper or a 2D display made up of 2-millimeter diameter

pixels and held two feet away. While such an embodiment may appear coarse to the viewer **130**, such an embodiment could be used for icons, large lettering, and/or other information that may not require fine detail. Similarly, a density of the mirrors **118** can be related to a pixel density, but also to voids between the mirrors **118**. If the image **126** formed with points of light visibly scattered over their surfaces are usable, then the area density of mirrors **118** on the mirror array **116** can be lower than may be required if high detail is desired. The number of rays for each point and the number of mirrors **118** for an object thus can be a function of the required image **126** fineness. The number of rays can be reduced by targeting individual viewers **130**, as discussed herein.

[0046] In an alternative embodiment, one or more of the mirrors **118** can be turned by one or more motors **120** in synchronization with sweeping and/or modulation of a laser beam so as to send plural beams to a single convergence point p_i from different portions of the mirror **118**, thus mimicking the action of a number of smaller, independently-operable mirrors **118** and increasing the amount of detail in the image **126** without decreasing the mirror size. For example, a mirror **118** can be turned so that at one time it reflects an impinging laser beam to the convergence point p_i from an upper-left corner portion of the mirror **118**, and a short time later reflects the same or a different laser beam from a different portion of the mirror **118**, to the same convergence point p_i. Thus, according to this embodiment, the area of the mirror **118** can be subdivided into portions, each portion corresponding to a pixel in a 2D display and acting independently of adjoining or other portions of the same mirror **118**, to increase the fineness and detail of the projected image **126**. Portions of the mirror **118** can target the same convergence point p_i from different angles in any sequence or pattern, or may target different points p_i, p_q in the same sequence or pattern, or, in another sequence or pattern. In one embodiment, the laser **110** may be dedicated to a specific portion (or portions) of each one of many mirrors **118**, or, one laser **110** may be dedicated to one or several adjacent mirrors **118**, and target portions in a repeating pattern. Any pattern that results in presenting a desired image **126** to the view can be used.

[0047] According to various embodiments, one or more aiming algorithms can be used to determine aiming parameters **122** and/or otherwise to control the mirror array display system **100**. According to various embodiments, if the mirror array display system **100** is used to display two different images to multiple viewers

130, an aiming algorithm can include determining positions of faces or eyes of the viewers **130**, relative to a set of coordinates fixed relative to the mirror array display system **100**. The distances can be calculated from images from cameras or by other means. The coordinates can be determined as Cartesian coordinates, for example with *x*, *y*, and *z* coordinates representing respectively each viewer's position, height from the floor, and distance from the mirror array **116**. For a first viewer **130**, each point p_i of the real image to be seen by the first viewer **130** can be determined and the controller **102** can calculate a ray passing to the center of the viewer's face through the real image point or convergence point, and where that ray intersects the mirror array **116**. The trajectory of this ray can be determined from a line equation given the position of the convergence point in *x*, *y*, and *z* coordinates, and the respective differences between the convergence point and the *x*, *y*, and *z* coordinates corresponding to the viewing area at the face of the viewer **130**, using the slope and intercept method.

[0048] In some embodiments, the controller **102** can assign an area of the mirror array **116**, for example an area surrounding the point on the mirror array **116** at which a ray drawn from a point on the face of the viewer **130** and through a real image point, corresponding to a convergence point, extends to intersect the mirror array **116**. The controller **102** can assign this area of the mirror array **116** to send rays through the convergence point and to the face of the viewer **130**. These rays can together form a solid double cone of light beams with the apex at the convergence point p_i. The controller **102** can calculate the angle of the mirrors **118** at each location within this mirror array **116** so that the laser beam scanning over the mirrors **118** will, at the instant it hits each mirror **118**, be reflected to the convergence point p_i and thence progress to the viewing area at the face of the viewer **130**. The mirror **118** can be moved to the correct orientation by the motor **120**. A laser beam flash can be aimed precisely to the convergence point p_i by timing the flash of light (i.e., by modulating the laser) such that the laser is firing at the instant the mirror **118** is at the precise angle to reflect the beam to the desired convergence point p_i, creating a point of light.

[0049] The controller **102** can repeat the process above for each point p_i, $i = 1, 2, 3 \ldots, n\text{-}1, n$ of the real image that the first viewer **130** is to see. There are various ways to arrange the scanning so that a beam can be sent through each point in the real image for the first viewer **130** within the time of persistence of vision so that the

image will appear steady. Each mirror **118** can send rays to the point p_i of the real image, but also can send rays to an adjoining point p_q of the real image because, due to the size of the face of the first viewer **130** face, rays can be sent to the point p_i from a set of adjoining mirrors **118**, and likewise rays can be sent to the point p_q from a set of adjoining mirrors **118**. The two sets of adjoining mirrors **118** can nearly overlap, so that each mirror **118** in the overlap area can send rays to both of the points p_i and p_q. The amount of overlap can decrease as the mirror array display system **100** is targeted more narrowly to a face or just the eyes of the viewer **130**. Furthermore, the amount of overlap, and the area of the mirror array **116** used to produce each point p_i,, can decrease as the tracking system **128** more accurately locates and targets the viewers eyes.

[0050] As such, a decrease in the area of the mirror array **116** used to target the viewer **130** and create a real image of the content **124** for that viewer **130** also can decrease the amount of time during which a scanning laser beam is aimed at each viewer **130**, thereby decreasing ray and angle computation, allowing more people to use the system **100**, and improving energy efficiency. In some embodiments, an optimum efficiency arrangement can correspond to an embodiment in which each mirror **118** sends exactly two rays to each point p_i, one ray directly into each eye of the first viewer **130**. In some other embodiments, a less-than-optimum efficiency arrangement can correspond to embodiments in which larger regions, relative to the optimum efficiency arrangement described above, of the viewer's face are targeted. In such embodiments, more of the mirrors **118** can be used to send rays toward the viewer **130** when creating a convergence point of the real image. The scanning beam or beams can hit every mirror **118** in the mirror array **116** that is behind an convergence point, as seen by the first viewer **130**, when forming not only a real image of a 3D object floating in space, but also a backdrop of the real image.

[0051] If the second viewer **130** is to see the same real image as the first viewer **130**, then the procedure outlined above can be augmented (or, expanded) by sending rays to each point p_i of the real image from additional areas corresponding to a cone intersecting a face or eyes of the second viewer **130**. As the first viewer **130** and the second viewer **130** move closer or farther from each other, the areas on the mirror array **116** that are sending rays through the point p_i can also move closer or farther. This can be true whether there are two real images in two image locations (each point p_i of the real image is in two places, one corresponding to one viewer's

real image and one to the other's), or only one image (there is only one point p_i of one real image, viewed by both viewers). In the latter case, the two viewers **130** can see the imaged object from different perspectives. If, however, the second viewer **130** is to see a different real image, the procedure outlined above can be recreated with different real image points p_j that have x, y, and z coordinates different from those of the first points p_i. The ray computations, the mirror angles, and the laser timing can be similar to, but independent of, the computations completed for sending the rays that create the first image **126** for the first viewer **130**. Thus, in some embodiments, the only interaction between the two images **126** can be where the active areas on the mirror array **116** overlap. In such overlap areas, the ray-sending calculations may be complicated by the fact that each mirror **118** may send rays to two different images **126**, which can involve larger changes in mirror orientation. This added complication, however, may not be different in principle from the complications resulting from rapid movements or changes to the real image **126** seen by the single viewer **130**. One scanning approach for two or more independent images **126** can be to alternate the scans, with the mirrors **118** first creating the first image **126** for the first viewer **130**, and then creating the second image **126** for the second viewer **130**. If each scan can be done in a tenth of a second or faster, then both images **126** can be stable due to the persistence of vision. Additional lasers **110** can be added to the mirror array display system **100** as needed or desired.

[0052] The mirror array display system **100** can also include other hardware **134**. The other hardware **134** can include display cases, mounts, supports, or other mounting hardware; accelerometers, magnetometers, gyroscopes, and/or other orientation sensors; proximity, infrared, temperature, sound, and/or other ambient condition sensors; processors; memory devices; combinations thereof, or the like. As such, the mirror array display system **100** can include various hardware associated with computer systems, mobile telephones, display systems, cameras, other devices, or the like. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0053] The other hardware **134** can be used in addition to, or instead of, the tracking system **128** to track movement of a viewing area. In particular, in some embodiments, an orientation sensor of a mobile device that includes a mirror array display system **100** can be used to determine a rotation angle through which the device is rotated. For example, an accelerometer, gyroscope, or other orientation

sensor can measure rotation of the device, if desired. The controller **102** can use the measured rotation to determine, using the orientation sensor, a rotation point associated with the mirror array display, an amount the device is moved, relative to the rotation point, and the rotation angle based, at least partially, upon the movement. The image **126** projected by the mirror array display system **100** can be modified, in response to the determined rotation, rotation point, and/or other aspects.

[0054] Although not illustrated in the FIGURES, various embodiments of the mirror array display system **100** can include light sensors embedded in the mirror array **116**. The light sensors can be configured to register a time at which the laser beam or other light strikes the light sensors, corresponding to scanning of a proximately located mirror **118**, and to report the time to the controller **102**. The controller **102** can use this information to synchronize pulsing of the laser **110** and/or rotation of the mirrors **118** and/or the steering mirror **112** to control performance of the mirror array display system **100**.

[0055] FIGURE **1** illustrates one controller **102**, one display subsystem **108**, and one tracking system **128**. It should be understood, however, that some implementations of the mirror array display system **100** include multiple controllers **102**, multiple display subsystems **108**, and/or multiple tracking systems **128**. Thus, the illustrated embodiments should be understood as being illustrative of some examples of the mirror array display system **100**, and should not be construed as being limiting in any way.

[0056] Turning now to FIGURE **2**, additional aspects of the mirror array display system **100** will be described in detail. FIGURE **2** is a line drawing illustrating additional aspects of the mirror array display system **100**, arranged according to at least some embodiments presented herein. In particular, FIGURE **2** illustrates a front elevation view of a mirror array **116**, according to some embodiments. The mirror array **116** includes a number of mirrors **118**, as described above with reference to FIGURE **1**. While the mirrors **118** are illustrated in FIGURE **2** as having a square profile, it should be understood that this embodiment is illustrative. In particular, various embodiments of the concepts and technologies disclosed herein make use of alternatively shaped and/or configured mirrors **118**. As such, the illustrated embodiment should be understood as being illustrative, and should not be construed as being limiting in any way. Furthermore, the mirrors **118** of the mirror array **116** can be deployed in various configurations in addition to, or

instead of, the illustrated rectangular arrangement having rows and columns. As such, the illustrated embodiment should be understood as illustrative of one example of a mirror array **116** and should not be construed as being limiting in any way.

[0057] The illustrated rectangular embodiment of the mirror array **116** includes one or more rows **200A-N** (hereinafter collectively and/or generically referred to as "rows **200**") of mirrors **118**. The mirrors **118** can also be arranged in one or more columns **202A-N** (hereinafter collectively and/or generically referred to as "columns **202**"). As shown in FIGURE **2**, the mirror array **116** can have a height ***h***, and the rows **200** can be arranged along the height ***h*** of the mirror array **116**. Similarly, the mirror array **116** can have a length ***l***, and the columns **202** can be arranged along the length ***l*** of the mirror array **116**. Although not visible in FIGURE **2**, each of the mirrors **118** can include the motor **120** or other hardware for moving and/or orienting the mirror **118** and/or a reflective surface of the mirror **118**. As explained above with reference to FIGURE **1**, the motor **120** can oscillate the mirror **118** to deflect, reflect, or otherwise aim light emitted from a light source. It should be understood that the embodiment illustrated in FIGURE **2** is illustrative, and should not be construed as being limiting in any way.

[0058] Referring now to FIGURE **3**, additional aspects of the mirror array display system **100** will be described in detail. FIGURE **3** is a line drawing illustrating additional aspects of the mirror array display system **100**, arranged according to at least some embodiments presented herein. FIGURE **3** shows a top view of the mirror array **116** shown in FIGURE **2**. As shown in FIGURE **3**, a light source **300** emits light **302**. According to some embodiments, the functionality of the light source **300** can be provided by the laser **110** and the light **302** emitted by the light source **300** can correspond to a modulated laser beam. For purposes of illustrating and describing the various embodiments disclosed herein in detail, the light source **300** is referred to herein as the laser **110** and the light **302** is referred to as light or, in some instances, as a light beam or a laser beam. Because other light sources and/or types of light or light beams can be used in accordance with the concepts and technologies disclosed herein, it should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0059] The light **302** can be directed toward and strike the steering mirror **112**. As noted above with reference to FIGURE **1**, the steering mirror **112** can be coupled to and/or include a motor such as the steering mirror motor **114** described above to

move, rotate, orient, and/or otherwise aim the light **302** emitted by the light source **300** toward the mirrors **118**. As explained above, the mirrors **118** can also be oscillated. In particular, the steering mirror motor **114** can orient a reflective surface of the steering mirror **112** to direct the light **302** toward the mirrors **118**. Thus, as shown in FIGURE **3**, reflected beams **304** corresponding to the light **302** reflected by the steering mirror **112** can be directed toward the mirrors **118**. In some embodiments, the light **302** can be modulated and the steering mirror **112** can be moved at a rate substantially equivalent to the modulation rate of the light **302**. As such, pulses of the light **302** can strike the steering mirror **112** and the steering mirror **112** can move between each pulse of the light **302** and direct beams of the light **302** toward respective ones of the mirrors **118**. The steering mirror **112** can also direct beams toward respective portions of the ones of the mirrors **118**, as mentioned above.

[0060] As such, the pulsing of the light **302** in combination with movements of the steering mirror **112** can be collectively or independently used to direct light pulses to each of the mirrors **118** in successive or randomized fashion. In one embodiment, mirrors **118** of the mirror array **116** or portions of the mirrors **118** can be lit in sequence by the modulated light **302** and the mirrors **118** can be aimed to direct the reflected beams **304** toward the viewer **130** as aimed beams **306**. The aimed beams **306** can be focused on a convergence point **308**, which can correspond to a single point *p* of the real image, as discussed above. After passing through the convergence point **308**, the aimed beams **306** can form a divergence cone ***DC*** corresponding to paths along which each of the aimed beams **306** continue. It can be appreciated from the description herein that rays diverging from the convergence point **308** can correspond to and illuminate a viewing area, which might correspond to the face, eye region, or pupils of the viewer **130**. As shown in FIGURE **3**, the viewing area can correspond to the approximate center of the eyes of the viewer **130** and the convergence point **308** can be in front of the viewing area. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0061] In one contemplated variation (not illustrated), the image **126** can appear to be located behind a mirror array **116**, rather than in front of the mirror array **116**. In particular, because the mirrors **118** can deflect a ray at an arbitrary angle, the rays can be arranged to diverge from a point behind the mirror array **116** rather than from a point in front of the mirror array **116**, although the rays still can originate at

the mirror array **116**. As such, if the image **126** is behind the mirror array **116**, then the image **126** can be a virtual image that has no convergence point, rather than a real image as described in detail herein. In some embodiments, virtual images behind the mirror array **116** can be combined with real images in front of the mirror array **116**, since mirrors **118** not used for virtual images can be used for real images and *vice versa*. Thus, embodiments of the concepts and technologies disclosed herein can be used to provide 3D images that appear to extend in depth from close to the viewer **130** out to any distance, including infinity. It follows that the display system **100** can also project images **126** confined to a plane, such as a drawing that appears to be printed on curved paper hanging in space. In particular, the display system **100** can also present a planar image that appears to coincide or nearly coincide with the mirror array **116**. Thus, the display system **100** can mimic an ordinary 2D display, and can be configured to present images indistinguishable from those presented by, for example, a conventional laptop screen. Thus, if the display system **100** is incorporated into a laptop, it can be configured to provide not only the possibility of 3D images for menu navigation, cursor control, and similar tasks, but also to present other views such as the usual typing screen with a greatly reduced energy drain. As mentioned elsewhere, by targeting a eyes of the viewer **130**, the display system **100** can show images **126** with much higher energy than can a 2D display, which radiates light in all directions, while at the same time presenting images **126** that are more colorful and brighter.

[0062] According to various embodiments of the concepts and technologies disclosed herein, movements of the steering mirrors **112** and the mirrors **118** can be minimized to reduce motion and to reduce computational demands on the controller **102** or other processor controlling movements of the steering mirrors **112** and the mirrors **118**. In some embodiments, for example, one of the columns **202** of mirrors **118** can be rotated about a vertical axis (*e.g.*, an axis that runs through the column **202** parallel to the length ***l*** illustrated in FIGURE **2**) during one scan or pass of the column **202**, thereby resulting in illumination of one vertical slice of the image **126** after another. In a subsequent scan, the mirrors **118** in the column **202** may be illuminated in a reverse direction or sequence. As such, the lasers **110** and the steering mirrors **112** and the mirrors **118** may cooperate to reduce movements of the various components of the display subsystem **108**. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0063] Due to human persistence of vision, light can appear to be substantially steady if pulsed at a rate of 15-20 Hz. In some instances, however, low repetition rates such as 5-6 Hz may result in some actual and/or perceived flicker. In some embodiments, multiple lasers **110** can be used and/or high wattage lasers **110** can be used to reduce the flicker by scanning multiple times per second at rates that exceed the rate of persistence of vision. In some embodiments, each scan can be completed within a time of persistence of vision, as described herein. The number of light beams needed for the mirror array display system **100**, within the time of persistence of vision, can be calculated as being equal to a number of points on surfaces of imaged objects in the image **126** multiplied by a steradian density of the light beams multiplied by the steradian angle of projection, *e.g.*, an angle subtended by the mirror array **116** a convergence point. A steradian point density can include a number of image **126** points in a solid angle. The above-calculated number can be reduced if there is no need to image the background as well as the objects of interest, but the number may be large relative to a number of light points in a 2D display. In some embodiments, however, the number of light points can be reduced by the controller **102** using image-recognition software to locate eyes of the viewer **130** to reduce the size of the divergence cone of rays at viewing area, and therefore reduce the area on the mirror array **116** that sends rays to the viewer **130**.

