US010969666B1

(12) **United States Patent**
Haseltine

(10) **Patent No.: US 10,969,666 B1**
(45) **Date of Patent: Apr. 6, 2021**

(54) **METHODS AND SYSTEMS OF DISPLAYING AN IMAGE FREE OF MOTION-BLUR USING SPINNING PROJECTORS**

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

(21) Appl. No.: **16/547,283**

(22) Filed: **Aug. 21, 2019**

(51) **Int. Cl.**

G03B 21/14	(2006.01)
H04N 9/31	(2006.01)
G03B 21/20	(2006.01)

(52) **U.S. Cl.**
CPC ***G03B 21/142*** (2013.01); ***G03B 21/145*** (2013.01); ***G03B 21/2046*** (2013.01); ***H04N 9/3147*** (2013.01)

(58) **Field of Classification Search**
CPC G03B 21/28; G03B 21/56; G03B 21/62; G03B 21/142; G03B 21/145; G03B 21/208; G03B 21/2046; G03B 21/2053; G03B 35/08; G03B 35/18; G03B 35/20; H04N 9/3141; H04N 9/3147; H04N 9/3155; H04N 9/3158; H04N 9/3164
See application file for complete search history.

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(57) **ABSTRACT**

According to one implementation, an image display system includes a motor configured to spin a rotor, first and second projectors, a projection screen having a first projection surface on a first side and a second projection surface on a second side opposite the first side, and a controller. The controller causes the motor to spin the rotor that spins the projection screen, the first projector, and the second projector about an axis, displays a first perspective of an image on the first projection surface using the first projector, and concurrently with displaying the first perspective of the image on the first projection surface, displays a second perspective of the image on the second projection surface using the second projector.

20 Claims, 9 Drawing Sheets

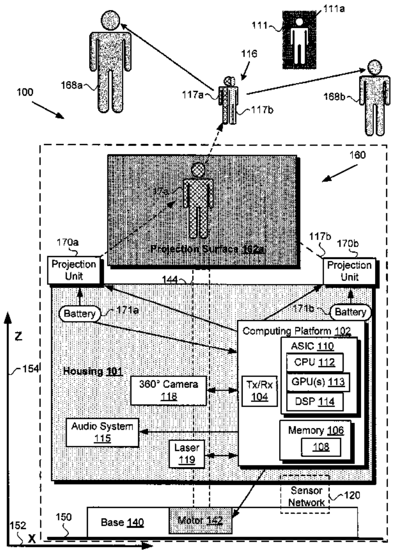

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Fig. 1A

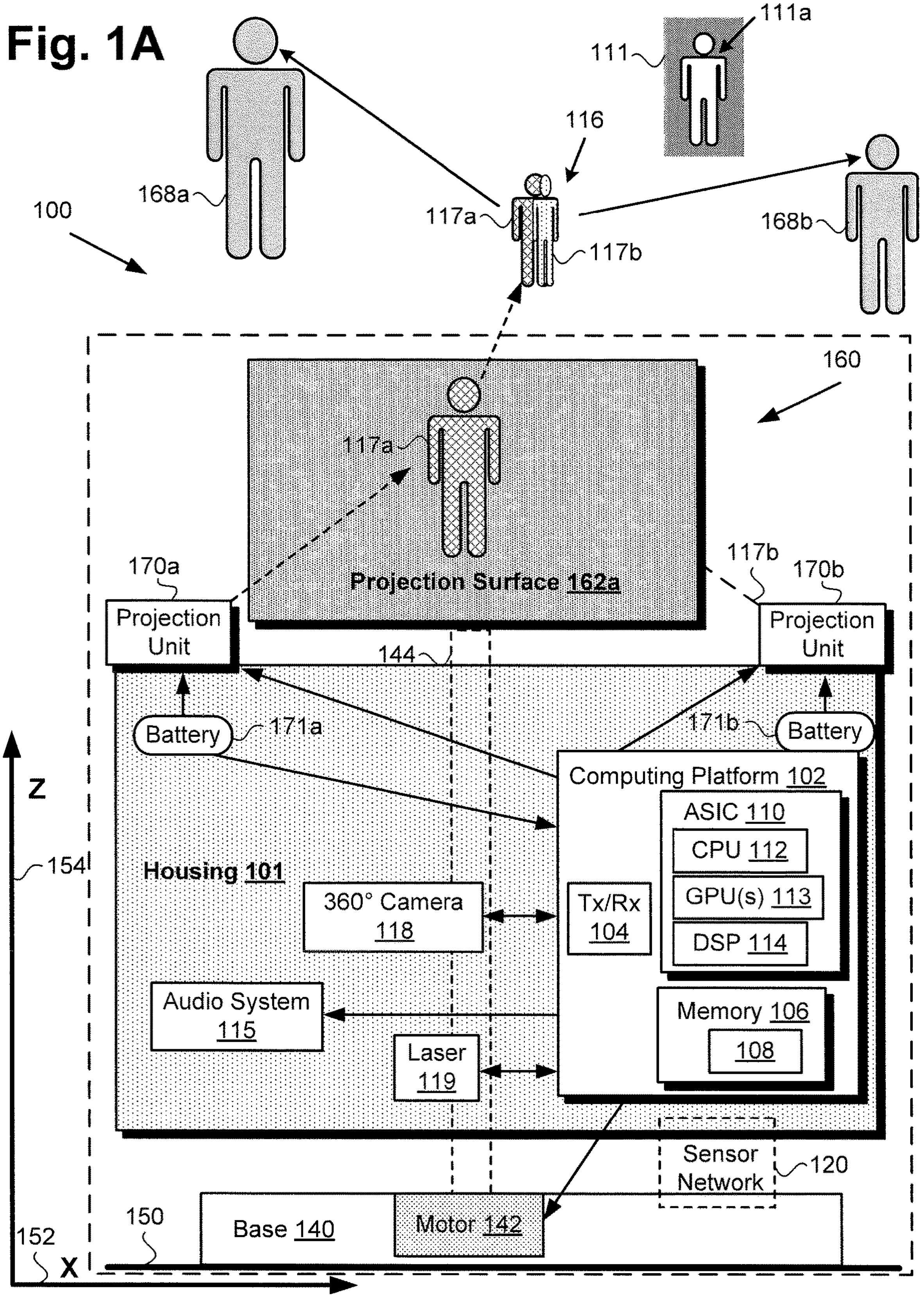

111a
111
116
168a
100
117a
117b
168b
160
117a
Projection Surface 162a
117b
170a
170b
Projection Unit
Projection Unit
144
Battery
171a
171b
Battery
Computing Platform 102
ASIC 110
CPU 112
GPU(s) 113
DSP 114
Z
154
Housing 101
360° Camera 118
Tx/Rx 104
Audio System 115
Memory 106
108
Laser 119
Sensor Network
120
150
152
X
Base 140
Motor 142