[0064] According to various embodiments, viewers **130** near the mirror array display system **100** can be located using cameras and software, distance sensors, and/or other localization devices. These and other devices, which can be included as part of the tracking system **128** described above, can be used to determine a position of viewers **130** and heads, eyes, and/or other appendages of the viewers **130**. Based upon a location of the eyes, for example, the controller **102** can determine an included angle of the ray-divergence cone from any real-image point, corresponding to a convergence point, to the eyes of the viewer **130** and also the direction of a cone axis, which can be aimed at, for example, the bridge of the nose of the viewer **130**. Thus, the controller **102** can extrapolate the convergence cone and determine what mirrors **118** of the mirror array **116** are to be illuminated to reflect, deflect, or otherwise aim light from the lasers **110** toward the real-image point, corresponding to the convergence point, to create the image **126** for the viewer **130**. In some embodiments, a circle shaped area of the mirror array **116** may not be used, rather, the area of the mirror array **116** used to aim the rays can correspond to a horizontal

ellipsoid or a rectangle to reduce the number of mirrors **118** used to project the image **126**. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0065] In some embodiments, the cone of light can be narrowed to reduce the number of rays needed for imaging, and therefore reduce the number of mirrors **118** that are used to direct laser beams. With accurate user localization (as described above and with reference to the tracking system **128** herein) that permits ray-targeting to eyes of the viewer **130**, the number of rays and the number of active mirrors **118** can be reduced further. According to some embodiments, extremely accurate localization can be used to direct a single ray of light toward an optical center of each eye of the viewer **130** (near the iris opening) and the number of rays for each point can therefore be reduced to one for each eye, with the divergence cone reduced to zero degrees. Such embodiments can limit the number of mirrors **118** used at any one time for imaging and therefore can increase the number of simultaneous users or the number of real images, or decrease the control bandwidth, for example. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0066] In some other embodiments a mobile device or tablet computer, for example, a camera and/or range detector, is used to locate positions and orientations of pupils of eyes of the viewer **130** in space. Thus, two rays can be sent through each convergence point, one ray to each eye, from the mirrors **118** in line with the pupils and the convergence point. In these embodiments, the mirror array display system **100** can produce a three-dimensional image **126** in front of the mirror array display system **100**. In some embodiments, this approach can use a number of mirrors **118** that can be two times a number of pixels used by a 2D display to create an image comparable to the image **126** created by the mirror array display system **100**. The above approaches to user targeting can be used by the controller **102** to ensure that the data rate for the mirror array display system **100** projecting 3D content can be still roughly equivalent to a data rate for a 2D display.

[0067] It can be appreciated that although each active area on the mirror array **116** (for example, each mirror **118**) can be associated with two angles as well as with a brightness and a color, the instantaneous active area (the area emitting light) can be smaller than an active area of a 2D display (the entire area of which must emit light). An additional reduction in the number of rays can be achieved in some embodiments

by having the controller **102** obtain tracking data **132** for tracking a gaze or other eye- or face-orientation information relating to the viewer **130**. The controller **102** can reduce a steradian density of laser beams coming from directions other than the direction in which the viewer **130** is looking. In some embodiments, the resolution in the center of the visual field can remain high, while peripheral areas of the visual field may lose resolution, all without affecting the image quality. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0068] Turning now to FIGURE **4**, additional aspects of the mirror array display system **100** are described in detail, according to an illustrative embodiment. FIGURE **4** is a line drawing illustrating additional aspects of the mirror array display system **100**, arranged according to at least some embodiments presented herein. As shown in FIGURE **4**, the light source **300**, the steering mirror **112**, the steering mirror motor **114**, the viewer **130**, and/or the convergence point **308** can be located on a same side, or different sides, of the mirror array **116**. With collective reference to FIGURES **3** and **4**, it can be appreciated that the viewer **130** can be located on an opposite side of the mirror array **116**, relative to the light source **300** as illustrated in FIGURE **3** or a same side as the light source **300** as illustrated in FIGURE **4**. In the embodiment illustrated in FIGURE **3**, the mirrors **118** may be less efficiently used than the mirrors **118** in the embodiment shown in FIGURE **4** because the mirrors **118** in the embodiment shown in FIGURE **4** may need to be turned sideways to the plane of the array. In this case, the mirrors **118** may be replaced with refracting elements such as transmission diffraction gratings that can precisely divert the path of a monochromatic laser beam as a function of the beam/grating angle without departing from the scope of the concepts and technologies disclosed herein. Furthermore, two gratings in series could replace one mirror **118**. Also, mirrors and diffraction gratings could be combined in one array, for example to achieve a low-profile device (fixed mirrors to deflect a scanning beam out of the plane of the device, and gratings to turn it to a desired angle, for example). As such, for purposes of the description and claims, the term "mirror" can include one or more "diffraction gratings." The mirror array **116** thus can have both mirrors and diffraction gratings, only mirrors, or only diffraction gratings.

[0069] Although not shown in the FIGURES, it further should be appreciated that the light source **300** can be located on a first side of the mirror array **116** and the

steering mirror **112** can be located on a second side of the mirror array **116**, if desired. Also, though not shown in the FIGURES, various components of the display subsystem **108** can be located on either or both sides of the mirror array **116** and/or multiple instances of these components can be included. These and other aspects of the mirror array display system **100** can be dependent upon user preferences, physical limitations, available space, and/or other considerations.

[0070] As shown in FIGURE **4**, the reflected beams **304** can be directed to the mirrors **118** by the steering mirror **112**. The mirrors **118** reflect or direct the reflected beams **304** and reflect aimed beams **306** to the convergence point **400**. As explained above, the aimed beams **306** can pass through the convergence point **400** and form a divergence cone ***DC***. As such, the light source **300** emits the light **302**, the light **302** strikes the steering mirror **112**, the steering mirror **112** redirects or otherwise aims the light **302** toward the mirror array **116** as the reflected beams **304**, and the mirror array **116** can be configured to reflect, deflect, direct, or otherwise aim the reflected beams **304** to the convergence point **400** as the aimed beams **306**. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0071] Turning now to FIGURE **5**, additional aspects of the mirror array display system **100** are described in additional detail, according to an illustrative embodiment. FIGURE **5** is a line drawing illustrating additional aspects of the mirror array display system **100**, arranged according to at least some embodiments presented herein. As shown in FIGURE **5**, a first viewing area VA_1 associated with the viewer **130** viewing the mirror array **116** at or near a first convergence point **500** can move with respect to the mirror array **116**. As such, the viewer **130** viewing the mirror array **116** can move away from a first convergence point **500** located at or near the first viewing area VA_1 and therefore may be unable to see the image **126** created by the mirror array display system **100**. According to various embodiments of the concepts and technologies disclosed herein, the mirror array display system **100** can be configured to recognize movement of the viewer **130** from a first viewing area VA_1 to a second viewing area VA_2.

[0072] In some embodiments, as explained above, the mirror array display system **100** can detect movement of the viewing areas and/or the viewer **130** by way of detecting movement of the viewer **130** and/or eyes, a body, appendages, or other entities associated with the viewer **130**. In response to detecting movement of a

viewer **130** from the first viewing area VA_1 to the second viewing area VA_2, the mirror array display system **100** can be configured to move a convergence point **500** of light **302** emitted by the mirror array display system **100** to a new convergence point **502** associated with and/or near the second viewing area VA_2.

[0073] As can be appreciated from the above description, the convergence point of the mirror array display system **100** can be moved, for example, by modifying orientations and/or positions of the steering mirror **112** and/or the mirrors **118**. Thus, in addition to receiving the tracking data **132** generated by the tracking system **128**, the controller **102** can be configured to use the tracking data **132** in conjunction with other considerations to generate the aiming parameters **122** and/or to modify aiming parameters **122** in response to detecting movement of the viewer **130**. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way. Convergence points can also be moved to change the displayed real images in response to viewer commands and/or gestures registered by the tracking system **128**.

[0074] Referring now to FIGURE **6A**, an illustrative display **600A** generated by the mirror array display system **100** is shown, according to an example embodiment. In particular, FIGURES **6A** and **6B** are line drawings illustrating illustrative displays generated by the mirror array display system, arranged according to at least some embodiments presented herein. It should be understood that the contents of the display **600A** shown in FIGURE **6A** are illustrative, and that almost any type of content can be shown. The simplified display **600A** is provided for purposes of illustrating and describing the concepts and technologies disclosed herein and should not be construed as being limiting in any way.

[0075] As shown in the display **600A**, an image containing three squares **602A**, **602B**, **602C** is shown. It can be appreciated from the description herein that the squares **602A**, **602B**, **602C** can be projected by the mirror array display system **100** by modulating the light source **300**, reflecting the modulated light **302** generated by modulating the light source **300** with a mirror such as the steering mirror **112** described above, and reflecting or directing reflected beams **304** with mirrors **118** to aim aimed beams **306** toward a convergence point such as the convergence point **308** shown in FIGURE **3**. With reference to FIGURES **3** and **6A**, it can be appreciated that the display **600A** shown in FIGURE **6A** can correspond to an example view at the convergence point **308** shown in FIGURE **3**.

[0076] Referring now to FIGURE **6B**, a display **600B** generated by the mirror array display system **100** is shown, according to another example embodiment. In the example embodiment shown in FIGURE **6B**, the viewer **130** has moved, relative to the convergence point **308**. While the mirror array display system **100** can be configured to detect such a movement (an example of which is shown in FIGURE **5** and described above with reference thereto), some embodiments of the concepts and technologies disclosed herein include not modifying the aiming parameters **122** and/or the displayed image **126** in response to movement of a viewing area and/or a viewer **130**. In such a case the real images **602A, 602B**, and **602C** of the displayed image **126** will appear to the viewer **130** as real objects that are fixed in space relative to the mirror array **116**. For example, the middle object "2" might appear larger as shown in the drawing due to perspective, as with actual objects in space.

[0077] In embodiments of the mirror array display system **100** in which the image **126** is not modified in response to movement of the viewer **130**, the image **126** displayed by the mirror array display system **100** may appear to move with the viewer **130**. As such, in some embodiments, the viewer **130** making a movement such as the movement shown in FIGURE **5** may see the display **600A** at the first viewing area VA_1 and at the second viewing area VA_2. In such a case, because the displayed image **126** moves along with the viewer **130**, the real images **602A, 602B**, and **602C** of the displayed image **126** might remain generally the same in appearance to the viewer **130.** It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0078] In other embodiments, as explained herein in detail, the mirror array display system **100** can be configured not to modify the image **126** or the convergence point in response to detecting a movement of the viewer **130**. As such, in some embodiments the viewer **130** making a movement such as the movement shown in FIGURE **5** may see the display **600A** shown in FIGURE **6A** at the first viewing area VA_1 and the display **600B** shown in FIGURE **6B** at the second viewing area VA_2. It can be appreciated with reference to FIGURE **6B** that the viewer **130** moving relative to the convergence point may see a distorted image and/or a change in size or relative size as illustrated in FIGURE **6B**. This can allow a user such as the viewer **130** to see perspective, to effectively zoom into a displayed image **126** by moving closer to it, or to experience other optical effects that may or may not be desirable.

[0079] In one contemplated example, the mirror array display system **100** is used to create only one real image **126**, one imaged object, and that object can be viewed from various angles. As such, more than one viewer **130** can see the image **126**, or one viewer **130** can move with respect to the mirror array **116** and see the image **126** from different perspectives. In this example, the image **126** corresponds to a stationary actual object (which, however, can be moved by the controller **102** or by the viewer **130** acting through the tracking system **128**). Different views of such an image **126** are illustrated in FIGURES **8**A-**8**C. These various views can result from a viewer **130** moving around a real image **802** that is fixed in space, similar to when the viewer **130** moves about a real object (as mentioned above), or, independently of any viewer motion relative to the image **802** and/or the mirror array **116**, from rotation of the image **802** in space by action of the display system **100** due to viewer commands or other reasons. In some embodiments, a single image **126** can be illuminated by all the mirrors **118** in the array **116**, or by only a few, depending on the tracking system **128**. In another contemplated example, one image **126** is provided for each of multiple viewers **130**. The images **126** may or may not be moved in accordance with movements of the viewer(s) **130**. In some embodiments, the controller **102** can split a single image **126** into two image components or sub-images (not shown), for example, if two different viewers **130** indicate, for example through the tracking system **128**, that the image **126** is to move or evolve in different ways. One example is a single image **126** that is manipulated by two different viewers **130** at the same time, and therefore evolves differently for the two viewers **130**. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0080] As shown in the example shown in FIGURE **6B**, the squares **602A**, **602B**, **602C** can be skewed with respect to the original dimensions shown in FIGURE **6A**. In light of the above description, it should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way. It will be understood that the display system **100** in principle can be capable of presenting any sorts of images to any number of people and of evolving those images in any way whatsoever, because the displayed image **126** can be based on visual content **124** that is completely arbitrary. In other embodiments, movements of the viewer **130** can be captured by the mirror array display system **100** and the image **126** can be modified to

provide the viewer **130** alternative views. An example of such embodiments is illustrated and described below with reference to FIGURES **7-8C**.

[0081] Turning now to FIGURE **7**, additional aspects of the mirror array display system **100** are described in additional detail, according to an illustrative embodiment. FIGURE **7** is a line drawing illustrating another example of using the mirror array display system, arranged according to at least some embodiments presented herein. As shown in FIGURE **7**, the viewer **130** (not shown in FIGURE **7**) can move from a first viewing area VA_1 associated with the viewer **130** viewing the mirror array **116** at a first convergence point **700** to a second viewing area VA_2. In some embodiments, the functionality of the mirror array **116** can be provided by hardware included on a handheld or other portable device and the movement shown in FIGURE **7** can be accomplished by rotating the mirror array **116** with respect to a static viewing area, the viewer, the Earth, or some other reference frame. That is, in contrast to the cases mentioned above, in which the (real) image **126** is fixed relative to the mirror array **116** (at least until moved by the mirror array display system **100**), the image **126** can be fixed relative to the Earth or relative to the viewer **130**, for example, with the controller **102** changing the aiming parameters **122** as the mirror array **116** moves, either by rotation or by translation through space, so as to keep the real image **126** immobile relative to the viewer **130**, the Earth, or some other reference frame, regardless of the motions of the mirror array **116**.

[0082] In such a mode, the viewer **130** can move the mirror array **116** in order to view different portions of an image **126** larger than what can be seen in front of the mirror array **116** (nothing will be seen outside the borders of the mirror array **116**, because rays can come only from the mirror array **116**). In other words, the mirror array **116** can effectively act in a similar manner to a window, allowing the viewer **130** to see images **126** either in front of the mirror array **116** or behind the mirror array **116**. According to various embodiments, additional portions of the image **126** can be viewed or accessed by moving the image **126** out of the viewing area, for example, moving the borders of the mirror array **116** so as to bring the next portion of the image **126** into view. As such, the mirror array display system **100** can provide an experience similar to scrolling icons on a touchscreen, except that the icons can be fixed in space while the viewing area moves, creating an effect similar to that of moving a piece of transparent glass mounted in an opaque border over images stationary on a tabletop. As such, the example provided herein with respect to a

moving viewer **130** is illustrative and should not be construed as being limiting in any way.

[0083] In response to detecting the movement of the viewer **130**, or detecting movement of a device that includes the mirror array display system **100**, the mirror array display system **100** can relocate a convergence point from near the first viewing area VA_1 to near the second viewing area VA_2. As such, a second convergence point **702** is shown in FIGURE **7**. In accordance with the various concepts and technologies disclosed herein, the image **126** shown at the first viewing area VA_1 and the second viewing area VA_2 can be identical. In other embodiments, as shown in FIGURES **8A-8C**, the image **126** can be maintained in a stationary position in an interaction space and may or may not be modified in response to detecting movement of the mirror array display system **100**, a device embodying the mirror array display system **100**, or the viewer **130** using the mirror array display system **100**.

[0084] In particular, FIGURES **8A-8C** are line drawings illustrating illustrative displays generated by the mirror array display system **100**, arranged according to at least some embodiments presented herein. The example display **800A** shown in FIGURE **8A** can correspond to a view of the image **126** at the first view area VA_1. Similarly, the display **800B** shown in FIGURE **8B** can correspond to a view of the image **126** at the second view area VA_2, and the display **800C** shown in FIGURE **8C** can correspond to a view of the image **126** at the third view area VA_3. In the embodiments illustrated in FIGURES **8A-8C**, the mirror array display system **100** can be configured to maintain the image **126** in a static position. As such, the viewer **130** can see different information and/or different aspects or angles of the image **126** at the various view areas VA_1, VA_2, VA_3. Similarly, although not shown in FIGURES **8A-8C**, the viewer **130** can "zoom" into or out of the image **126** by moving toward, or away from, the image **126**, respectively.