Fig. 1B

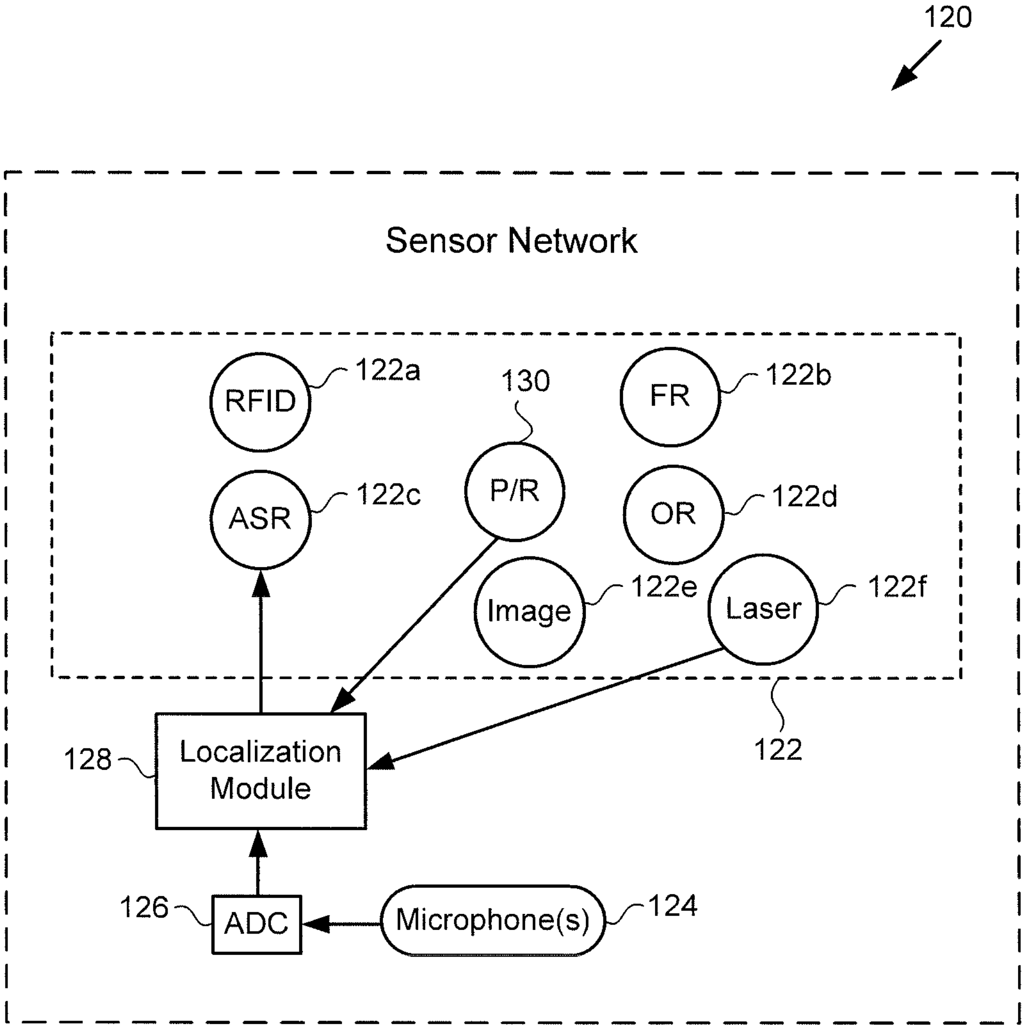

120
Sensor Network
RFID
122a
130
FR
122b
ASR
122c
P/R
OR
122d
Image
122e
Laser
122f
122
128
Localization Module
126
ADC
Microphone(s)
124

Fig. 1C

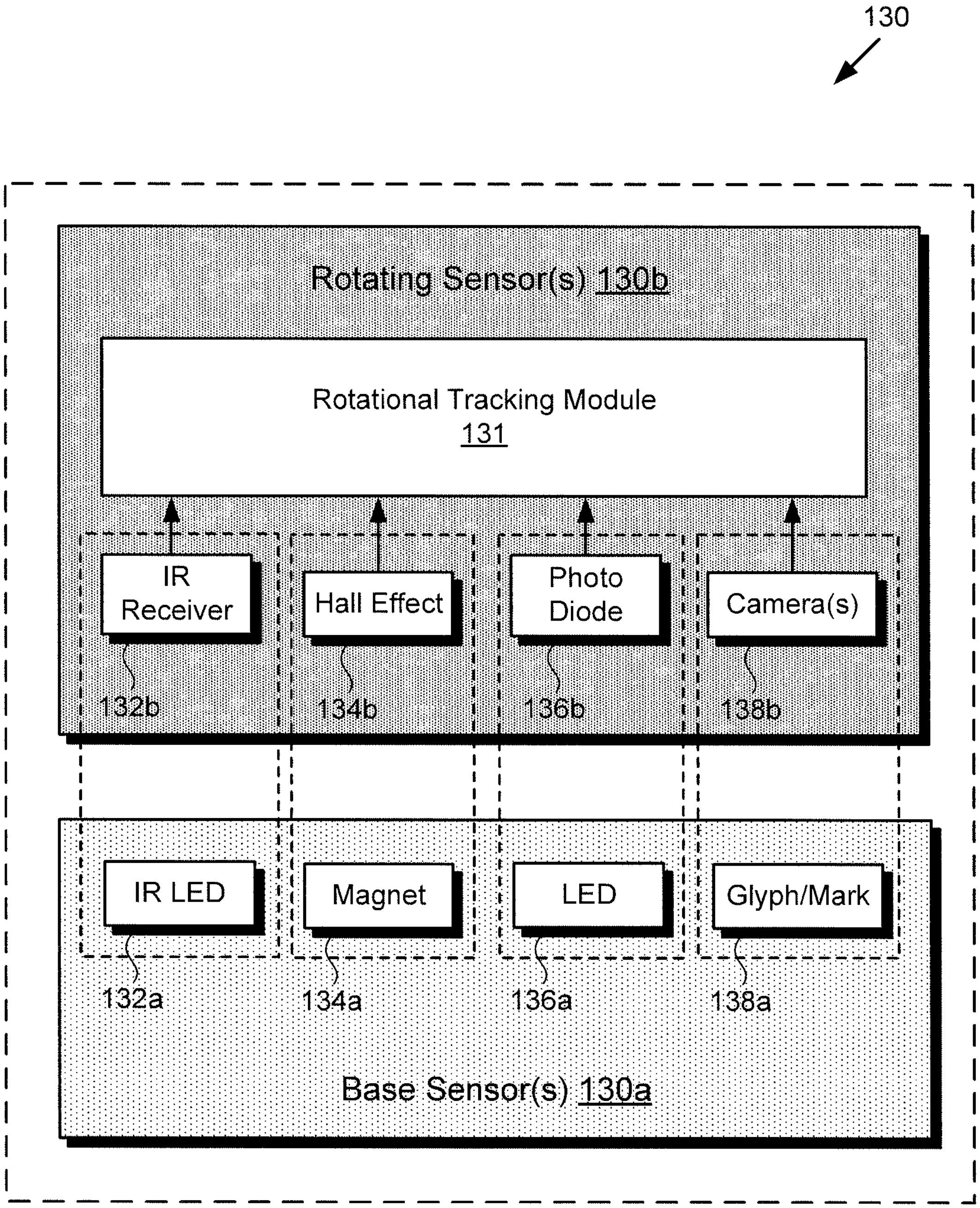

130
Rotating Sensor(s) 130b
Rotational Tracking Module
131
IR Receiver
Hall Effect
Photo Diode
Camera(s)
132b
134b
136b
138b
IR LED
Magnet
LED
Glyph/Mark
132a
134a
136a
138a
Base Sensor(s) 130a

Fig. 2A

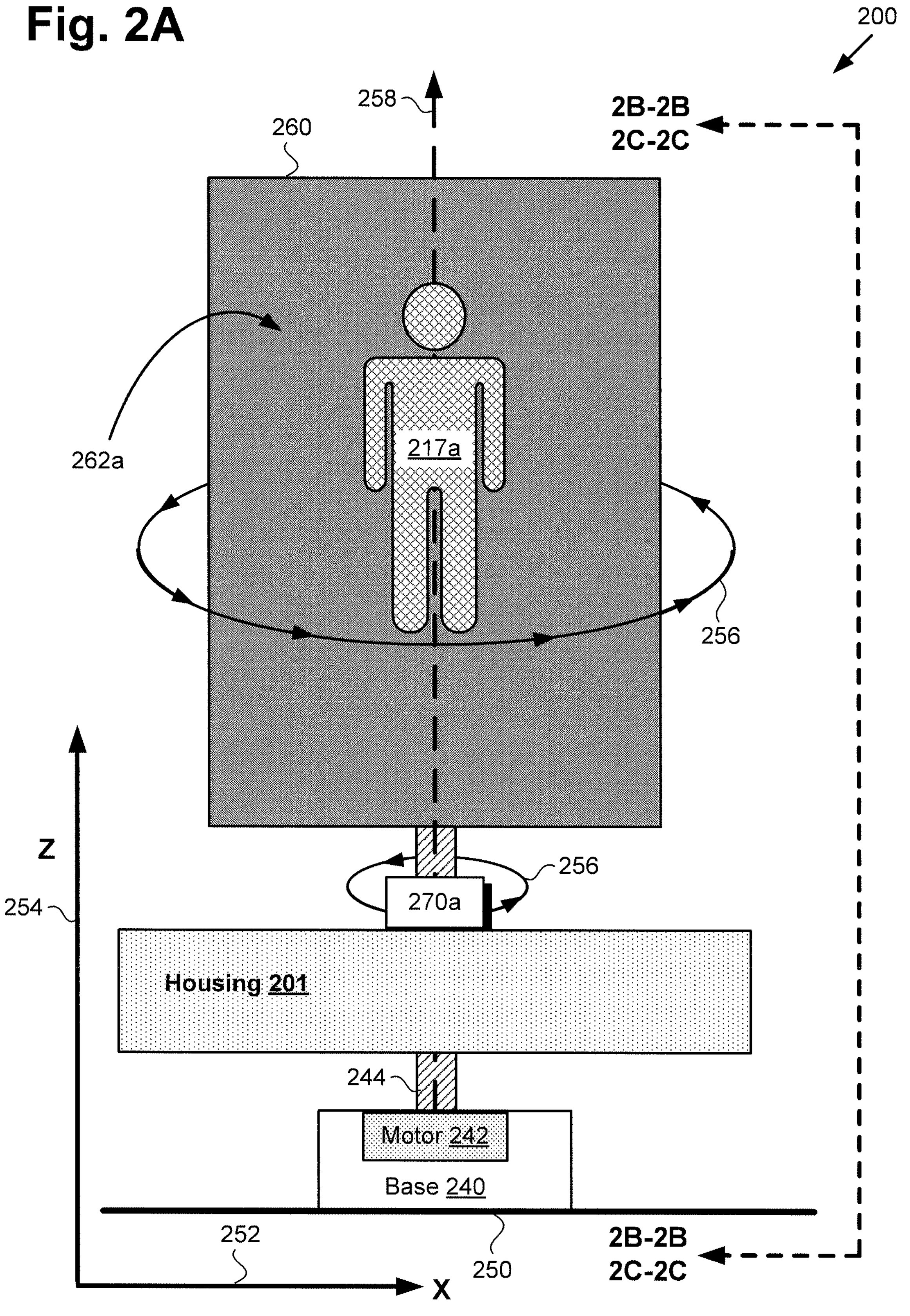

200
258
2B-2B
2C-2C
260
262a
217a
256
Z
254
256
270a
Housing 201
244
Motor 242
Base 240
252
250
X
2B-2B
2C-2C

Fig. 2B

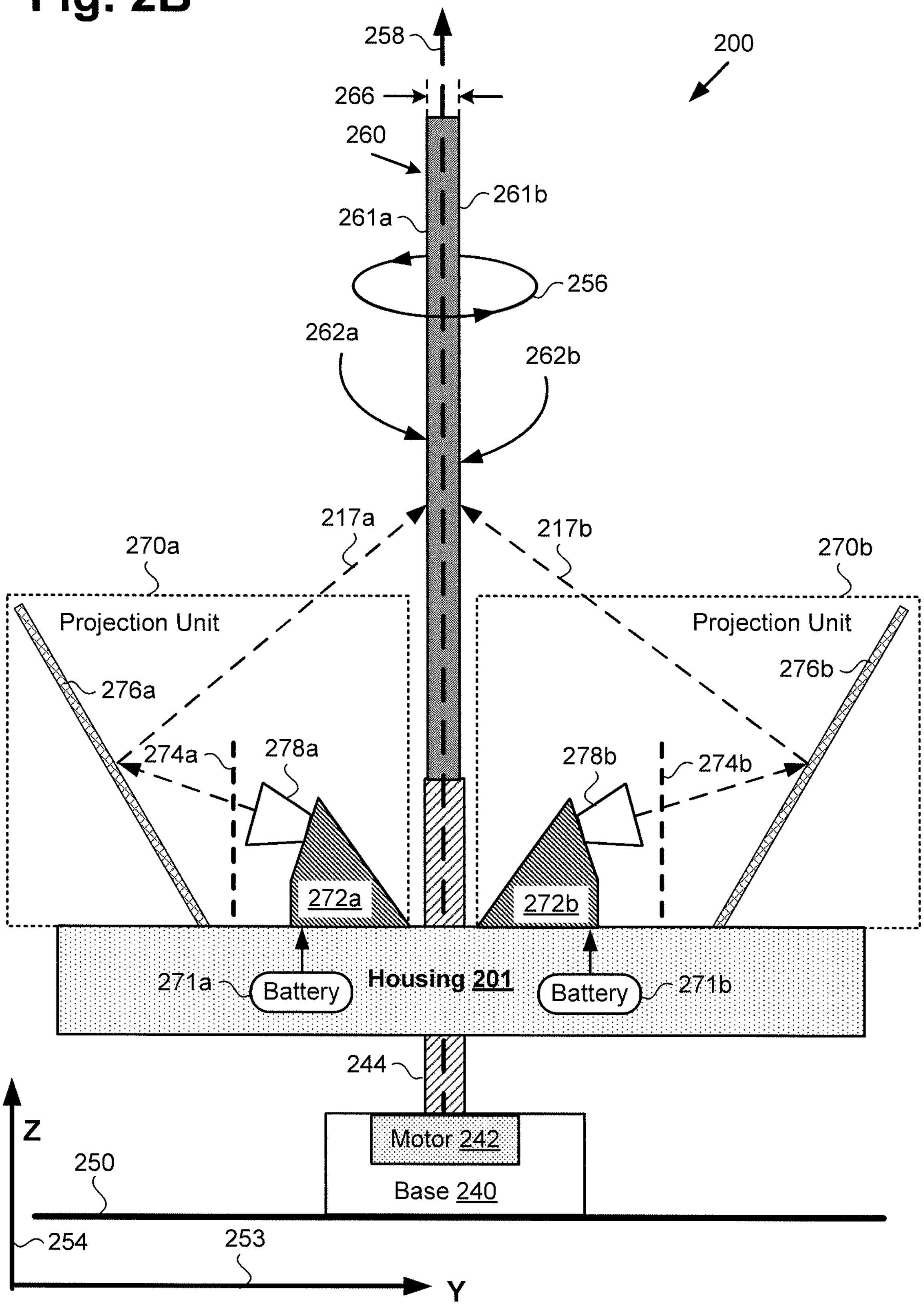
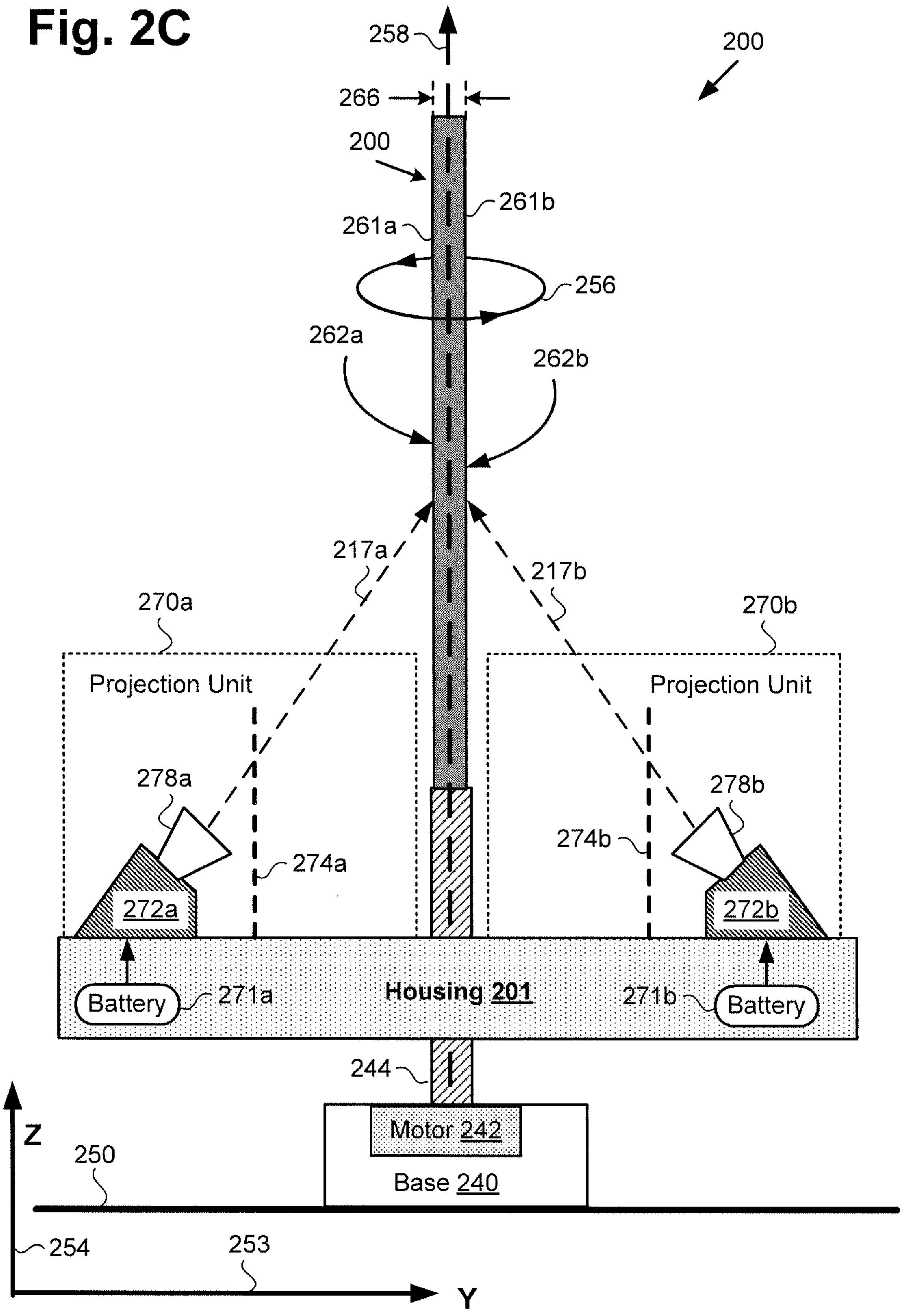