[0085] As explained above, the mirror array display system **100** can also be configure to modify the displayed image **126** in response to movement of the viewer **130** relative to the mirror array **118** and/or in response to movement of the mirror array **118** relative to the viewer **130**. In one contemplated embodiment, the mirror array **118** is embodied in a handheld device and movement of the handheld device, relative to eyes of the viewer **130** or other viewing area, can be detected by the controller **102** via the tracking system **128** or other mechanisms. In response to detecting the movement, the controller **102** can modify the image **126** to shift the

displayed image **126** out of a viewable space and to shift other content into the viewable space. Thus, devices with limited display space and/or space for supporting the mirror array **116** can be used to provide interactions with the image **126** as disclosed herein. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way.

[0086] The mirror array display system **100** thus can be embodied in a handheld device and manipulated relative to eyes of the viewer **130**, for example, or relative to space or the Earth, via rotation and/or translation to access alternative views of the image **126** or different portions of the image **126**. Furthermore, the concepts and technologies disclosed herein shown in this simple example can be extended to allow viewers **130** to explore complex three dimensional structures, to provide various views of information, and/or for other purposes as described herein. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0087] Turning now to FIGURE **9**, additional aspects of the mirror array display system **100** are described in additional detail, according to an illustrative embodiment. FIGURE **9** is a line drawing illustrating additional aspects of the mirror array display system, arranged according to at least some embodiments presented herein. While the functionality of the tracking system **128** has been primarily discussed herein above with reference to embodiments in which the tracking system **128** tracks movement of the viewer **130**, embodiments of the concepts and technologies disclosed herein include tracking systems **128** that additionally or alternatively track movements of viewer appendages, eyes, or other entities. An example of one embodiment for providing such a feature is illustrated and described with reference to FIGURE **9**.

[0088] As shown in FIGURE **9**, the viewer **130** is shown interacting with the mirror array display system **100**. From the perspective of the viewer **130** at a viewing area ***VA*** within a divergence cone ***DC*** and beyond a convergence point ***CP***, a real image **900** can be visible to the viewer **130**. As can be appreciated from the description herein, the convergence point ***CP*** can correspond to a single image point on the real image **900**. As such, it can be appreciated that the real image **900** can be formed by any number of convergence points ***CP***, but typically hundreds, or thousands, or more, of convergence points ***CP***, though only a single convergence point is illustrated and labeled for the sake of clarity. Furthermore, it should be

understood that all convergence points ***CP*** of the real image **900** can exist between the mirror array **116** and the viewing area ***VA***.

[0089] In the illustrated embodiment, the viewer **130** can move an arm **902** or other appendage to interact with the real image **900**. For example, the viewer **130** may move the arm **902** in a swipe motion, a grab motion, a wave motion, a push motion, a pull motion, other motions, other gestures, combinations thereof, or the like. The tracking system **128** can be configured to recognize movements of the arm **902** or other appendages of the viewer **130** and to modify the image **126** in response to detecting these and/or other movements. Thus, the viewer **130** can interact with the mirror array display system **100** to navigate a computer desktop, to navigate menus, to view information, and/or to take other actions with respect to the image **126**. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0090] According to some embodiments of the concepts and technologies disclosed herein, interactions of the viewer **130** with the real image **900** can correspond to moving or selecting 3D icons. Using various cameras, capacitance sensors, or other technologies, the controller **102** can receive tracking data **132** for determining a position of a hand or the arm **902** of the viewer **130** in relation to the real image **900**, and the controller **102** can manipulate the image **126** to reflect modifications made in response to tracked movements. In one embodiment, the controller **102** moves the real image **900** such that the arm **902** can be maintained out of "contact" with the real image **900**. Thus, the viewer **130** can "push" the real image **900** up, down, sideways, forward, and/or back to achieve various options. Hand gestures can also be used to rotate, compress or expand an image **900**.

[0091] In some embodiments, for example, the real image **900** can be enlarged if brought forward by the viewer **130**. Thus, the real image **900** can be viewed by the viewer **130** in additional detail relative to a position farther from the viewer **130**. Similarly, if the viewer **130** pushes the real image **900** away, the controller **102** may reduce detail or brightness of real image **900**. The tracking system **128** can also track rates of movement, and these rates can be used to alter input and/or output. For example, depending on a force, speed, or acceleration of the gesture, the real image **900** or other image **126** can be "thrown" to a desired location in the viewable space and/or can be thrown out of the viewable space. Similarly, opening and shutting a fist can be tracked by the tracking system **128** and interpreted by the controller **102** to

correspond, along with movement of the fists, to a command enlarge or rotate the real image **900**, among other commands such as selecting an icon (corresponding to a mouse click).

[0092] In some embodiments, the mirror array display system **100** can include speakers and/or microphones for audio input and/or output. Thus, auditory signaling can be used to enter commands. In some embodiments, for example, the viewer **130** can generate auditory commands by snapping fingers, clapping hands, speaking, or the like. These and other auditory commands can be implemented by the controller **102**. If these auditory commands and/or other movements are made in conjunction with one another, the controller **102** can implement additional and/or alternative commands. Furthermore, movements associated with some auditory commands such as clapping, snapping, or the like, can also be tracked and, if made in proximity to the real image **900**, can prompt the controller **102** to implement additional and/or alternative commands or other actions. There are many possibilities for manipulation without any physical contact and as such, the above embodiments should be understood as being illustrative of the concepts and technologies disclosed herein, and should not be construed as being limiting in any way.

[0093] Turning now to FIGURE **10**, additional aspects of the mirror array display system **100** are described in additional detail, according to an illustrative embodiment. FIGURE **10** is a line drawing illustrating additional aspects of the mirror array display system, arranged according to at least some embodiments presented herein. As shown in FIGURE **10**, two viewers **130A**, **130B** are shown as viewing the mirror array display system **100**. The controller **102** can be configured to identify the two viewers **130A**, **130B**; to determine convergence points for the two or more viewers **130A**, **130B**; and to configure the aiming parameters **122** in accordance with the determined convergence points.

[0094] In some embodiments, the tracking system **128** can be configured to associate, automatically or manually, each of the viewers **130A**, **130B** with visual content **124**. Furthermore, either, neither, or both of the users **130A**, **130B** can be registered with the tracking system **128** and/or associated with one or more instances of the visual content **124**. As such, the two or more viewers **130A**, **130B** can view the same visual content **124** and/or two or more of the viewers **130A**, **130B** can view the same or different visual content **124**.

[0095] Additionally, the tracking system **128** can be configured to independently track movements of the viewers **130A**, **130B** and/or movements of the viewers **130A**, **130B** using facial recognition technologies, motion tracking technologies, biometric technologies, cameras, pressure and/or other proximity sensors, voice recognition technologies, infrared and/or other optical technologies, combinations thereof, or the like. As such, the convergence points associated with each of the viewers **130A**, **130B** can be modified in response to movements of the viewers **130A**, **130B.** It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[0096] It can be appreciated from the description herein that the mirror array display system **100** can create the images **126** by aiming beams of light to each point of a real image (or from each point of a virtual image) from the mirrors **118** of the mirror array **116**. As such, any number of people standing in a viewable space associated with the mirror array **116** may see the same object, though from different angles. If convergence cones associated with the objects are narrowed as described above, then each person may look at a different area on the mirror array **116** and many of the mirrors **118** can be configured to send rays to one person only. As such, embodiments of the mirror array display system **100** can support showing different images **126** to different viewers **130**, who can interact with the interface independently of each other. The viewers **130** thus can be able to manipulate the objects they see, which can affect the displayed objects for that viewer **130**. Thus, one mirror array **116** can support two or more viewers **130**.

[0097] It should be noted that even with narrow convergence cones or even single rays to pupils of the viewers **130**, areas on the mirror array **116** that correspond to the various objects seen by the various different viewers **130** may not always be disjoint. In some cases, the multiple objects may overlap depending on proximities of the objects and/or the viewers **130**, as well as sizes and positions of the objects, and/or whether or not direction-of-gaze detection is used to reduce visual-field peripheral ray density. In some embodiments, images **126** displayed for two viewers **130** may be projected using one mirror **118** if the mirror **118** is able to quickly shift from displaying the image **126** for one viewer **130** to the image **126** for another viewer **130**. This can be done within the time of persistence of vision, or, the images can be allowed to degrade slightly where there is mirror overlap.

[0098] Turning now to FIGURE **11**, a flow diagram illustrating an example process **1100** for displaying content using a mirror array, arranged according to at least some embodiments presented herein, will be described. It should be understood that the operations of the processes described herein are not necessarily presented in any particular order and that performance of some or all of the operations in an alternative order(s) is possible and is contemplated. The operations have been presented in the demonstrated order for ease of description and illustration. Operations may be added, omitted, and/or performed simultaneously, without departing from the scope of the appended claims.

[0099] It also should be understood that the illustrated processes can be ended at any time and need not be performed in its entirety. Some or all operations of the processes, and/or substantially equivalent operations, can be performed by execution of computer-readable instructions included on a computer storage media, as defined herein. The term "computer-readable instructions," and variants thereof, as used in the description and claims, is used expansively herein to include routines, applications, application modules, program modules, programs, components, data structures, algorithms, or the like. Computer-readable instructions can be implemented on various system configurations, including single-processor or multiprocessor systems, minicomputers, mainframe computers, personal computers, hand-held computing devices, microprocessor-based, programmable consumer electronics, combinations thereof, or the like.

[00100] For purposes of illustrating and describing the concepts of the present disclosure, the process **1100** is described as being performed by the controller **102**. It should be understood that this embodiment is illustrative, and should not be viewed as being limiting in any way. Furthermore, as explained above with reference to FIGURE **1**, the controller **102** can execute one or more applications including, but not limited to, the aiming module **104** and/or the image control module **106** to provide the functionality described herein.

[00101] The process **1100** begins at operation **1102** (obtain content), wherein the controller **102** obtains visual content **124** from one or more sources of the visual content **124**. As explained above, the visual content **124** can include animated content, static content, and/or combinations thereof. Furthermore, the visual content **124** can be obtained from any type of device or source associated with the visual content **124**. Therefore, the controller **102** can obtain the visual content **124** via a

transmission from a source, via a broadcast to any number of devices including the controller **102**, and/or otherwise can obtain the visual content **124**. As such, operation **1102** can include downloading or receiving the visual content **124**, accessing one or more streams of data corresponding to the visual content **124**, retrieving the visual content **124** from one or more types of media, and/or otherwise obtaining the visual content **124**.

[00102] From operation **1102**, the process **1100** proceeds to operation **1104** (determine convergence point), wherein the controller **102** determines a convergence point to which the visual content **124** received in operation **1102** is to be projected. It should be understood that in some embodiments, wherein the mirror array display system **100** is used to project virtual images, operation **1104** can include determining a divergence point for the virtual images in addition to, or instead of, determining a convergence point for real images. In some embodiments, the convergence point can be based upon a known or expected viewing area of the mirror array display system **100**. For example, a viewing area, and therefore a convergence point, can be assumed to be at a particular distance, viewing angle, and/or other defined location relative to the mirror array display system **100**. As explained and illustrated above, the convergence point may or may not coincide with a viewing area. Similarly, in some embodiments the viewing area and/or the convergence point can be default settings that can be set by users, software controls, user settings, or the like. As such, operation **1104** can be skipped in some embodiments.

[00103] In other embodiments, the viewing area and/or the convergence point can be determined by the controller **102**. For example, the controller **102** can access tracking data **132** obtained by the tracking system **128** or other systems or devices to determine a location of the viewer **130**. In still other embodiments, viewers **130**, users, or other entities can set a viewing area and/or convergence point associated with the mirror array display system **100**. As such, operation **1104** can include obtaining input from users relating to viewing areas and/or convergence points. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[00104] From operation **1104**, the process **1100** proceeds to operation **1106** (determine aiming parameters), wherein the controller **102** determines aiming parameters **122** for one or more light sources **300** and one or more mirrors such as, for example, the steering mirrors **112** and/or mirrors **118** of the mirror array **116**. As

explained above, the aiming parameters **122** can include parameters for specifying a modulation rate of the light sources **300** and an oscillation, rotation, or other movement rate associated with one or more of the steering mirrors **112** and/or mirrors **118**. As such, the aiming parameters **122** can include various hardware control signals for controlling output associated with the mirror array display system **100**.

[00105] From operation **1106**, the process **1100** proceeds to operation **1108** (display image), wherein the controller **102** displays an image or images corresponding to the visual content **124** such as, for example, the image **126**. According to various embodiments, the image **126** can be displayed via scanning modulated light pulses generated by the light source **300** across some, all, or none of the mirrors **118** of the mirror array **116** and aiming the light pulses to the viewer **130** at a convergence point to effectively "draw" the image **126** at the convergence point. Other embodiments are possible and are contemplated. As such, this embodiment should be understood as being illustrative and should not be construed as being limiting in any way.

[00106] From operation **1108**, the process **1100** proceeds to operation **1110** (viewing area change?), wherein the controller **102** determines if a position, orientation, location, and/or other aspect of a viewing area has changed. For example, the operation **1110** can include obtaining, requesting, and/or receiving tracking data **132** from the tracking system **128**. Thus, while not explicitly illustrated as an operation in FIGURE **11**, the controller **102** can analyze or monitor tracking data **132** to determine if the viewing area has changed.

[00107] If the controller **102** determines, in operation **1110**, that the viewing area has not changed, the process **1100** can proceed to operation **1112** (command to modify image?), wherein the controller **102** determines if a command to modify the image **126** has been received or detected. As explained herein, the viewer **130** can interact with the image **126** by way of voice commands, hand gestures, interactions with input devices, keystrokes, and/or other mechanisms for entering a command for modifying the image **126**. As such, the operation **1112** can include monitoring various devices or systems associated with the mirror array display system **100**, requesting and/or analyzing tracking data **132** to determine if gestures or other movements for interacting with the image **126** have been received or obtained, or otherwise determining if input for modifying the image **126** has been received. A

command to modify the image may also come from the display system **100**. For example the visual content **124** might change at intervals.

[00108] If the controller **102** determines, in operation **1112**, that a command to modify the image **126** has not been received, the process **1100** can return to operation **1110**, wherein the controller **102** again determines if the viewing area has changed. As such, execution of the process **1100** by the controller **102** can, but does not necessarily, pause at or reiterate operations **1110-1112** until a viewing area change is detected by the controller **102** in operation **1110** and/or until a command to modify the image **126** is detected or received in operation **1112**.

[00109] If the controller **102** determines, in any iteration of operation **1110**, that the viewing area has changed, the process **1100** proceeds to operation **1114** (modify image?), wherein the controller **102** determines if the image **126** is to be modified in response to the viewing area change detected in operation **1110**. Similarly, the process **1100** can proceed to operation **1114** if the controller **102** determines, in any iteration of operation **1112**, that a command to modify the image **126** has been received or detected. While FIGURE **11** illustrates operations **1112** and **1114** as being executed in the alternative, it should be understood that this is not necessarily the case. Rather, in some embodiments, the controller **102** can determine that a viewing area has changed and that a command to modify the image **126** also has been received or detected. As such, the illustrated embodiment should be understood as being illustrative and should not be construed as being limiting in any way.

[00110] As explained above, the controller **102** can be configured to modify the image **126** in a number of ways. For example, the controller **102** can modify the image **126** by projecting the image **126** to a new viewing area associated with the viewer **130**. Also, the controller **102** can modify the image **126** by modifying the projected image **126** in accordance with the command to modify the image **126** received in operation **1112**. Thus, the controller **102** can modify the viewing area from which the image **126** is visible as well as, or instead of, modifying the content and/or position and/or orientation of the image **126**. Because other modifications are possible and are contemplated, as disclosed herein, it should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[00111] If the controller **102** determines, in operation **1114**, that the image **126** is to be modified, the process **1100** proceeds to operation **1116** (modify image),

wherein the controller **102** modifies the displayed image **126** to project the image **126** toward a new viewing area and/or to include additional and/or alternative information. Various embodiments of modifying the image **126** are described herein and are therefore not repeated here.

[00112] From operation **1116**, and/or from operation **1114** if the controller **102** determines in operation **1114** that the image **126** is not to be modified, the process **1100** proceeds to operation **1118** (modify convergence point). At operation **1118**, the controller **102** can modify the convergence point in accordance with the viewing area change detected in operation **1110**. Because the convergence point can be modified whether or not the image content is to be modified, it can be understood that the controller **102** can modify output of the mirror array display system **100** to project the image **126** to a new viewing area by modifying the convergence point of the image **126** while retaining the same information in the image **126**. It therefore can be appreciated that in some embodiments, the functionality described with respect to operation **1118** can be omitted, as mentioned above.