258
200
266
260
261b
261a
256
262a
262b
217a
217b
270a
270b
Projection Unit
Projection Unit
276a
276b
274a
278a
278b
274b
272a
272b
271a
Battery
Housing 201
Battery
271b
244
Z
Motor 242
250
Base 240
254
253
Y

Fig. 2C


258
200
266
200
261b
261a
256
262a
262b
217a
217b
270a
270b
Projection Unit
Projection Unit
278a
278b
274b
274a
272a
272b
Battery
271a
Housing 201
271b
Battery
244
Motor 242
Z
250
Base 240
254
253
Y

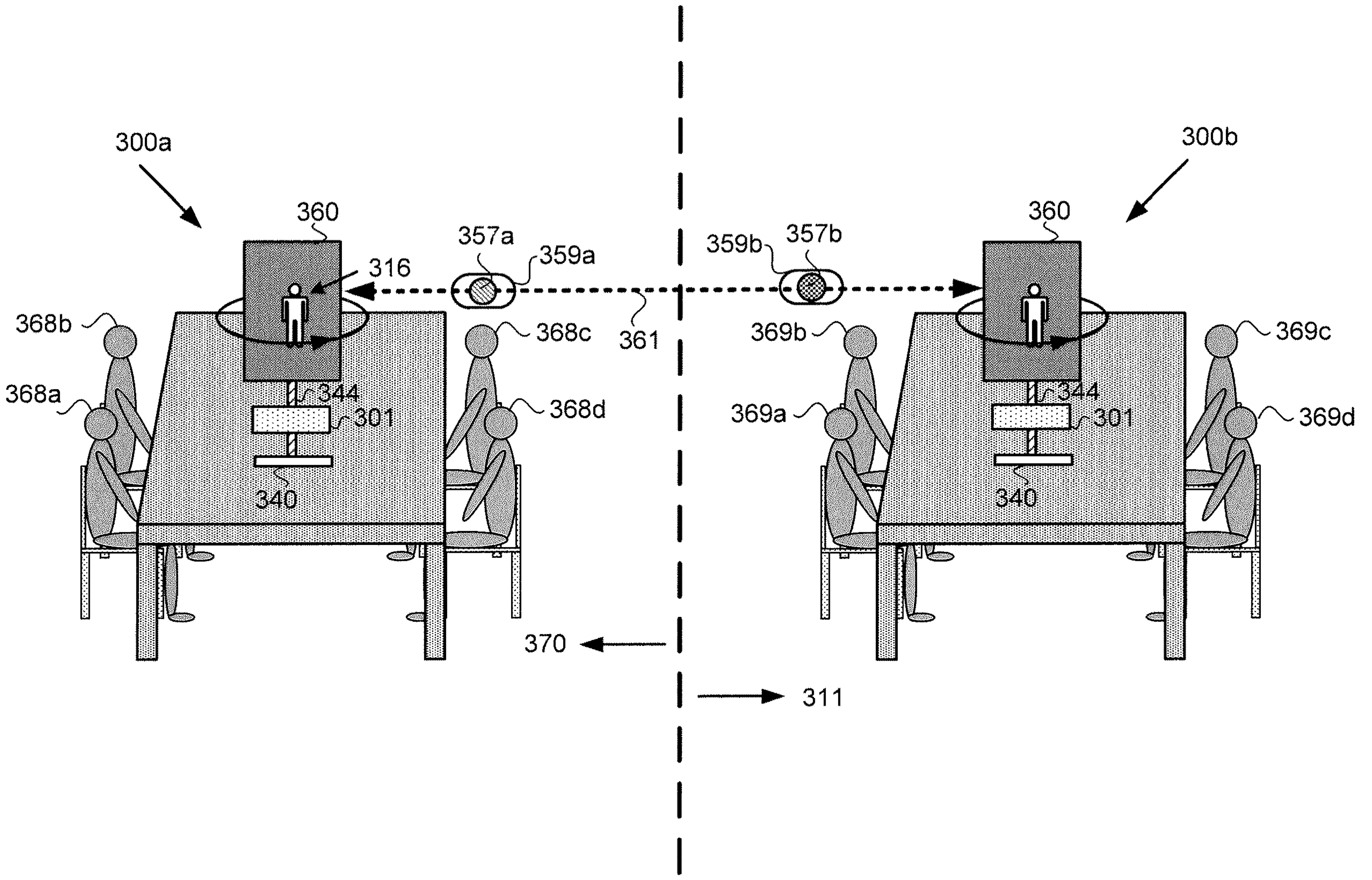

300a
300b
360
316
357a
359a
359b
357b
360
368b
368c
361
369b
369c
368a
344
301
368d
369a
344
301
369d
340
340
370
311

Fig. 3

Fig. 4

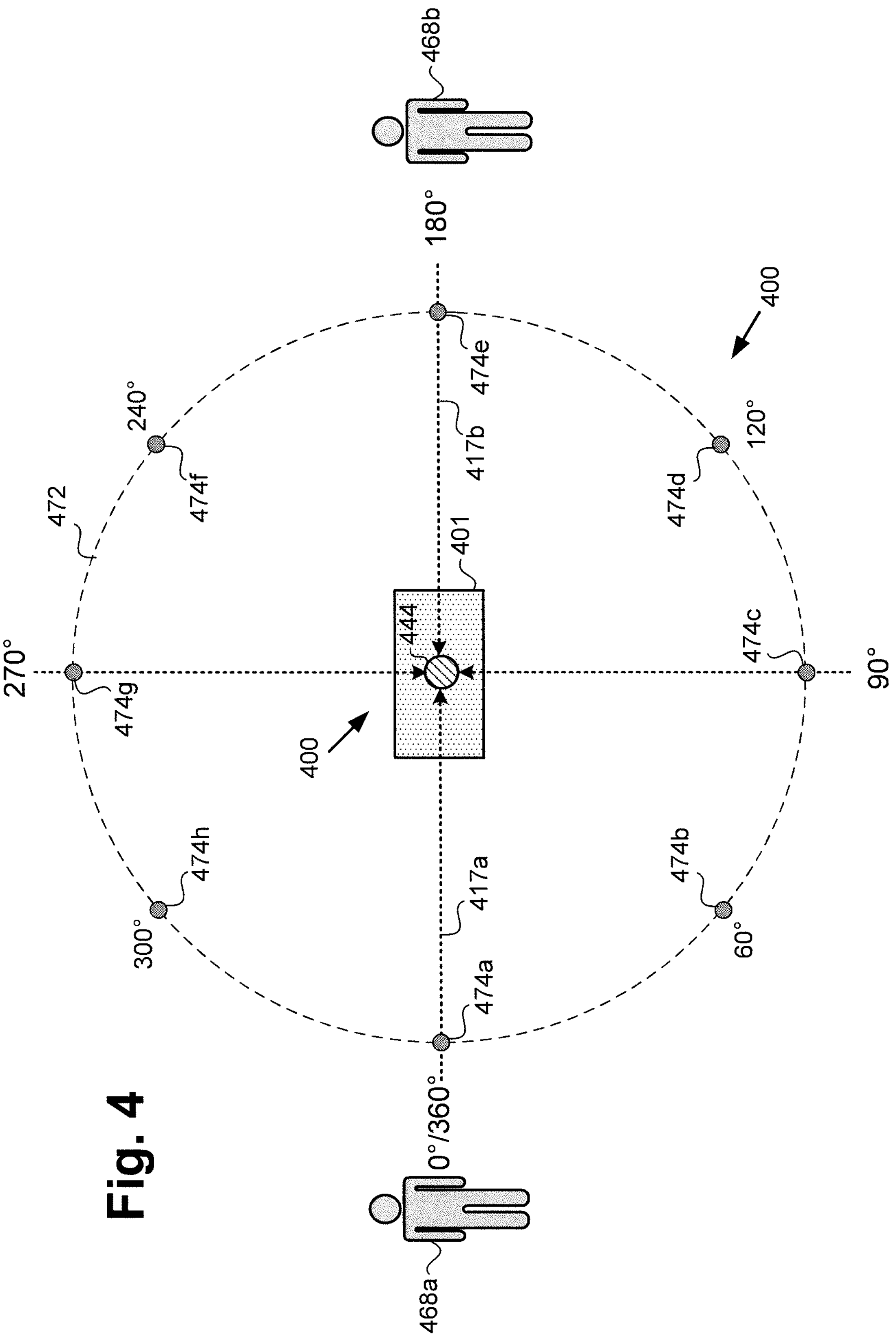
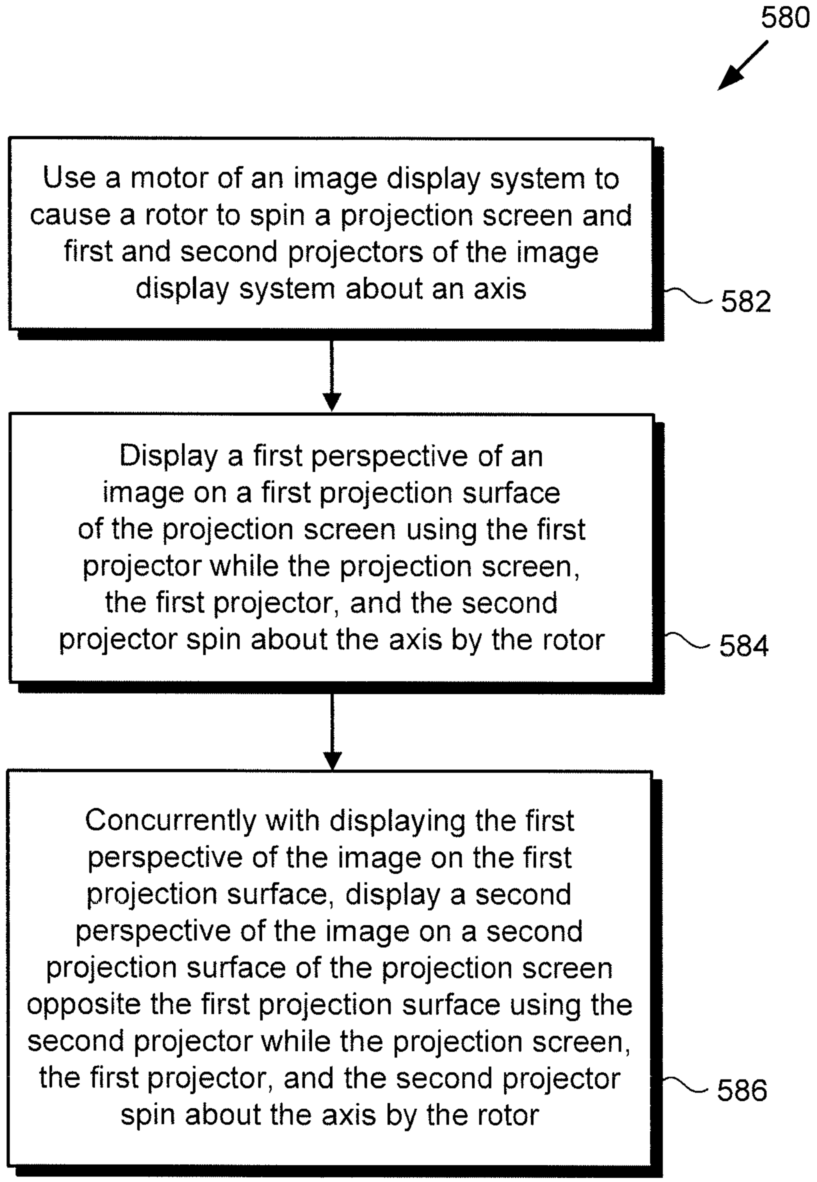

468a
468b
0°/360°
180°
90°
270°
60°
120°
240°
300°
400
400
401
444
417a
417b
472
474a
474b
474c
474d
474e
474f
474g
474h

Fig. 5


580
Use a motor of an image display system to cause a rotor to spin a projection screen and first and second projectors of the image display system about an axis
582
Display a first perspective of an image on a first projection surface of the projection screen using the first projector while the projection screen, the first projector, and the second projector spin about the axis by the rotor
584
Concurrently with displaying the first perspective of the image on the first projection surface, display a second perspective of the image on a second projection surface of the projection screen opposite the first projection surface using the second projector while the projection screen, the first projector, and the second projector spin about the axis by the rotor
586

METHODS AND SYSTEMS OF DISPLAYING AN IMAGE FREE OF MOTION-BLUR USING SPINNING PROJECTORS

BACKGROUND

Increases in computing power have made possible the generation of richly featured virtual imagery capable of simulating in-person interactivity. However, the display screens with which many modern communication devices are equipped are typically designed to display a two-dimensional (2D) image from a single viewing perspective. As a result, and despite their ability to display sharp, richly featured, high definition images, interactive group communications such as video conferencing and multi-player gaming using those devices tend to be less engaging and immersive than if the participants could be provided with the illusion of being together in person.