[00113] From operation **1118**, the process **1100** returns to operation **1106** (determine aiming parameters), wherein the controller **102** determines aiming parameters **122** based upon the modified convergence point and/or the modified image **126**. As explained above with regard to operation **1118**, the aiming parameters **122** can be modified to modify the image **126** or to project the same image **126** toward a new viewing area and/or associated convergence points. The process **1100** may repeat (e.g., periodically, continuously, or on-demand) or terminate at any time, as noted above.

[00114] Turning now to FIGURE **12**, a flow diagram illustrating another example process **1200** for displaying content using a mirror array, arranged according to at least some embodiments presented herein, will be described. For purposes of illustrating and describing the concepts of the present disclosure, the process **1200** is described as being performed by the controller **102**. It should be understood that this embodiment is illustrative, and should not be viewed as being limiting in any way. Furthermore, as explained above with reference to FIGURE **1**, the controller **102** can execute one or more applications including, but not limited to, the aiming module **104** and/or the image control module **106** to provide the functionality described herein.

[00115] The process **1200** begins at operation **1202** (obtain content), wherein the controller **102** obtains visual content **124** from one or more sources of the visual

content **124**. Generally speaking, the controller **102** can obtain the visual content **124** in operation **1202** in a manner substantially similar to the manner in which the visual content **124** is obtained in operation **1102** described above with reference to FIGURE **11**. In operation **1202**, however, the controller **102** can obtain multiple instances of visual content **124**, for example, a first instance of visual content **124** for the first viewer **130A** and a second instance of visual content **124** for the second viewer **130B**. Although multiple instances of visual content **124** can be obtained, the multiple instances of visual content **124** nonetheless can be identical.

[00116] From operation **1202**, the process **1200** proceeds to operation **1204** (identify viewers), wherein the controller **102** identifies one or more viewers **130**. As used herein, the term "identify" can refer to one or more of recognizing a person (or animal) as a user or potential user; recognizing a person as a particular individual; recognizing a person as a member, group, or type; or the like. As such, for example, the controller **102** can identify a person as John Smith of 123 Pantopia Way, Anytown; a woman; a young person; a person wearing a tie; or the like. With reference to the example shown in FIGURE **10**, the controller can identify the first viewer **130A** and the second viewer **130B**. It should be understood that this embodiment is illustrative, and should not be construed as being limiting in any way. According to various embodiments, the controller **102** identifies the viewers **130** based upon input received at the controller **102**, based upon analysis such as facial or ocular recognition technologies, via other input or analysis, or the like.

[00117] From operation **1204**, the process **1200** proceeds to operation **1206** (select viewer), wherein the controller **102** can select a viewer from the identified viewers **130**. The controller **102** selects the viewer **130** for purposes of determining a convergence point, an identity of the viewer **130**, visual content **124** associated with the viewer **130**, or the like. As such, it should be understood that the choice as to which viewer **130** to configure first can be random, can be based upon user preferences, based upon software settings, or the like. Similarly, some embodiments of the mirror array display system **100** can be configured to contemporaneously configure multiple viewers **130** and as such, operation **1206** can be skipped, if desired. As such, the description herein of the process **1200**, wherein the viewer **130** can be selected and configured, should be understood as being illustrative and should not be construed as being limiting in any way.

[00118] From operation **1206**, the process **1200** proceeds to operation **1208** (identify content associated with the selected viewer), wherein the controller **102** identifies, from among the visual content **124** obtained in operation **1202**, visual content **124** associated with the viewer selected in operation **1206**. This identification can be set by a user, determined by the controller **102**, for example based upon an order in which viewers **130** are detected, or the like. In other embodiments, viewers **130** manually specify visual content **124** to be associated with the viewer **130**. Regardless of how the association is made, the controller **102** can be configured to associate visual content with the viewer **130**. In some cases, a viewer such as the viewer **130**, on initially approaching the mirror array display system **100**, can be presented with introductory content and/or can be invited to search or modify the content. The introductory content may be generic or may be customized for the individual identity, type, group, or other aspect of the viewer **130** as explained above.

[00119] From operation **1208**, the process **1200** proceeds to operation **1210** (determine convergence point), wherein the controller **102** determines a convergence point to which the visual content **124** determined in operation **1208** is to be viewed by the associated viewer **130**. Again, this determination can be made automatically by the controller **102** and/or based upon user input. Furthermore, the tracking system **128** can detect a face or eyes associated with the viewer **130** and determine an orientation, position, and/or range to the viewer **130** and determine the viewing area based upon these and/or other determinations. The convergence point can be determined based, at least partially, upon the viewing area.

[00120] Although not separately shown in FIGURE **12**, the process **1200** and/or the operation **1210** can include dedicating a portion of the mirror array **116** to a viewer **130**. As such, a first portion of the mirror array **116** can be controlled by the controller **102** to provide visual content **124** to the first viewer **130** and a second portion of the mirror array **116** can be controlled by the controller **102** to provide visual content **124** to the second viewer **130**. As noted above with reference to FIGURE **11**, determination of the convergence point for each viewer **130** can be completed automatically and/or based upon input received at the controller **102**.

[00121] From operation **1210**, the process **1200** proceeds to operation **1212** (determine aiming parameters), wherein the controller **102** determines aiming parameters **122**. As explained above, the aiming parameters **122** can include hardware or software signaling or instructions for controlling one or more light

sources **300** such as the laser **110**. Additionally, or alternatively, the aiming parameters **122** can include hardware or software signaling or instructions for controlling one or more mirrors such as, for example, the steering mirror **112** and/or the mirrors **118** of the mirror array **116** via control of one or more motors such as, for example, and the steering mirror motor **114** and/or the motors **120**. It should be understood that these embodiments are illustrative, and should not be construed as being limiting in any way.

[00122] From operation **1212**, the process **1200** proceeds to operation **1214** (display image), wherein the controller **102** displays an image or images, for example the image **126**, which can correspond to visual content **124** identified in operation **1208**. From operation **1214**, the process **1200** proceeds to operation **1216** (another viewer?), wherein the controller **102** determines if another viewer **130** is to be configured. If the controller **102** determines that another viewer **130** is to be configured, the process **1200** returns to operation **1206**, wherein the controller **102** selects another viewer **130** to configure and the operations **1208-1216** can be repeated.

[00123] If the controller **102** determines, in operation **1216**, that another viewer is not to be configured, the process **1200** proceeds to operation **1218** (viewing area change?), wherein the controller **102** determines if a position, orientation, location, and/or other aspect of a viewing area associated with one or more of the viewers **130** identified in operation **1204** has changed. For example, the operation **1210** can include obtaining, requesting, and/or receiving tracking data **132** from the tracking system **128**. Thus, while not explicitly illustrated as an operation in FIGURE **12**, the controller **102** can analyze or monitor tracking data **132** to determine if the viewing area has changed.

[00124] If the controller **102** determines, in operation **1218** that the viewing area has not changed, the process **1200** can return to operation **1218**, wherein the controller **102** again determines if the viewing area associated with any of the viewers **130** identified in operation **1204** has changed. As such, execution of the process **1200** by the controller **102** can, but does not necessarily, pause at or reiterate operation **1218** until a viewing area change is detected by the controller **102**. Although not illustrated in FIGURE **12**, the controller **102** also can determine if a command to modify the image **126** has been received or detected, as explained above with regard to FIGURE 11. If the controller **102** determines, in any iteration of operation **1218**,

that a viewing area associated with the viewer **130** has changed, the process **1200** can return to operation **1210** (determine convergence point), wherein the controller **102** determines a convergence point based upon a changed viewing area. Although not shown in FIGURE **12**, if the controller **102** determines, in any iteration of operation **1218** or another operation, that a command to modify the image **126** has been received or detected, the process **1200** can return to operation **1212** (determine aiming parameters), wherein the controller **102** can determine aiming parameters **122** for the modified image **126**. The process **1200** may repeat (*e.g.*, periodically, continuously, or on-demand) or terminate at any time, as noted above.

[00125] As described herein, the mirror array display system **100** can provide a 3D display. A 3D display can be used, in some embodiments, to allow the viewers **130** to interact in free space with floating signs, icons, menus, and/or other information and/or objects. As such, embodiments of the concepts and technologies disclosed herein can be used to enable rich interactions with these and other objects and/or can reduce chances that multiple viewers will crowd each other. In some embodiments, viewers **130** can move icons in space and place them in new positions corresponding to new classifications, deletions, selections, or other actions.

[00126] As such, icons, rather than being on a flat surface of a screen display, can be located in free space, located on a 3D rotatable cylindrical surface in free space, or located on other entities in free space. Similarly, the icons can also be rotatable and thus may have multiple actions or associations accessible by rotating the icons. The viewers **130** may designate icons by gestures, finger snaps, or voice commands. Menu trees in three-dimensions may include more branches than 2D counterparts and may be easy to navigate. Similarly, menu trees also may be configured to rotate about one axis or more than one axis. Objects of interest to a viewer **130** can be drawn as being "located" closer to the viewer **130** to allow the viewer **130** to see and/or manipulate the object while objects not of interest to the viewer **130** can be pushed aside, away, or out of a displayable space. An object may be expanded or compressed by hand gestures to show more or less detail. The virtual mass and friction of laterally-moving touch-screen icons can also be incorporated into the icons.

[00127] In another embodiment, the mirror array display system **100** can be used to visualize 3D objects, because the convergence points CP of a real image are not opaque, as are the points on a corresponding real image; that is, the viewer **130**

can see each image point but can also see what is behind it. Just as a sphere made of Christmas tree lights is largely transparent, so the real images made by the display system **100** can be transparent. The display system **100** might project for example, a series of parallel plane images, one behind the other, and the viewer **130** would be able to see all of them. More complicated real objects can also be projected. For example, an engine such as an automobile engine can be explored using the mirror array display system **100**. With the mirror array display system **100**, the viewer **130** can command that the real-image engine rotate in space, have its parts move as when running, and so on. The viewer **130** might also be able to indicate a cut or slice of the engine to view separately. Any manipulation of the image is possible. With a 2D display, cross sections and perspective cutaway views are possible, but these are once removed from the real geometry. A transparent 3D engine may be easier for a viewer to understand than a series of 2D pictures. These and other interactions with 3D objects all can occur without using any sort of special gear. Thus, the mirror array display system **100** can be used for public displays, large or small.

[00128] As such, embodiments of the mirror array display system **100** can be used to provide an interactive, immersive, 3D display to viewers **130** without glasses, headgear, or other special gear. Thus, embodiments of the concepts and technologies disclosed herein can be located in airports, malls, and other places where people arrive without 3D gear. Additionally, as shown above in FIGURE **10**, embodiments of the mirror array display system **100** may be used by a group of viewers **130** at a particular time. Because the viewers **130** may have varied interests, and as such may want to view varied types of content, the mirror array display system **100** can support multiple independent viewers **130**.

[00129] Embodiments of the concepts and technologies disclosed herein can be used to realize various benefits over existing display systems. For example, embodiments of the concepts and technologies disclosed herein can allow the display of more information than traditional displays because there can be more room for images and icons, relative to other display systems. Embodiments of the concepts and technologies disclosed herein also can allow use of more gestures than may be possible with other input devices. Embodiments of the mirror array display system **100** can be focus free, can have a long depth of view, and can operate in low light and/or bright light conditions by varying output power of the **110**. Various embodiments can be used to provide 3D icons and menus that do not require high

image quality and/or high image quality with good resolution, or, the mirrors **118** can be made small enough and close enough to provide high resolution images, or various portions of larger mirrors **118** can be individually used as discussed above to provide high resolution.

[00130] Various embodiments can also provide high energy efficiency. While light from traditional displays may emanate indiscriminately and may be almost entirely wasted since only a tiny fraction enters pupils of the viewers **130**, embodiments of the concepts and technologies disclosed herein can target the light directly at pupils of the viewer **130**, thereby reducing or even eliminating wasted energy. Thus, embodiments of the mirror array display system **100** can be incorporated in battery-powered devices. Embodiments of the concepts and technologies disclosed herein can also be used to improve and/or simplify cameras, which may often use traditional viewfinders and shutter mirrors since use of the concepts and technologies disclosed herein may result in saving energy that may be drained by 2D displays displaying similar or comparable imagery. Embodiments of the concepts and technologies disclosed herein can also be used to improve image quality, relative to other display technologies, due to the high brightness and the Helmholtz-Kohlrausch effect mentioned above, which can be used to provide rich colors from three highly monochromatic lasers. Similarly, the mirror array **116** can be shaped or configured in any shape and need not be planar. As such, embodiments of the mirror array **116** can be curved, *e.g.*, around a room or a curved wall. Thus, a viewer **130** can be surrounded by images **126** that move along with the viewer **130**, thereby providing a sense of immersion.

[00131] In some embodiments, the functionality of the mirrors **118** can be provided by mirrors that can be oriented and/or driven according to electrical driving signals. These mirrors **118** can be similar, in some embodiments, to some mirrors that may be used in various projection systems. For example, some projection systems can reflect laser beams off of a mirror, wherein the laser beam the instantaneous position of the mirror can be coordinated to project the desired image onto a surface for viewing. Three differently-colored lasers also can be used concurrently to project a full-color image. Thus, some embodiments of the concepts and technologies disclosed herein can include an array of projector systems that are used in accordance with various calculations for determining coordinates of the points of a desired three-dimensional real image from the position of the projector systems. This appearance,

when suitably encoded in instructions, can be used as the driving signal for the projector system and as such, can correspond to the aiming parameters **122** disclosed herein.

[00132] Furthermore, while the various embodiments of the concepts and technologies disclosed herein have been described as including shining a laser beam into eyes of a viewer **130**, albeit for brief intervals of time, it should be understood that such embodiments are generally not believed to be harmful to viewers. In particular, various embodiments use a laser **110** with a low duty ratio. Thus, the brief flashes of the laser beam can be safe for the viewer **130**. Furthermore, while the various images **126** projected by the mirror array display system **100** may be transparent, the mirror array **116** behind the image **126** can be featureless and therefore generally will not distract the viewer **130**. The mirrors **118** can, in their resting position, show the viewer **130** a portion of a bland surface, such as a black or gray surface.

[00133] FIGURE **13** is a block diagram illustrating an example computer **1300** capable of displaying content using a mirror array display system arranged according to at least some embodiments presented herein. As depicted, the computer **1300** includes a processor **1310**, a memory **1320** and one or more drives **1330**. The computer **1300** may be implemented as a conventional computer system, an embedded control computer, a laptop, or a server computer, a mobile device, an STB, a kiosk, a vehicular information system, a mobile telephone, a customized machine, or other hardware platform.

[00134] The drives **1330** and their associated computer storage media, provide storage of computer readable instructions, data structures, program modules and other data for the computer **1300**. The drives **1330** can include an operating system **1340**, application programs **1350**, program modules **1360**, and a database **1380**. The program modules **1360** may include a controller, such as the controller **102**. The controller **102** may be adapted to execute either or both of the processes **1100** and/or **1200** for displaying content using a mirror array as described in greater detail above (*e.g.*, see previous description with respect to one or more of FIGURES **1** - **12**). The computer **1300** further includes user input devices **1390** through which a user may enter commands and data. The input devices **1390** can include one or more of an electronic digitizer, a microphone, a keyboard and pointing device, commonly referred to as a mouse, trackball or touch pad. Other input devices may include a

joystick, game pad, satellite dish, scanner, other devices, or the like. In some embodiments, the other input devices include the mirror array display system **100**, as users can input data or choices by manipulating real images produced by the mirror array **116** as described above.

[00135] These and other input devices can be coupled to the processor **1310** through a user input interface that is coupled to a system bus, but may be coupled by other interface and bus structures, such as a parallel port, game port or a universal serial bus ("USB"). Computers such as the computer **1300** also may include other peripheral output devices such as speakers, printers, displays, mirror array display systems **100**, and/or other devices, which may be coupled through an output peripheral interface **1394** or the like. In some embodiments, the peripheral interface **1394** can include the mirror array display system **100**.

[00136] The computer **1300** may operate in a networked environment using logical connections to one or more computers, such as a remote computer (not illustrated), a mirror array display system **100**, and/or other devices operating as part of or in communication with a network **1308** coupled to a network interface **1396**. The remote computer may be a personal computer, a server, a router, a network PC, a peer device or other common network node, and can include many or all of the elements described above relative to the computer **1300**. Networking environments are commonplace in offices, enterprise-wide area networks ("WAN"), local area networks ("LAN"), intranets, and the Internet.

[00137] When used in a LAN or WLAN networking environment, the computer **1300** may be coupled to the LAN through the network interface **1396** or an adapter. When used in a WAN networking environment, the computer **1300** typically includes a modem or other means for establishing communications over the WAN, such as the Internet or the network **1308**. The WAN may include the Internet, the illustrated network **1308**, various other networks, or any combination thereof. It will be appreciated that other mechanisms of establishing a communications link, ring, mesh, bus, cloud, or network between the computers may be used.

[00138] According to some embodiments, the computer **1300** may be coupled to a networking environment. The computer **1300** may include one or more instances of a physical computer-readable storage medium or media associated with the drives **1330** or other storage devices. The system bus may enable the processor **1310** to read code and/or data to/from the computer storage media. The media may represent an

apparatus in the form of storage elements that are implemented using any suitable technology, including but not limited to semiconductors, magnetic materials, optical media, electrical storage, electrochemical storage, or any other such storage technology. The media may represent components associated with memory **1320**, whether characterized as RAM, ROM, flash, or other types of volatile or nonvolatile memory technology. The media may also represent secondary storage, whether implemented as the storage drives **1330** or otherwise. Hard drive implementations may be characterized as solid state, or may include rotating media storing magnetically-encoded information.