An alternative to the conventional approach to providing 2D images is to render group communications using 3D imagery. For example, a spinning display may be used to generate an apparently three-dimensional (3D) image that appears to float in space. However, rotational and translational motion-blur resulting from spinning of a conventional display screen may be readily detectable to the eye of a human user, and may undesirably reduce the immersiveness of the interactive experience for the user.

SUMMARY

There are provided systems and methods for displaying an image free of motion-blur using spinning projectors, substantially as shown in and/or described in connection with at least one of the figures, and as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A shows a diagram of an image display system for generating multiple perspectives of a floating image free of motion-blur, according to one implementation;

FIG. **1**B shows a diagram of an exemplary sensor network suitable for use as part of the image display system of FIG. **1**A, according to one implementation;

FIG. **1**C shows a diagram of exemplary position and/or rate (P/R) sensors suitable for use as part of the image display system of FIG. **1**A, according to one implementation;

FIG. **2**A shows a diagram of an exemplary image display system for generating multiple perspectives of a floating image free of motion-blur, according to another implementation;

FIG. **2**B shows a side view of the exemplary image display system shown in FIG. **2**A along perspective lines **2**B-**2**B in that figure, according to one implementation;

FIG. **2**C shows a side view of the exemplary image display system shown in FIG. **2**A along perspective lines **2**C-**2**C in that figure, according to another implementation;

FIG. **3** shows an exemplary use case for the image display systems of FIGS. **1**, **2**A, **2**B, and **2**C;

FIG. **4** shows a diagram of exemplary locations for viewing different perspectives of a floating image free of motion-blur displayed by the systems and according to the methods disclosed in the present application; and

FIG. **5** shows a flowchart outlining an exemplary method for use by an image display system for generating multiple perspectives of a floating image free of motion-blur, according to one implementation.

DETAILED DESCRIPTION

The following description contains specific information pertaining to implementations in the present disclosure. One skilled in the art will recognize that the present disclosure may be implemented in a manner different from that specifically discussed herein. The drawings in the present application and their accompanying detailed description are directed to merely exemplary implementations. Unless noted otherwise, like or corresponding elements among the figures may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present application are generally not to scale, and are not intended to correspond to actual relative dimensions.

FIG. **1**A shows a diagram of exemplary image display system **100** for generating multiple perspectives of a floating image that are substantially free of motion-blur, according to one implementation. As shown in FIG. **1**A, image display system **100** includes projection screen **160** and housing **101** configured to rotate with rotor **144**, as well as stationary base **140** coupled to housing **101** and projection screen **160** by rotor **144**. Housing **101** includes computing platform **102** communicatively coupled to motor **142** integrated with base **140**, first projection unit **170***a*, second projection unit **170***b*, audio system **115**, optional 360° degree camera **118**, optional laser **119**, and sensor network **120** bridging stationary base **140** and housing **101**.

In addition, housing **101** can also include batteries **171***a* and **171***b*. As shown in FIG. **1**A, batteries **171***a* and **171***b* may be situated on opposite sides of housing **101**, and may be used to provide power to first and second projection units **170***a* and **170***b*, as well as to computing platform **102**. Batteries **171***a* and **171***b* may be deployed on opposite sides of housing **101** to optimize both static and dynamic balance of image display system **100**.

As further shown in FIG. **1**A, computing platform **102** may include transceiver **104**, application specific integrated circuit (ASIC) **110** (hereinafter “controller **110**”) including central processing unit (CPU) **112** implemented as a hardware processor, one or more graphics processing unit(s) (GPU(s)) **113**, and may further include digital signal processor (DSP) **114**. Computing platform **102** may also include system memory **106** implemented as a non-transitory storage device storing software code **108**.

According to the exemplary implementation shown in FIG. **1**A, base **140** includes motor **142** for spinning rotor **144**, housing **101**, and projection screen **160**. Moreover, according to the present exemplary implementation, first projection unit **170***a* and second projection unit **170***b* are mounted on or otherwise secured to housing **101** on opposite sides of projection screen **160**, and are configured to spin with rotor **144**, housing **101**, and projection screen **160**. In some use cases, it may be advantageous or desirable to implement motor **142** as a brushless synchronous motor, due to the high temporal stability of such a motor. It is noted that, in some implementations, batteries **171***a* and **171***b* may be used to drive motor **142**. However, in other implementations, motor **142** can be driven by a separate, wall-plug driven power supply (wall-plug driven power supply not shown in FIG. **1**A).

Base **140** is situated on surface **150**, which may be a floor or any other substantially horizontal surface. In addition, FIG. **1**A shows horizontal axis **152** (hereinafter also "X axis **152**") substantially parallel to surface **150**, and vertical axis **154** (hereinafter also "Z axis") substantially perpendicular to surface **150** and X axis **152**. Also shown in FIG. **1**A are image **116** appearing to float in space (hereinafter "floating image **116**"), first perspective **117***a* of floating image **116** projected onto first projection surface **162***a* of projection screen **160** by first projection unit **170***a*, local observers **168***a* and **168***b* of floating image **116**, and remote venue **111** from which, in some implementations, source image **111***a* corresponding to floating image **116** may originate.

It is noted that, although not visible from the perspective shown in FIG. **1**A, second perspective **117***b* of floating image **116** is projected onto a second projection surface of projection screen **160** opposite to first projection surface **162***a* by second projection unit **170***b*. It is further noted that the depiction of first and second projection units **170***a* and **170***b* in FIG. **1**A is provided in the interests of conceptual clarity. A more accurate representation according to the perspective shown by FIG. **1**A would have first projection unit **170***a* situated on housing **101** in front of and obscuring portions of rotor **144** and first projection surface **162***a*, while second projection unit **170***b* would be situated on housing **101** behind rotor **144** and projection screen **160**, and would be at least partially obscured by first projection unit **170***a*.

It is also noted that the combination of motor **142**, sensor network **120**, and computing platform **102** including controller **110** enable the necessary time synchronization between the revolutions per minute (rpm) of motor **142** and rotor **144**, and the frame rate in frames per second (fps) at which image display system **100** can render respective perspectives **117***a* and **117***b* of floating image **116** on projection screen **160**.

For the purposes of the present application, the terms "central processing unit" or "CPU" and "graphics processing unit" or "GPU" have their customary meaning in the art. That is to say, a CPU includes an Arithmetic Logic Unit (ALU) for carrying out the arithmetic and logical operations of computing platform **102**, as well as a Control Unit (CU) for retrieving programs, such as software code **108**, from system memory **106**. A GPU is configured to reduce the processing overhead of the CPU by performing computationally intensive graphics processing tasks.

In addition, for the purposes of the present application, the term "perspective" refers to the particular viewing angle from which an object, virtual object, or image is viewed by an observer. Referring to FIG. **1**A, for example, a perspective of floating image **116** refers to the viewing angle of an observer of floating image **116** with respect to an imaginary circle substantially concentric with rotor **144** of image display system **100**, in a plane substantially perpendicular to rotor **144** and vertical Z axis **154**.

Moreover, the terms "render" and "rendering" are defined to mean causing one or more images to be displayed on a projection screen, such as projection screen **160** for example. Thus, rendering an image may mean causing an entirely new image to be displayed on the projection screen, or refreshing an image previously displayed on the projection screen.

With respect to the term "display interval," as used in the present application, "display interval" refers to a predetermined time interval during a rotation of first and second projection units **170***a* and **170***b* and projection screen **160** by rotor **144** during which at least one of first and second perspectives **117***a* and **117***b* is displayed using respective projection units **170***a* and **170***b*. Thus, a display interval of first and second projection units **170***a* and **170***b* will typically be substantially less than the time required for rotor **144** to complete a single rotation. As a specific example, rotor **144** may have a spin rate in a range from approximately 900 rpm to approximately 3600 rpm, which translates to a range of time intervals from approximately sixty-seven milliseconds (67 ms) to approximately 17 ms. By contrast, a display interval of first and second projection units **170***a* and **170***b* will typically be less than or equal to 1.0 ms.

Although FIG. **1**A shows two observers **168***a* and **168***b*, that representation is also provided merely for conceptual clarity. More generally, observers **168***a* and **168***b* may correspond to a single observer, or to more or many more than two observers who may be positioned so as to view floating image **116** from a variety of perspectives. For example, in some implementations, observers **168***a* and **168***b* may be situated so as to view floating image **116** from a number of discrete perspectives, such as two discrete perspectives located approximately one hundred and eighty degrees (180°) apart on a 360° circle surrounding floating image **116** and concentric with rotor **144** in a plane substantially perpendicular to rotor **144** and vertical Z axis **154**. However, in other implementations, observers **168***a* and **168***b* may be able to view floating image **116** from the perspectives of other locations on such a circle surrounding floating image **116**, such as four locations approximately 90° apart on the circle, or six locations approximately 60° apart, for example.

In some implementations, observers **168***a* and **168***b* may be interactively engaged with remote venue **111** from which the source image originates via image display system **100** including computing platform **102**, 360° camera **118**, laser **119**, first and second projection units **170***a* and **170***b*, audio system **115**, sensor network **120**, and projection screen **160**. That is to say, in those implementations, controller **110** may be configured to execute software code **108** to utilize transceiver **104**, first and second projection units **170***a* and **170***b*, audio system **115**, sensor network **120**, GPU(s) **113**, and projection screen **160** to generate and display floating image **116** corresponding to source image **111***a* during communications with remote venue **111**.

Although FIG. **1**A depicts audio system **115** as structurally integrated with housing **101**, that representation is merely exemplary. In various implementations, audio system **115** may be wholly integrated with housing **101**, may include elements, such as audio speakers, controlled by computing platform **102** but remote from housing **101**, or may be partially integrated with housing **101** while including remote audio elements. In one implementation, audio system **115** may include a theater quality Dolby® high definition (HD) surround-sound system, for example.

According to the exemplary implementation shown in FIG. **1**A, image display system **100** includes an image capture device in the form of 360° camera **118** communicatively coupled to computing platform **102**. It is noted that, in some implementations, 360° camera **118** may be communicatively coupled to, but not structurally integrated with, housing **101**. For example, 360° camera **118** may be strategically situated in a venue local to image display system **100** to capture images of the local venue, as well as gestures and/or facial expressions by observers **168***a* and **168***b*. Alternatively, in some implementations, 360° camera **118** may be mounted on or otherwise integrated with stationary base **140** or with housing **101**. In various implementations, 360° camera **118** may be in wireless communication with computing platform **102** and may be wirelessly controlled by controller **110**.

As further shown in FIG. **1**A, in some implementations, image display system **100** may further include an image capture device including laser **119** communicatively coupled to computing platform **102** and configured to rotate with housing **101**. Laser **119** may be controlled by CPU **112** of controller **110** and may be implemented in conjunction with a laser sensor included in sensor network **120** (laser sensor not shown in FIG. **1**A) to function as a Lidar type probe for mapping the venue local to image display system **100** and/or determining the locations of observers **168***a* and **168***b* within that local venue.

Transceiver **104** may be implemented as a wireless communication unit controlled by CPU **112** of controller **110** and enabling image display system **100** to exchange data with remote venue **111**. For example, transceiver **104** may be implemented to support communication via WiFi, may take the form of a 3G or 4G wireless transceiver, or may be a 5G wireless transceiver configured to satisfy the IMT-2020 requirements established by the International Telecommunication Union (ITU).

FIG. **1**B shows a more detailed exemplary implementation of sensor network **120**, in FIG. **1**A. As shown in FIG. **1**B, sensor network **120** includes multiple sensors **122** controlled by CPU **112** of controller **110**. According to the exemplary implementation shown in FIG. **1**B, sensor network **120** also includes one or more microphone(s) **124**, analog-to-digital converter (ADC) **126**, and localization module **128**. As further shown in FIG. **1**B, sensors **122** of sensor network **120** may include radio-frequency identification (RFID) sensor **122***a*, facial recognition (FR) sensor **122***b*, automatic speech recognition (ASR) sensor **122***c*, object recognition (OR) sensor **122***d*, image sensor **122***e*, laser sensor **122***f*, and one or more position and/or rate (P/R) sensor(s) **130**.

It is noted that the specific sensors shown to be included among sensors **122** of sensor network **120** are merely exemplary, and in other implementations, sensors **122** of sensor network **120** may include more, or fewer, sensors than RFID sensor **122***a*, FR sensor **122***b*, ASR sensor **122***c*, OR sensor **122***d*, image sensor **122***e*, laser sensor **122***f*, and P/R sensor(s) **130**. RFID sensor **122***a*, FR sensor **122***b*, ASR sensor **122***c*, OR sensor **122***d*, image sensor **122***e*, laser sensor **122***f*, and P/R sensor(s) **130** may be implemented using any suitable sensors for those respective functions, as known in the art. Microphone(s) **124** may include one or more stationary and/or moving microphone(s). For example, stationary microphone(s) of microphone(s) **124** may be distributed in a 360° array surrounding base **140** to enhance directional sensing of sound, such as speech, produced by one or more of observers **168***a* and **168***b*.

In some implementations, one or more moving microphone(s) of microphone(s) **124** may rotate in synchronization with rotor **144**, housing **101**, and projection screen **160**. In those implementations, P/R sensor(s) **130** may be used in combination with microphone(s) **124** to identify the direction from which a sound sensed using microphone(s) **124** is received.

Image sensor **122***e* may correspond to one or more sensors for obtaining visual images of observers **168***a* and **168***b*, as well as the local venue in which image display system **100** and observers **168***a* and **168***b* are located. Image sensor **122***e* may be implemented as one or more stationary and/or rotating video cameras, for example.

As indicated in FIG. **1**B, in some implementations, data from P/R sensor(s) **130**, and/or data from laser sensor **122***f*, and/or data generated by ADC **126** from sounds detected by microphone(s) **124** may be processed by localization module **128** to identify the distance and/or direction of the respective sources of the sounds received by microphone(s) **124**, such as observers **168***a* and **168***b*. In those implementations, the output from localization module **128** may be provided to ASR sensor **122***c* to enhance the performance of ASR sensor **122***c* in discriminating among environmental sounds, noise, and purposeful speech by one or more of observers **168***a* and **168***b*.