[00139] The storage media may include one or more program modules **1360**. The program modules **1360** may include software instructions that, when loaded into the processor **1310** and executed, transform a general-purpose computing system into a special-purpose computing system. As detailed throughout this description, the program modules **1360** may provide various tools or techniques by which the computer **1300** may participate within the overall systems or operating environments using the components, logic flows, and/or data structures discussed herein.

[00140] The processor **1310** may be constructed from any number of transistors or other circuit elements, which may individually or collectively assume any number of states. More specifically, the processor **1310** may operate as a state machine or finite-state machine. Such a machine may be transformed to a second machine, or specific machine by loading executable instructions contained within the program modules **1360**. These computer-executable instructions may transform the processor **1310** by specifying how the processor **1310** transitions between states, thereby transforming the transistors or other circuit elements constituting the processor **1310** from a first machine to a second machine. The states of either machine may also be transformed by receiving input from the one or more user input devices **1390**, the network interface **1396**, other peripherals, other interfaces, or one or more users or other actors. Either machine may also transform states, or various physical characteristics of various output devices such as printers, speakers, video displays, or otherwise.

[00141] Encoding the program modules **1360** may also transform the physical structure of the storage media. The specific transformation of physical structure may depend on various factors, in different implementations of this description. Examples of such factors may include, but are not limited to: the technology used to implement

the storage media, whether the storage media are characterized as primary or secondary storage, or the like. For example, if the storage media are implemented as semiconductor-based memory, the program modules **1360** may transform the physical state of the semiconductor memory **1320** when the software is encoded therein. For example, the software may transform the state of transistors, capacitors, or other discrete circuit elements constituting the semiconductor memory **1320**.

[00142] As another example, the storage media may be implemented using magnetic or optical technology such as drives **1330**. In such implementations, the program modules **1360** may transform the physical state of magnetic or optical media, when the software is encoded therein. These transformations may include altering the magnetic characteristics of particular locations within given magnetic media. These transformations may also include altering the physical features or characteristics of particular locations within given optical media, to change the optical characteristics of those locations. It should be appreciated that various other transformations of physical media are possible without departing from the scope and spirit of the present description. As used in the claims, the phrase "computer storage medium," and variations thereof, does not include waves, signals, and/or other transitory and/or intangible communication media, *per se*.

[00143] FIGURE **14** is a schematic diagram illustrating computer program products **1400** for displaying visual content using a mirror array display system arranged according to at least some embodiments presented herein. An illustrative embodiment of the example computer program product **1400** is provided using a signal bearing medium **1402**, and may include at least one instruction **1404**. The at least one instruction **1404** may include: one or more instructions for obtaining content for display at a mirror array display comprising a mirror array having a plurality of mirrors and a light source; one or more instructions for determining at least one aiming parameter for at least one of the plurality of mirrors and a modulation rate of light emitted by the light source; one or more instructions for emitting light, using the light source; or one or more instructions for aiming the light emitted by the light source to a convergence point to generate a three-dimensional representation of the content, wherein the light is aimed by moving the at least one of the plurality of mirrors in accordance with the at least one aiming parameter and emitting the light in accordance with the modulation rate. In some embodiments, the signal bearing medium **1402** of the one or more computer program products **1400** include a

computer readable medium **1406**, a recordable medium **1408**, and/or a communications medium **1410**.

[00144] While the subject matter described herein is presented in the general context of program modules that execute in conjunction with the execution of an operating system and application programs on a computer system, those skilled in the art will recognize that other implementations may be performed in combination with other types of program modules. Generally, program modules include routines, programs, components, data structures, and other types of structures that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the subject matter described herein may be practiced with other computer system configurations, including hand-held devices, multi-core processor systems, microprocessor-based or programmable consumer electronics, minicomputers, mainframe computers, or the like.

[00145] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, compounds, or compositions, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[00146] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[00147] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (*e.g.*, bodies of the appended claims) are generally intended as "open" terms (*e.g.*, the term "including" should be interpreted as

"including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (*e.g.*, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (*e.g.*, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[00148] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[00149] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," "greater than," "less than," or the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 elements refers to groups having 1, 2, or 3 elements. Similarly, a group having 1-5 elements refers to groups having 1, 2, 3, 4, or 5 elements, and so forth.

[00150] While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

I Claim:

1. A computer-implemented method for displaying content using a mirror array display comprising a controller, a mirror array having a plurality of mirrors, and a light source, the computer-implemented method comprising computer-implemented operations for:

obtaining, by the controller, the content;

determining, by the controller, at least one aiming parameter associated with the plurality of mirrors and the light source;

emitting light, using the light source; and

aiming the light emitted by the light source to a convergence point to generate a three-dimensional representation of the content, wherein the light is aimed in accordance with the at least one aiming parameter.

2. The method of claim 1, wherein the convergence point comprises a first convergence point and a second convergence point, and wherein the content comprises a first content component visible at the first convergence point and a second content component visible at the second convergence point.

3. The method of claim 2, further comprising:

determining, using a tracking system associated with the mirror array display, a first location, relative to the mirror array display, of a first viewer;

determining, using the tracking system, a second location, relative to the mirror array display, of a second viewer;

determining the first convergence point based, at least partially, upon the first location; and

determining the second convergence point based, at least partially, upon the second location.

4. The method of claim 3, wherein aiming the light comprises aiming a first portion of the light emitted by the light source to the first convergence point and aiming a second portion of the light emitted by the light source to the second convergence point.

5. The method of claim 1, wherein determining the aiming parameter comprises executing an aiming algorithm at the controller based, at least partially, upon the convergence point.

6. The method of claim 5, wherein determining the aiming parameter comprises determining, using the aiming algorithm, a modulation rate for the light source and a rotation angle, relative to the light source, of at least one of the plurality of mirrors.

7. The method of claim 5, wherein the light source comprises a laser and wherein determining the aiming parameter comprises determining, using the aiming algorithm, a modulation rate of a laser beam emitted by the laser and a rotation angle, relative to the light source, of at least one of the plurality of mirrors.

8. The method of claim 7, wherein the mirror array display further comprises a secondary mirror for aiming the laser beam emitted by the laser, and wherein determining the aiming parameter further comprises determining the rotation angle, relative to the light source, of the secondary mirror.

9. The method of claim 1, further comprising:

determining, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewer; and

determining the convergence point based, at least partially, upon the location of the viewer.

10. The method of claim 9, further comprising:

determining that the viewer has moved relative to the convergence point;

in response to determining that the viewer has moved, determining at least one modified aiming parameter and a modified convergence point; and

aiming the light emitted by the light source to the modified convergence point, wherein the light is aimed in accordance with the at least one modified aiming parameter.

11. The method of claim 1, further comprising:

determining, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewing area;

determining the convergence point based, at least partially, upon the location of the viewing area;

determining that the viewing area has moved relative to the convergence point;

in response to determining that the viewing area has moved

determining a rotation angle, relative to a rotation axis associated with the mirror array display, of a movement of the viewing area,

modifying the content in accordance with the rotation angle to obtain modified content,

determining a modified convergence point, in accordance with the rotation angle, and

aiming the light emitted by the light source to the modified convergence point.

12. The method of claim 1, further comprising detecting, with a tracking system in communication with the controller, a movement of a user corresponding to an interaction with the three-dimensional representation.

13. The method of claim 12, further comprising modifying the content in response to the interaction.

14. A computer readable medium comprising computer executable instructions that, when executed by a computer, cause the computer to:

obtain content for display at a mirror array display comprising a mirror array having a plurality of mirrors and a light source;

determine at least one aiming parameter for at least one of the plurality of mirrors and a modulation rate of light emitted by the light source;

emit light, using the light source; and

aim the light emitted by the light source to a convergence point to generate a three-dimensional representation of the content, wherein the light is aimed by moving

the at least one of the plurality of mirrors in accordance with the at least one aiming parameter and emitting the light in accordance with the modulation rate.

15. The computer readable medium of claim 14, further comprising computer executable instructions that, when executed by the computer, cause the computer to:

determine, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewing area associated with a viewer; and

determine the convergence point based, at least partially, upon the location of the viewing area.

16. The computer readable medium of claim 15, further comprising computer executable instructions that, when executed by the computer, cause the computer to:

determine that the viewer has moved relative to the convergence point;

when a determination is made that the viewer has moved, determine at least one modified aiming parameter and a modified convergence point; and

aim the light emitted by the light source to the modified convergence point, wherein the light is aimed in accordance with the at least one modified aiming parameter.

17. The computer readable medium of claim 15, further comprising computer executable instructions that, when executed by the computer, cause the computer to:

determine that the viewing area has moved relative to the convergence point;

when a determination is made that the viewing area has moved,

determine a rotation angle, relative to a rotation axis associated with the mirror array display, of a movement of the viewing area,

modify the content in accordance with the rotation angle to obtain modified content,

determine a modified convergence point, in accordance with the rotation angle, and

aim the light emitted by the light source to the modified convergence point.

18. The computer readable medium of claim 17, wherein to determine the rotation angle, the computer executable instructions, when executed by the computer, further cause the computer to:

determine a rotation point associated with the mirror array display;

track movement, using the tracking system, of the viewing area relative to the rotation point; and

calculate the rotation angle based, at least partially, the movement.

19. The computer readable medium of claim 17, wherein the tracking system comprises an image capture device for tracking movement of the viewer.

20. The computer readable medium of claim 17, wherein the tracking system comprises an orientation sensor of a device, and wherein to determine the rotation angle, the computer executable instructions, when executed by the computer, further cause the computer to determine, using the orientation sensor

a rotation point associated with the mirror array display,

an amount the device is moved, relative to the rotation point, and

the rotation angle based, at least partially, upon the movement.

21. The computer readable medium of claim 14, further comprising computer executable instructions that, when executed by the computer, cause the computer to:

detect, via receiving tracking data generated by a tracking system in communication with the computer, a movement of a user corresponding to an interaction with the three-dimensional representation; and

modify the content in response to the interaction.

22. A mirror array display for generating a three-dimensional representation of content, the mirror array display comprising:

a mirror array having a plurality of mirrors;

a light source configured to emit light for projection by the plurality of mirrors; and

a controller configured to execute computer executable instructions to

determine at least one aiming parameter for at least one of the plurality of mirrors,

determine a modulation rate of light emitted by the light source,

control the light source to emit light in accordance with the modulation rate, and

control an orientation of at least one of the plurality mirrors to project the light toward a convergence point, wherein the controller controls the orientation of the at least one of the plurality of mirrors in accordance with the at least one aiming parameter.

23. The mirror array display of claim 22, further comprising a secondary mirror configured to direct light emitted by the light source toward at least one of the plurality of mirrors, wherein the controller is further configured to control an orientation of the secondary mirror, and wherein the light source comprises a laser.

24. The mirror array display of claim 23, wherein the controller is further configured to execute computer executable instructions to:

determine, using a tracking system associated with the mirror array display, a location, relative to the mirror array display, of a viewing area associated with a viewer; and

determine the convergence point based, at least partially, upon the location of the viewing area.

25. The mirror array display of claim 24, wherein the controller is further configured to execute computer executable instructions to:

determine that the viewer has moved relative to the convergence point;

when a determination is made that the viewer has moved, determine at least one modified aiming parameter and a modified convergence point; and

aim the light emitted by the light source to the modified convergence point, wherein the light is aimed in accordance with the at least one modified aiming parameter.

26. The mirror array display of claim 24, wherein the controller is further configured to execute computer executable instructions to:

determine that the viewing area has moved relative to the convergence point;

when a determination is made that the viewing area has moved,

determine a rotation angle, relative to a rotation axis associated with the mirror array display, of a movement of the viewing area,

modify the content in accordance with the rotation angle to obtain modified content,

determine a modified convergence point, in accordance with the rotation angle, and

aim the light emitted by the light source to the modified convergence point.

27. The mirror array display of claim 22, wherein the mirror array has a first side and a second side, and wherein the light source is located at the first side and the convergence point is located at the second side.

28. The mirror array display of claim 22, wherein the mirror array has a first side and a second side, and wherein the light source and the convergence point are located at the first side of the mirror array.

29. The mirror array display of claim 22, wherein the controller is further configured to execute computer executable instructions to:

detect, via receiving tracking data generated by a tracking system in communication with the controller, a movement of a user corresponding to an interaction with the three-dimensional representation; and

modify the content in response to the interaction.

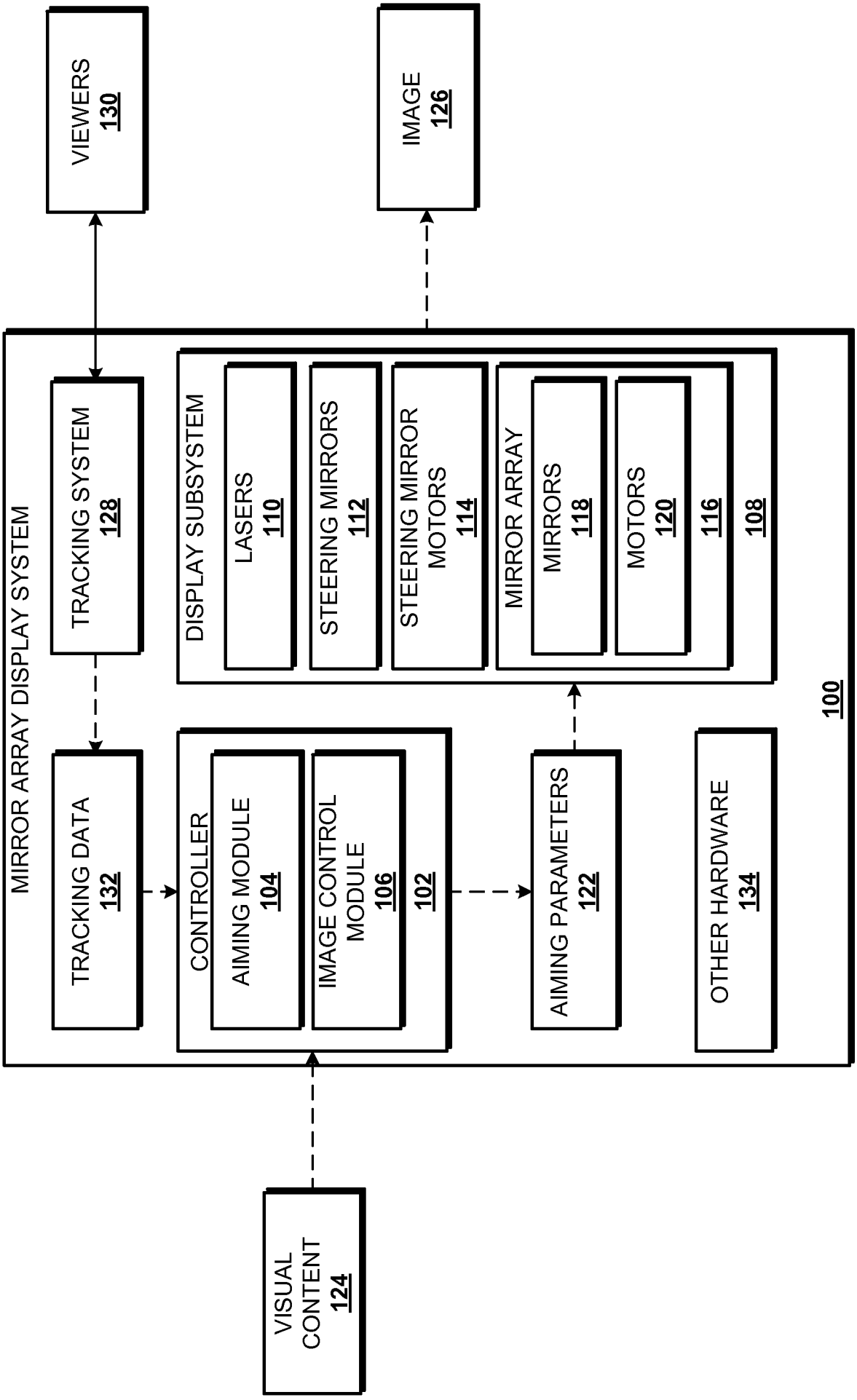

VIEWERS
130
IMAGE
126
MIRROR ARRAY DISPLAY SYSTEM
TRACKING SYSTEM
128
DISPLAY SUBSYSTEM
LASERS
110
STEERING MIRRORS
112
STEERING MIRROR MOTORS
114
MIRROR ARRAY
MIRRORS
118
MOTORS
120
116
108
TRACKING DATA
132
CONTROLLER
AIMING MODULE
104
IMAGE CONTROL MODULE
106
102
AIMING PARAMETERS
122
OTHER HARDWARE
134
100
VISUAL CONTENT
124

FIGURE 1

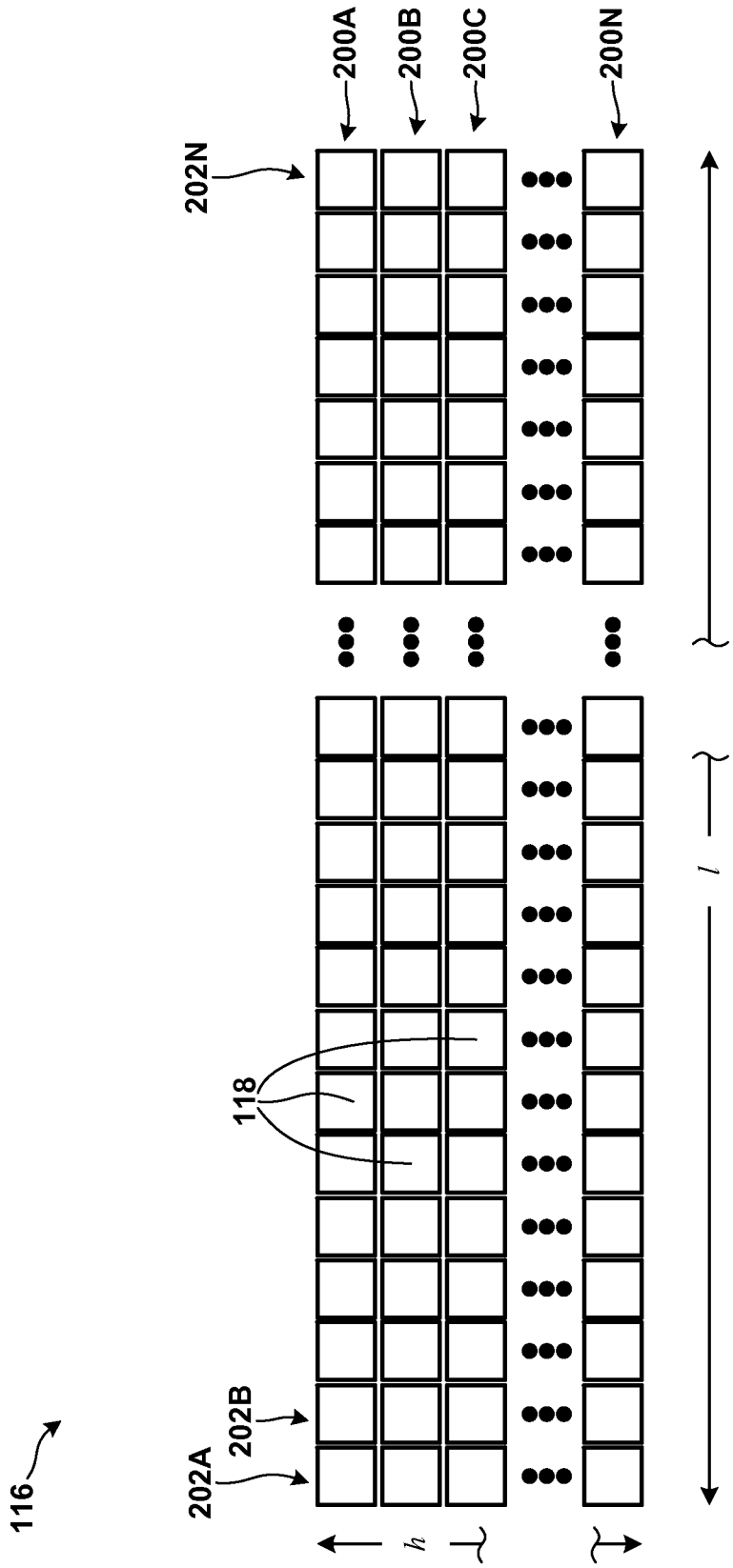


FIGURE 2

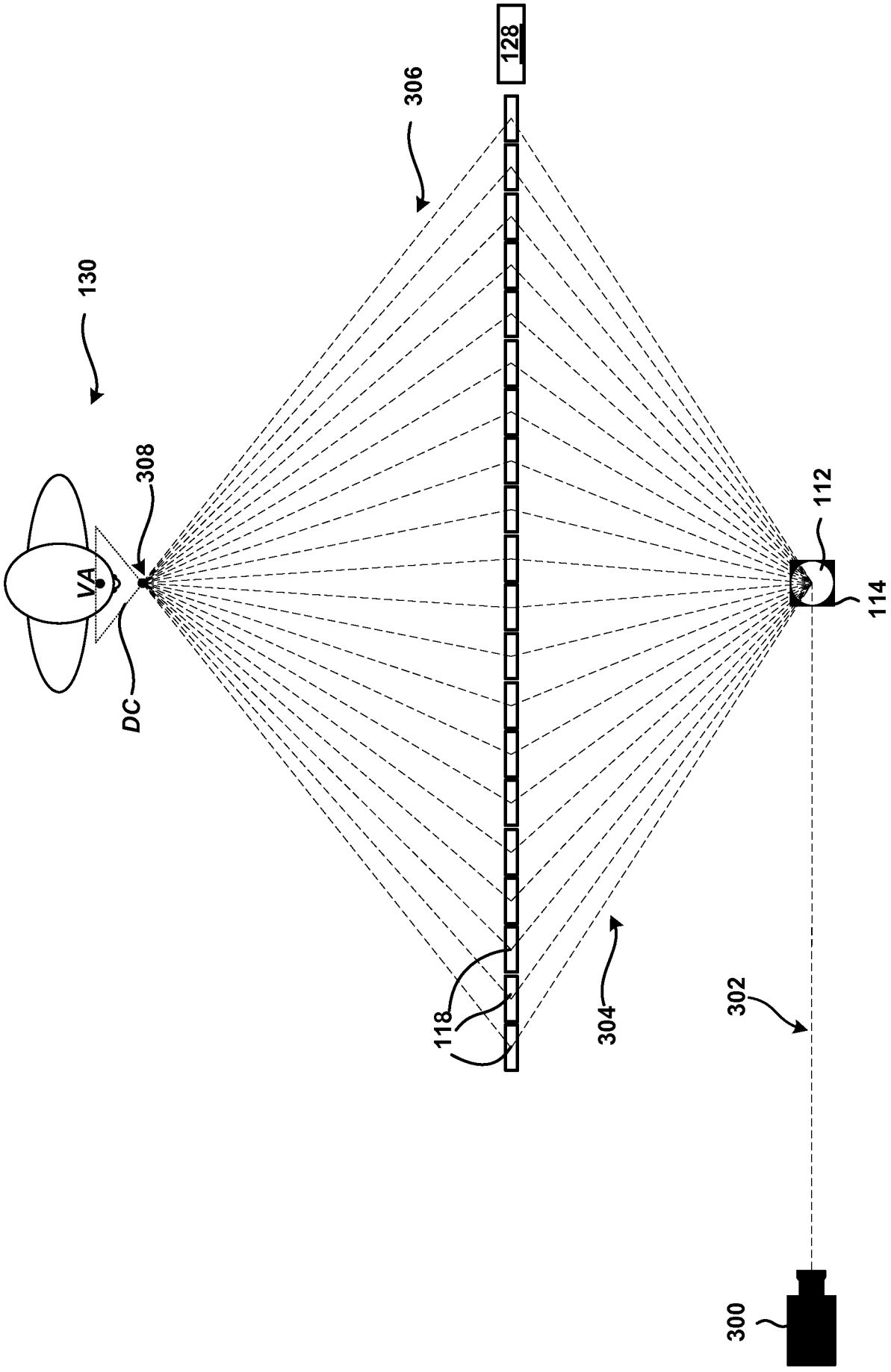


FIGURE 3

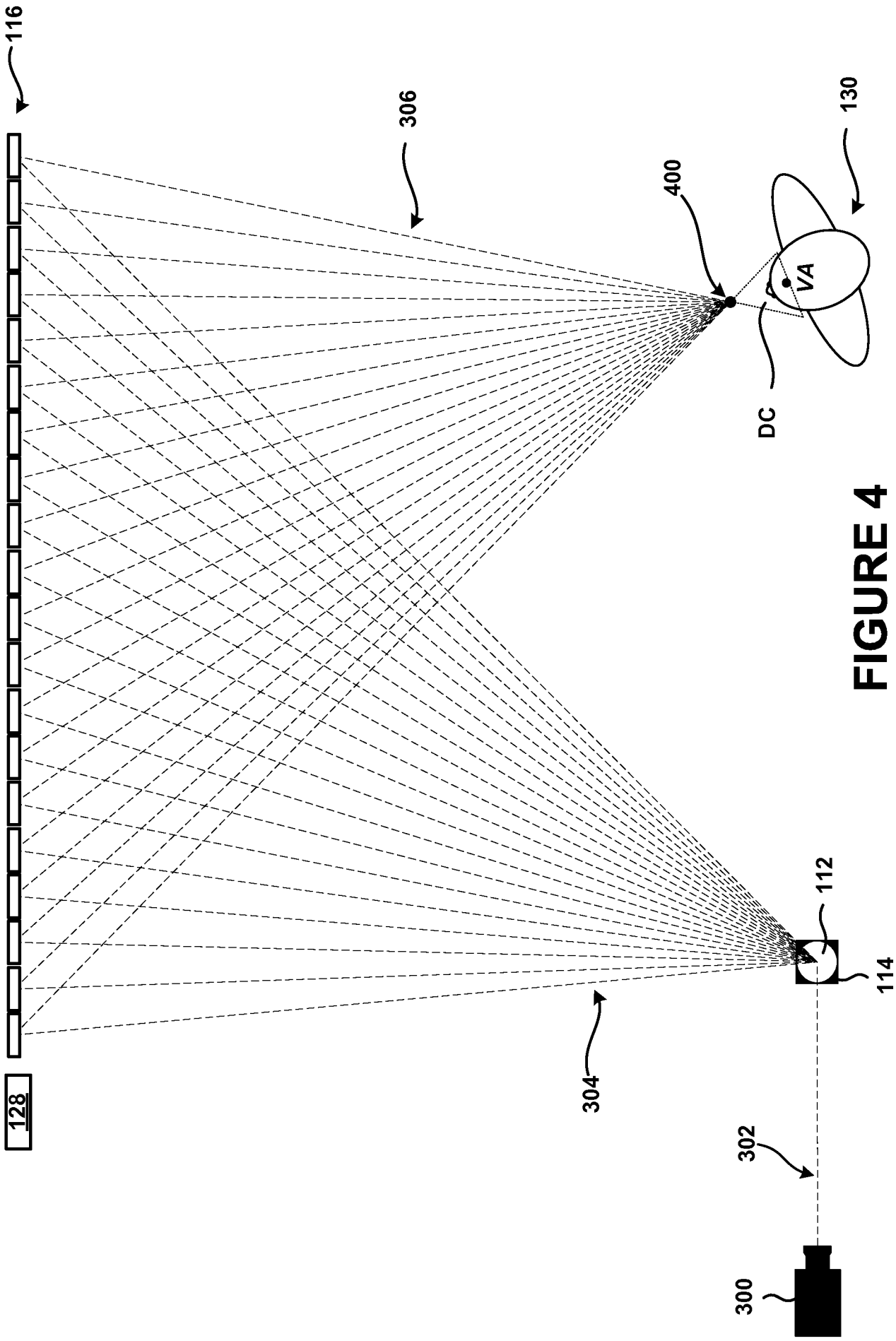


FIGURE 4

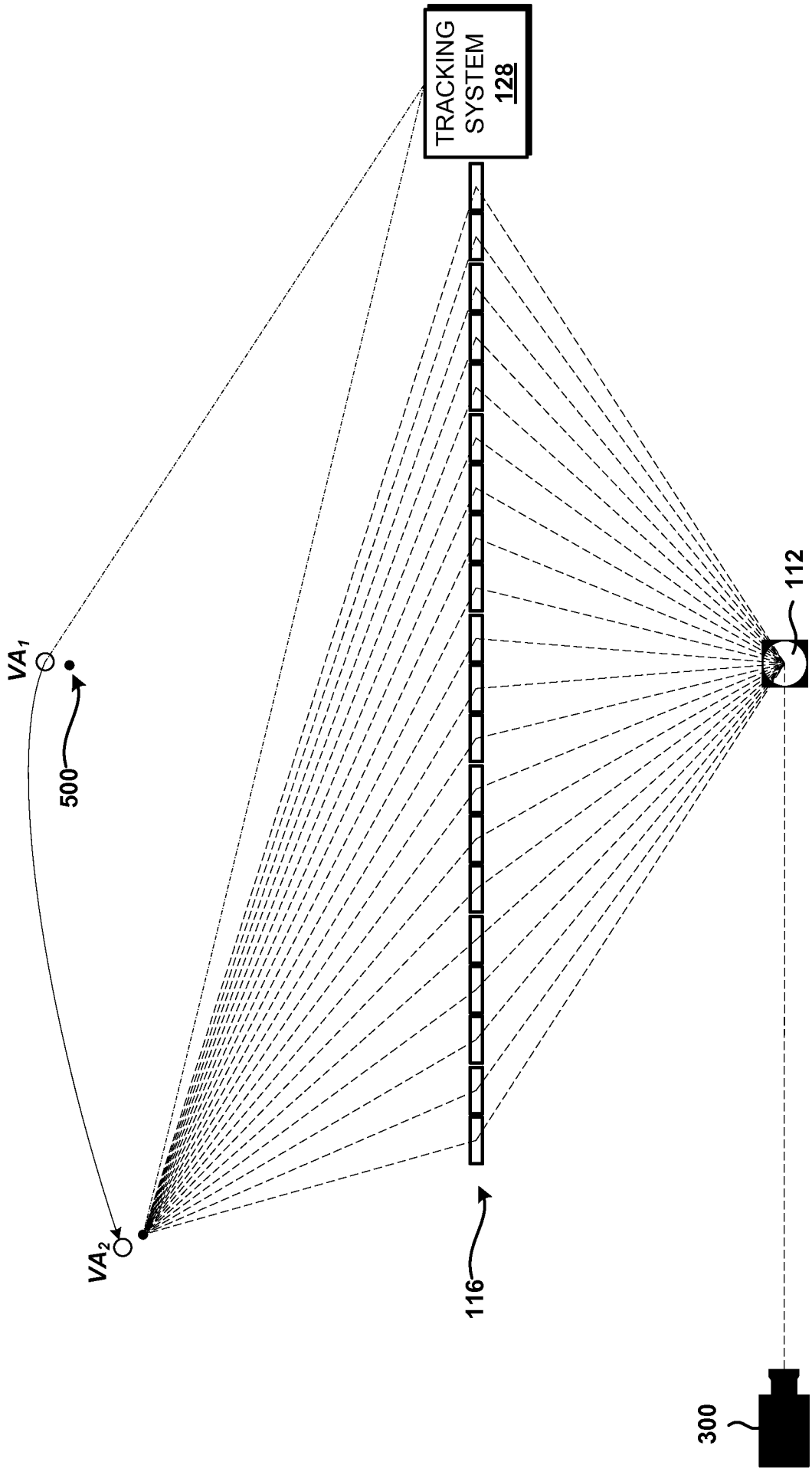


FIGURE 5

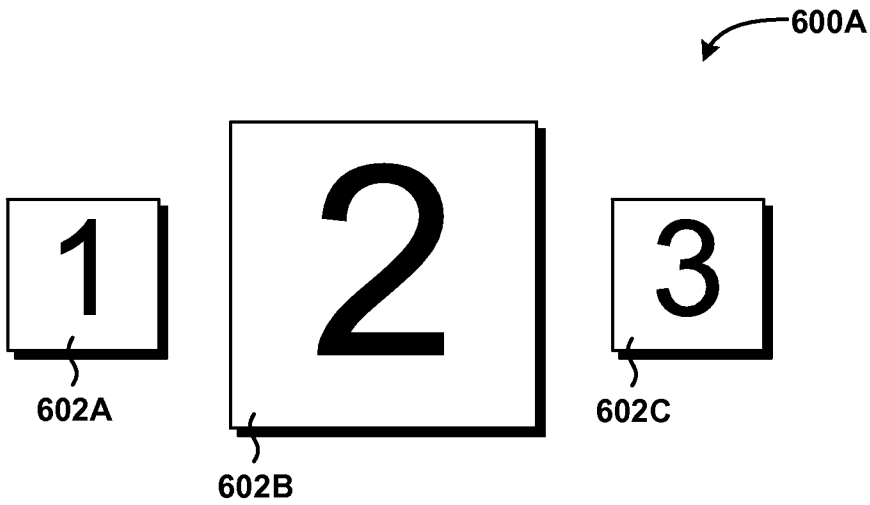


FIGURE 6A

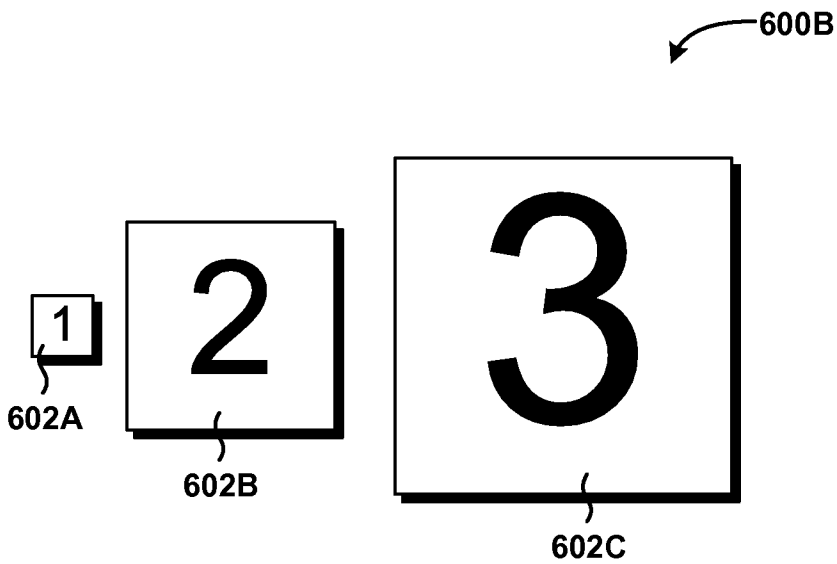


FIGURE 6B

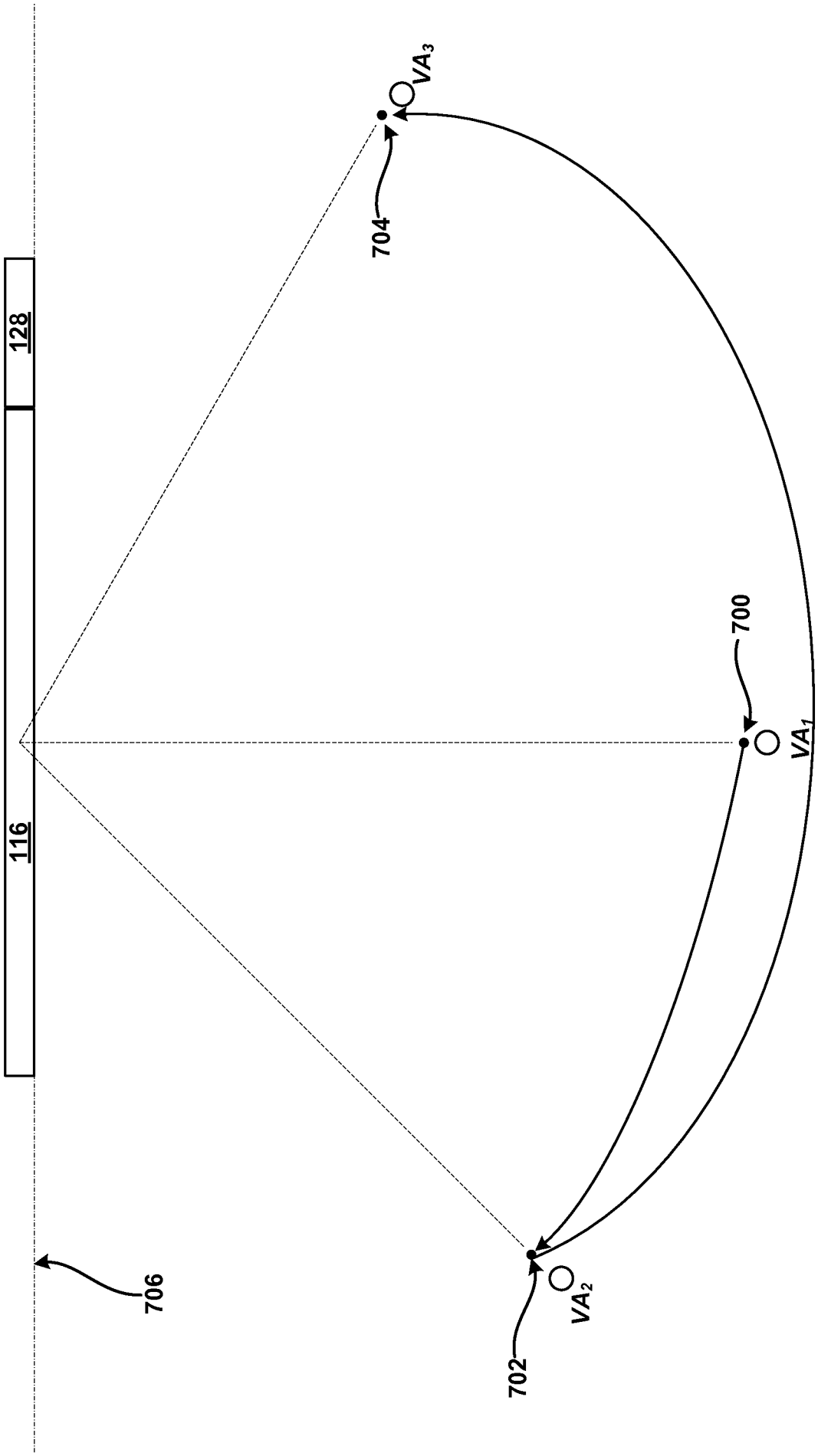


FIGURE 7

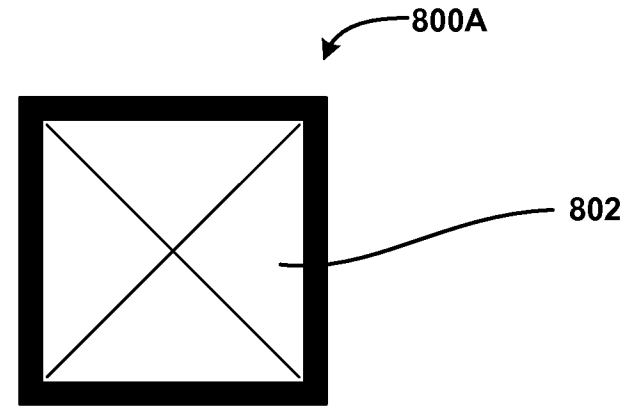


FIGURE 8A

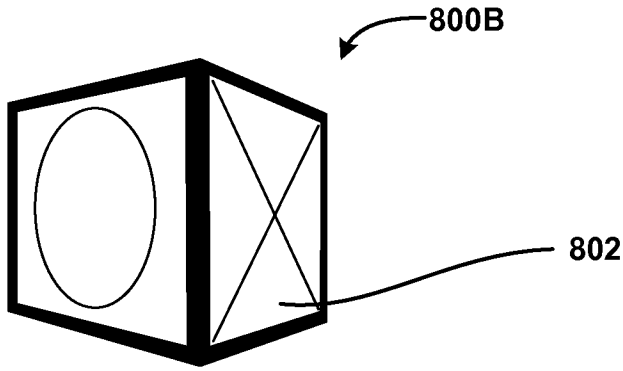


FIGURE 8B

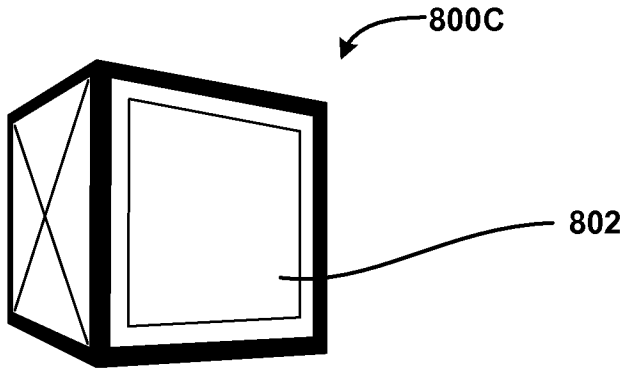


FIGURE 8C

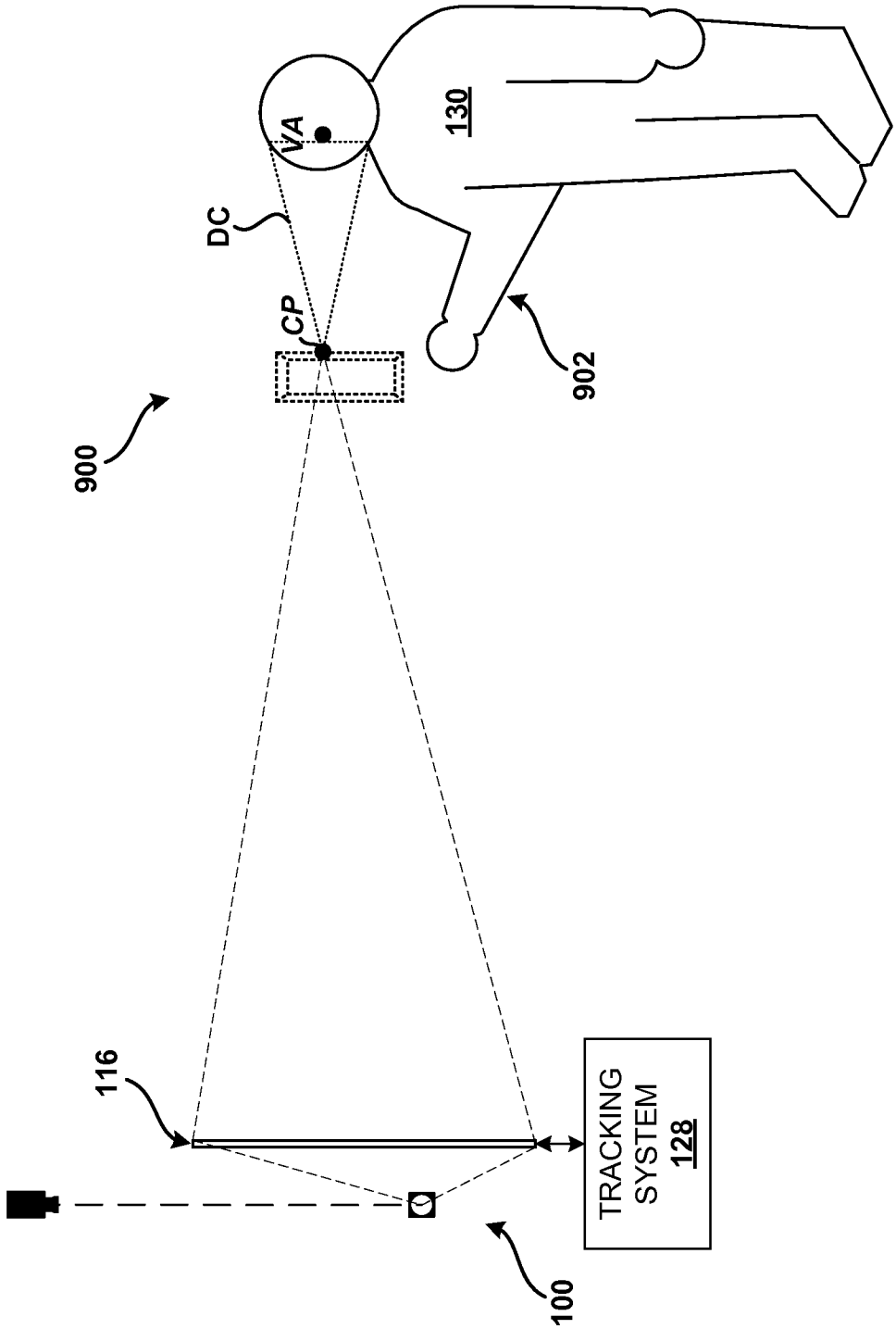


FIGURE 9

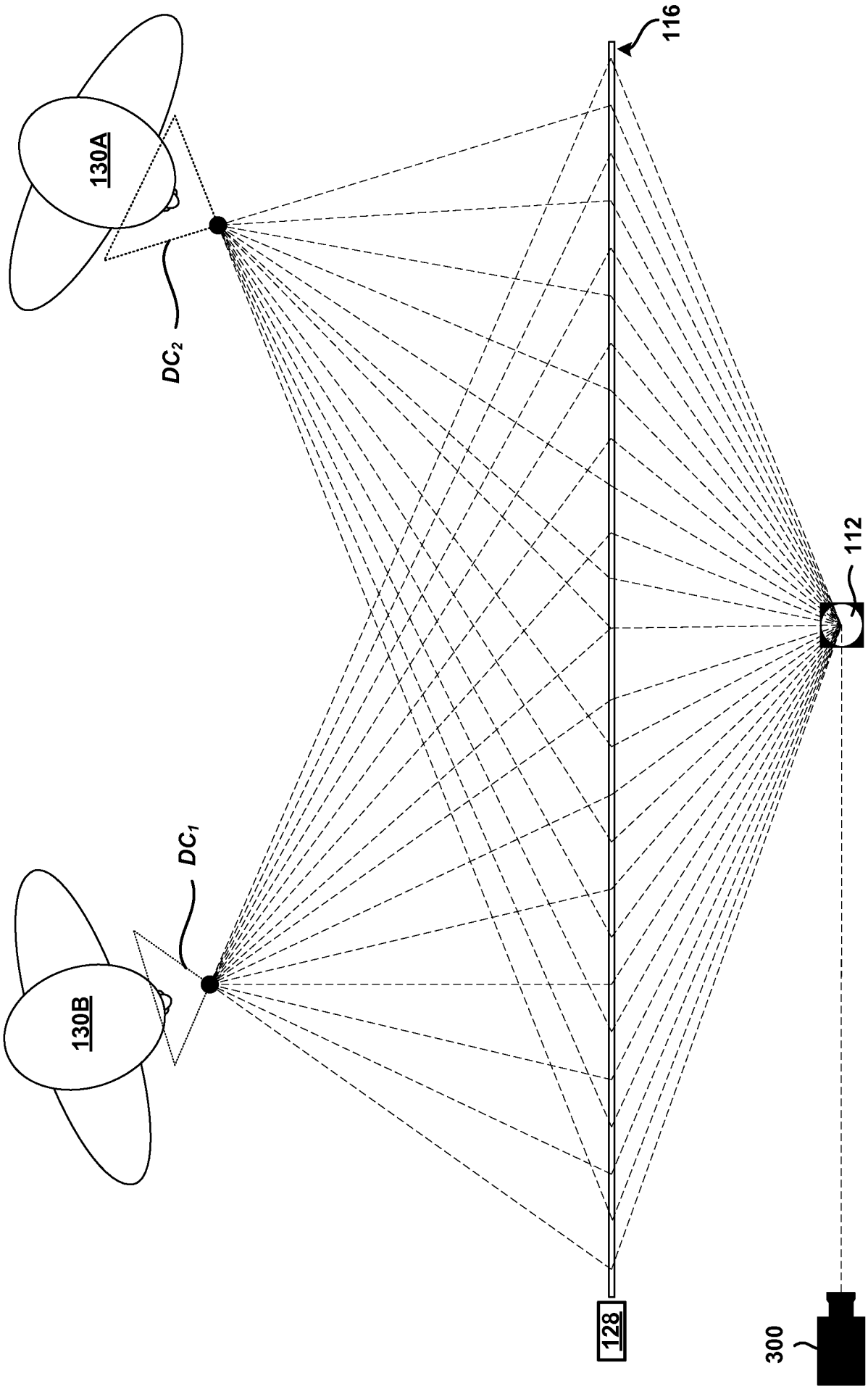


FIGURE 10

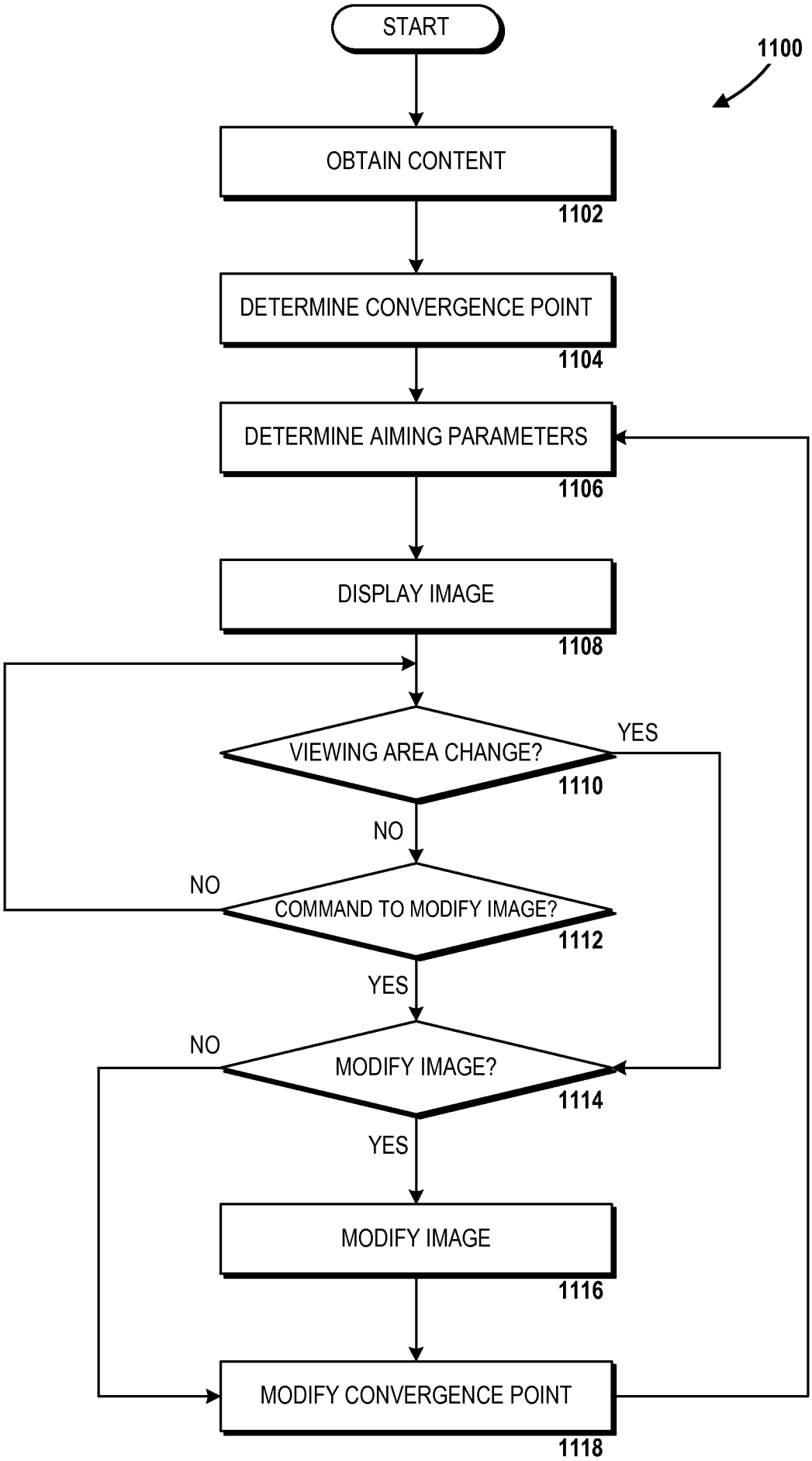

START
1100
OBTAIN CONTENT
1102
DETERMINE CONVERGENCE POINT
1104
DETERMINE AIMING PARAMETERS
1106
DISPLAY IMAGE
1108
VIEWING AREA CHANGE?
1110
YES
NO
NO
COMMAND TO MODIFY IMAGE?
1112
YES
NO
MODIFY IMAGE?
1114
YES
MODIFY IMAGE
1116
MODIFY CONVERGENCE POINT
1118

FIGURE 11

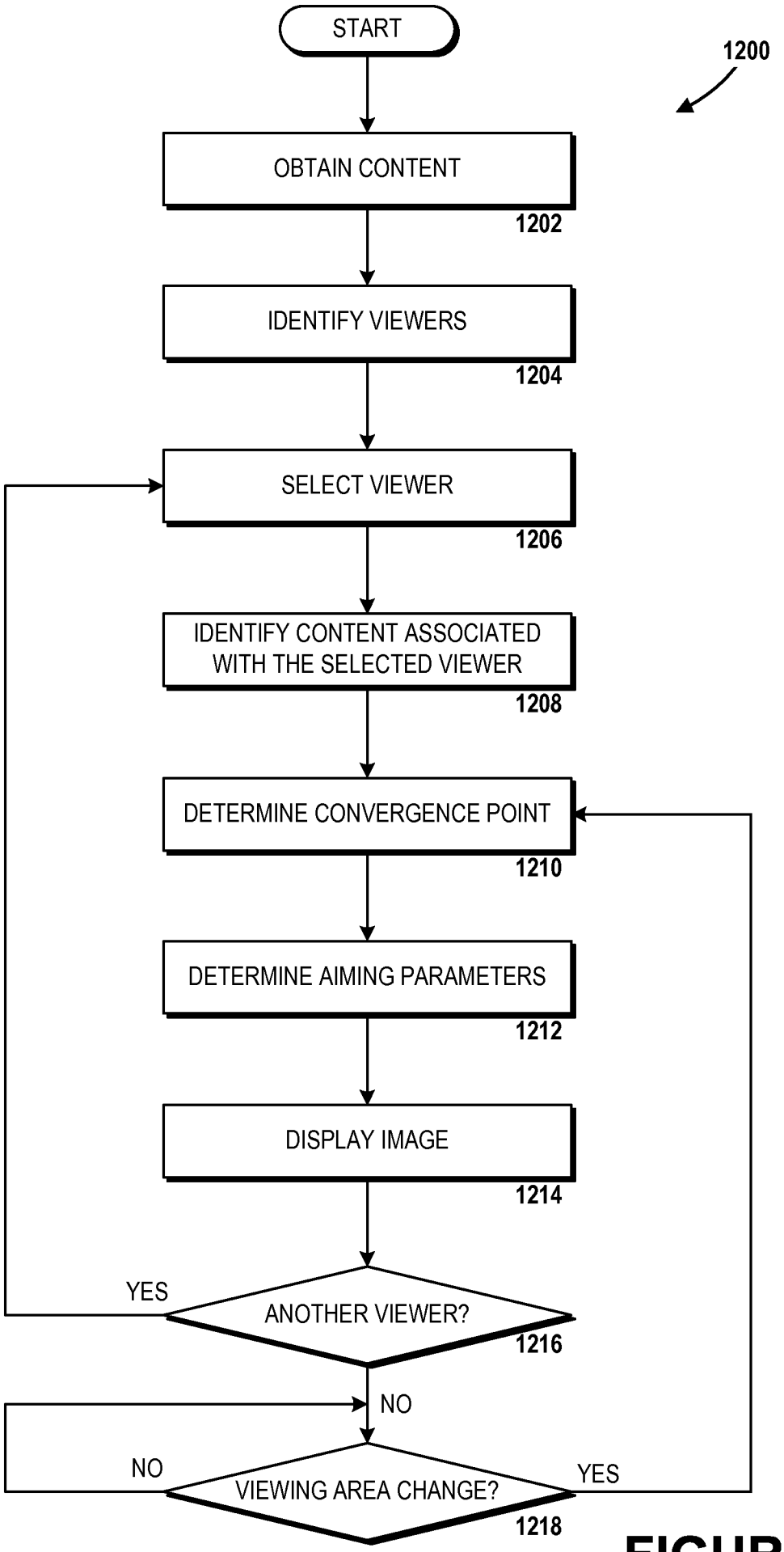

START
1200
OBTAIN CONTENT
1202
IDENTIFY VIEWERS
1204
SELECT VIEWER
1206
IDENTIFY CONTENT ASSOCIATED WITH THE SELECTED VIEWER
1208
DETERMINE CONVERGENCE POINT
1210
DETERMINE AIMING PARAMETERS
1212
DISPLAY IMAGE
1214
YES
ANOTHER VIEWER?
1216
NO
NO
VIEWING AREA CHANGE?
YES
1218

FIGURE 12

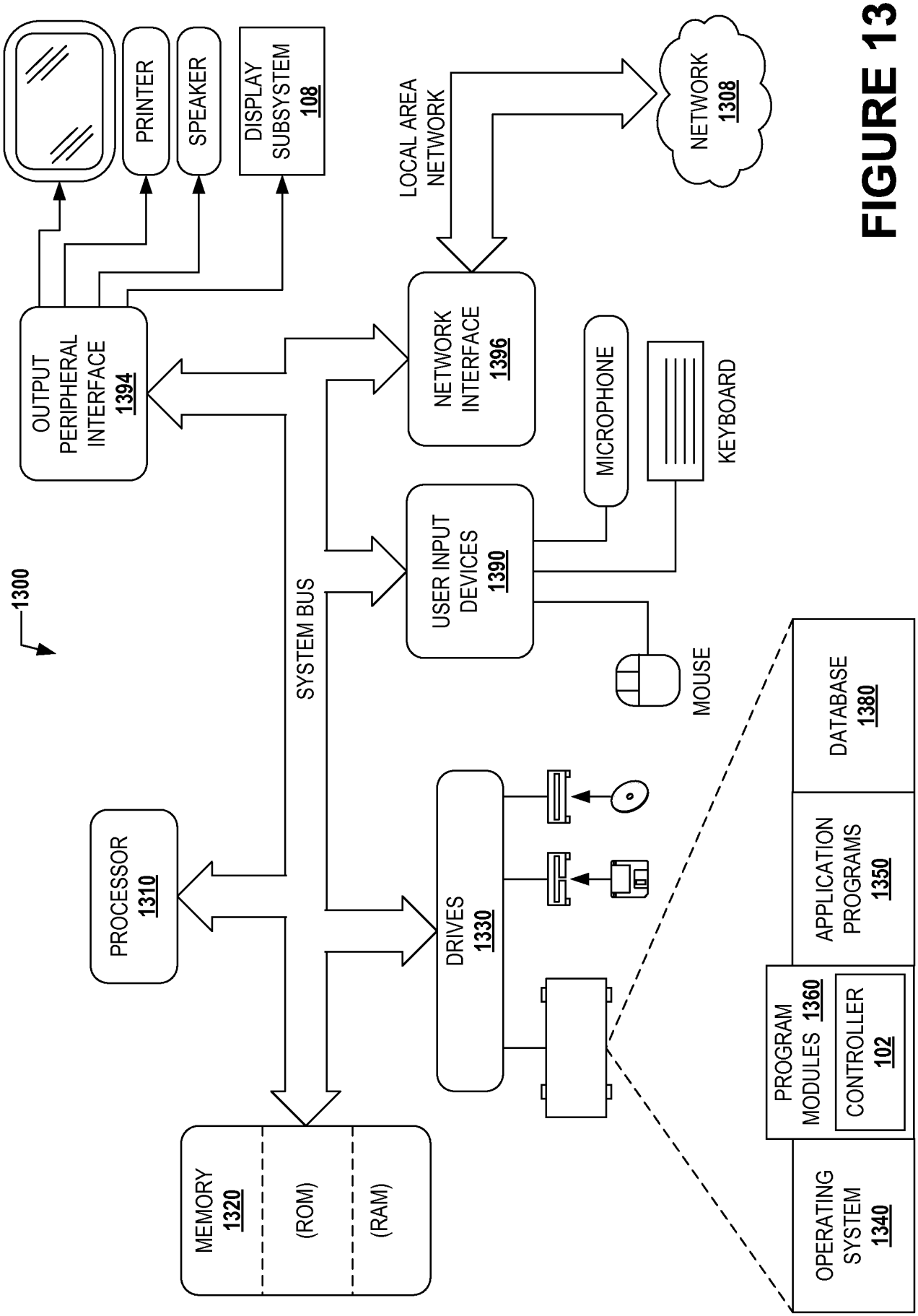

1300
PROCESSOR 1310
MEMORY 1320
(ROM)
(RAM)
SYSTEM BUS
DRIVES 1330
OPERATING SYSTEM 1340
PROGRAM MODULES 1360
CONTROLLER 102
APPLICATION PROGRAMS 1350
DATABASE 1380
USER INPUT DEVICES 1390
MOUSE
MICROPHONE
KEYBOARD
OUTPUT PERIPHERAL INTERFACE 1394
NETWORK INTERFACE 1396
LOCAL AREA NETWORK
NETWORK 1308
PRINTER
SPEAKER
DISPLAY SUBSYSTEM 108

FIGURE 13

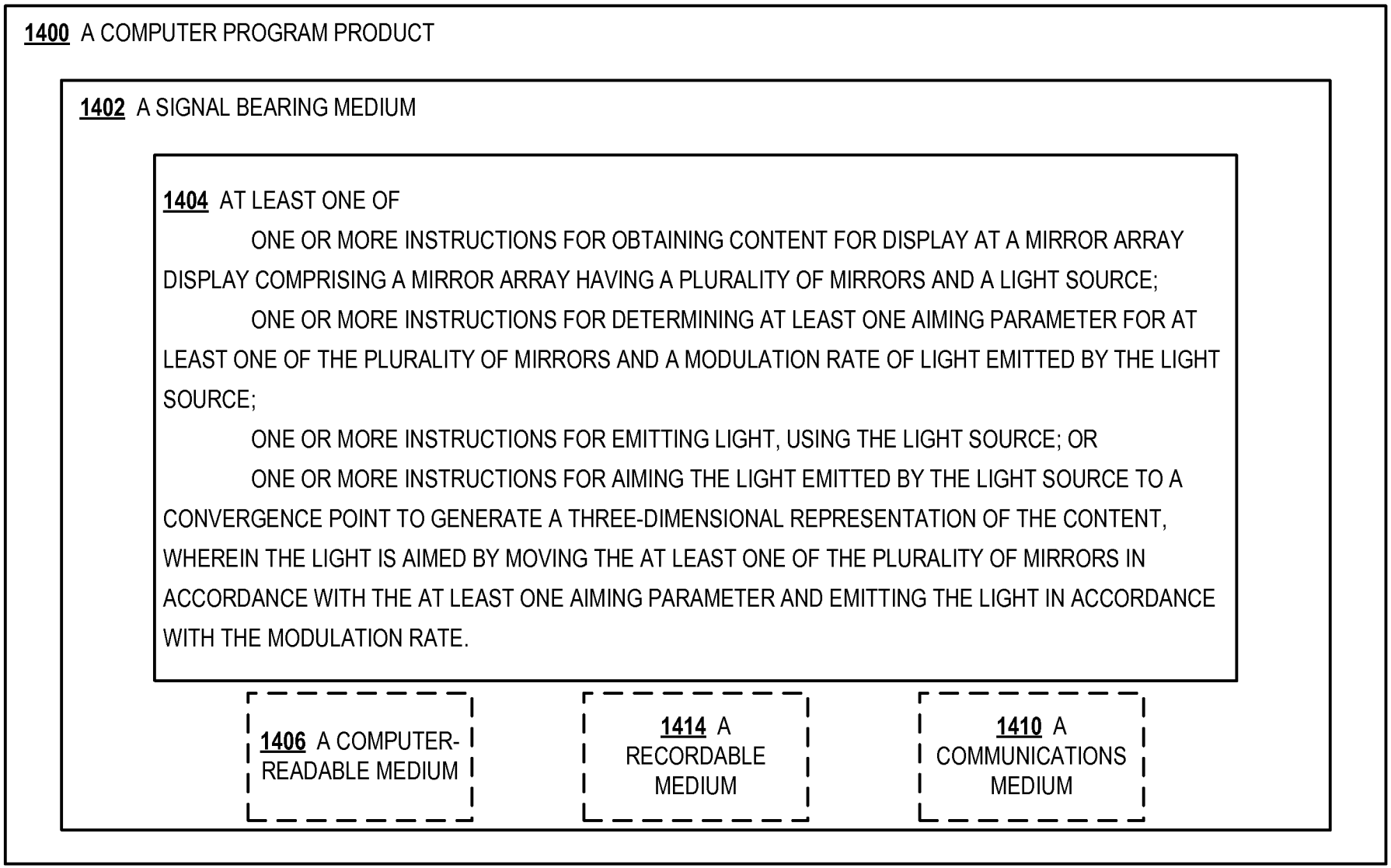

1400 A COMPUTER PROGRAM PRODUCT
1402 A SIGNAL BEARING MEDIUM
1404 AT LEAST ONE OF
ONE OR MORE INSTRUCTIONS FOR OBTAINING CONTENT FOR DISPLAY AT A MIRROR ARRAY DISPLAY COMPRISING A MIRROR ARRAY HAVING A PLURALITY OF MIRRORS AND A LIGHT SOURCE;
ONE OR MORE INSTRUCTIONS FOR DETERMINING AT LEAST ONE AIMING PARAMETER FOR AT LEAST ONE OF THE PLURALITY OF MIRRORS AND A MODULATION RATE OF LIGHT EMITTED BY THE LIGHT SOURCE;
ONE OR MORE INSTRUCTIONS FOR EMITTING LIGHT, USING THE LIGHT SOURCE; OR
ONE OR MORE INSTRUCTIONS FOR AIMING THE LIGHT EMITTED BY THE LIGHT SOURCE TO A CONVERGENCE POINT TO GENERATE A THREE-DIMENSIONAL REPRESENTATION OF THE CONTENT, WHEREIN THE LIGHT IS AIMED BY MOVING THE AT LEAST ONE OF THE PLURALITY OF MIRRORS IN ACCORDANCE WITH THE AT LEAST ONE AIMING PARAMETER AND EMITTING THE LIGHT IN ACCORDANCE WITH THE MODULATION RATE.
1406 A COMPUTER-READABLE MEDIUM
1414 A RECORDABLE MEDIUM
1410 A COMMUNICATIONS MEDIUM

FIGURE 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/21961

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02B 5/08 (2013.01)
USPC - 359/851
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): G02B 5/08 (2013.01)
USPC: 359/851

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 359/27; 359/310; 359/861; 353/8; 353/31; 715/702; 715/767; 348/40; 348/42; 348/43; 348/46; 348/51; 348/54; 348/67; 348/E9.026 (keyword limited - view terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Google Scholar; Google Web; Google Patents; PatBase.
Search Terms: mirror, array, display, light, content, control, aim, parameter, attribute, converge, three dimension, location, position, view, modulate, rotate, angle, laser, beam, move, change, interact, convergence point

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0032365 A1 (YETT) 10 February 2011 (10.02.2011) entire document, especially Abstract; para [0012], [0015], [0016], [0018], [0022], [0023], [0025], [0027], [0029], [0102], [0105], [0107]-[0109], [0123], [0125]-[0127], [0129], [0156], [0191], [0192], [0214], [0216], [0287], [0395]; Fig. 1I	1-29
A	US 2008/0261693 A1 (ZALEWSKI) 23 October 2008 (23.10.2008) entire document	1-29
A	US 2009/0303597 A1 (MIYAWAKI et al.) 10 December 2009 (10.12.2009) entire document	1-29
A	US 2005/0094230 A1 (KLUG et al.) 05 May 2005 (05.05.2005) entire document	1-29

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2013 (19.04.2013)	20 MAY 2013
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