FIG. **1**C shows a more detailed exemplary implementation of P/R sensor(s) **130**, in FIG. **1**B. As shown in FIG. **1**C, P/R sensor(s) **130** can include one or more base sensor(s) **130***a* integrated with base **140**, and one or more rotating sensor(s) **130***b* integrated with housing **101** and configured to spin with housing **101**.

According to the exemplary implementation shown in FIG. **1**C, base sensor(s) **130***a* may include one or more of infrared (IR) light-emitting diode (LED) **132***a*, magnet **134***a*, visible light LED **136***a*, and glyph or other visible marker **138***a*, to name a few examples. As further shown in FIG. **1**C, rotating sensor(s) **130***b* may include one or more of IR receiver **132***b* for sensing IR LED **132***a*, Hall effect sensor **134***b* for sensing magnet **134***a*, photo diode **136***b* for sensing visible light LED **136***a*, and one or more camera(s) **138***b* for sensing glyph or visible marker **138***a*. In addition, rotating sensor(s) **130***b* are shown to be coupled to rotational tracking module **131**.

It is noted that the distribution of features identified by reference numbers **132***a*, **134***a*, **136***a*, **138***a*, **132***b*, **134***b*, **136***b*, and **138***b* between base sensor(s) **130***a* and rotating sensor(s) **130***b* is merely exemplary. In another implementation, for example, the positions of features **132***a*, **134***a*, **136***a*, **138***a*, **132***b*, **134***b*, **136***b*, and **138***b* may be reversed. That is to say, one or more of IR LED **132***a*, magnet **134***a*, visible light LED **136***a*, and glyph or visible marker **138***a* may be included as rotating sensor(s) **130***b*, while one or more of IR receiver **132***b*, Hall effect sensor **134***b*, photo diode **136***b*, and camera(s) **138***b* may be included as base sensor(s) **130***a*. It is further noted that camera(s) **138***b* may include one or more still camera(s) and/or one or more video camera(s), for example.

As indicated in FIG. **1**C, in some implementations, data from one or more of IR receiver **132***b*, Hall effect sensor **134***b*, photo diode **136***b*, and camera **138***b* is processed by rotational tracking module **131** to identify the rotational position of projection screen **160** being tracked by P/R sensor(s) **130** at any point in time. In those implementations, the output from rotational tracking module **131** may be provided to controller **110** or software code **108** to enhance the performance of image display system **100** in displaying multiple perspectives of floating image **116**, or in capturing image data of the venue local to image display system **100** for transmission to remote venue **111**.

As noted above by reference to FIG. **1**A, in some implementations, motor **142** may be a brushless synchronous motor, due to the high temporal stability of such a motor. Moreover, in some implementations, the spin rate at which motor **142** spins rotor **144**, first projection unit **170***a*, second projection unit **170***b*, housing **101**, and projection screen **160** can be served, based on inputs from P/R sensor(s) **130** and/or rotational tracking module **131**, to ensure that first and second perspectives **117***a* and **117***b* of floating image **116** display are in reliably appropriate and repeatable positions for each of observers **168***a* and **168***b*.

FIG. **2**A shows a diagram of an exemplary image display system for generating multiple perspectives of a floating image free of motion-blur, according to another implementation. As shown in FIG. **2**A, image display system **200** includes stationary base **240**, first projection unit **270***a* mounted on or otherwise secured to housing **201**, and projection screen **260**. Base **240** is shown to include motor **242**, and to be situated on surface **250**, which may be a floor or any other substantially horizontal surface. In addition, according to the exemplary implementation shown in FIG. **2**A, image display system **200** includes rotor **244** coupling base **240** to housing **201** and projection screen **260**.

Housing **201** includes first projection unit **270***a* mounted on or otherwise secured to housing **201** and configured to spin with rotor **244**, housing **201**, and projection screen **260**. In addition, FIG. **2**A shows first projection surface **262***a* of projection screen **260** having first perspective **217***a* corresponding to first perspective **117***a* of floating image **116**, in FIG. **1**A, displayed thereon by first projection unit **270***a*. Also shown in FIG. **2**A are horizontal X axis **252** substantially parallel to surface **250**, vertical Z axis **254** substantially perpendicular to surface **250**, spin direction **256** of rotor **244**, housing **201**, first projection unit **270***a*, and projection screen **260**, as well as perspective lines **2**B-**2**B and **2**C-**2**C.

As further shown FIG. **2**A, rotor **244** is configured to spin housing **201**, first projection unit **270***a* secured to housing **201**, and projection screen **260** about axis of rotation **258** of rotor **244**, which is parallel to vertical Z axis **254** and perpendicular to horizontal X axis **252**. It is noted that projection screen **260** is situated on axis of rotation **258** of rotor **244**, housing **201**, first projection unit **270***a*, and projection screen **260**. For example, in some implementations, projection screen **260** may be sufficiently thin to have first projection surface **262***a* and a second projection surface opposite first projection surface **262***a* precisely aligned on axis of rotation **258**, and so as to be centered on axis of rotation **258** (second projection surface not visible from the perspective shown by FIG. **2**A).

Image display system **200** corresponds in general to image display system **100**, in FIG. **1**A. As a result, image display system **200** may share any of the characteristics attributed to image display system **100** by the present disclosure, and vice versa. For example, like image display system **100**, image display system **200** includes sensor network **120** bridging base **240** and housing **201**. In addition, rotor **244**, base **240**, and motor **242**, correspond in general to rotor **144**, base **140**, and motor **142**, in FIG. **1**A. Thus, rotor **244**, base **240**, and motor **242** may share any of the characteristics attributed to rotor **144**, base **140**, and motor **142** by the present disclosure, and vice versa.

Moreover, projection screen **260** having first projection surface **262***a* displaying first perspective **217***a*, in FIG. **2**A, corresponds in general to projection screen **160** having first projection surface **162***a* displaying first perspective **117***a* of floating image **116**, in FIG. **1**A. Thus, projection screen **260** may share any of the characteristics attributed to projection screen **160** by the present disclosure, and vice versa.

Housing **201** and first projection unit **270***a* mounted on or otherwise secured to housing **201** correspond respectively in general to housing **101** and first projection unit **170***a*, in FIG. **1**A. In other words, although not explicitly shown in FIG. **2**A, housing **201** includes features corresponding respectively to computing platform **102** including transceiver **104**, controller **110** having CPU **112**, GPU(s) **113**, optional DSP **114**, and batteries **171***a* and **171***b*, and may include system memory **106** storing software code **108**. In addition, computing platform **102** of housing **201** may be communicatively coupled to one or more of, audio system **115**, 360° degree camera **118**, and laser **119**. Furthermore, and although also not shown in the perspective offered by FIG. **2**A, image display system **200** further includes a second projection unit corresponding to second projection unit **170***b* mounted on or otherwise secured to housing **201** on the opposite side of rotor **244** from first projection unit **270***a*.

FIG. **2**B shows a side view of exemplary image display system **100**/**200** along perspective lines **2**B-**2**B in FIG. **2**A, according to one implementation. It is noted that the features identified in FIG. **2**B by reference numbers identical to reference numbers shown in FIG. **2**A correspond respectively to those previously described features and may share any of the characteristics attributed to those corresponding features by the present disclosure, and vice versa.

As shown in FIG. **2**B, image display system **100**/**200** includes stationary base **140**/**240**, first projection unit **170***a*/**270***a* mounted on or otherwise secured to housing **101**/**201**, battery **271***a* for powering first projection unit **170***a*/**270***a*, second projection unit **270***b* mounted on or otherwise secured to housing **101**/**201** opposite first projection unit **170***a*/**270***a*, and battery **271***b* for powering second projection unit **270***b*. Image display system **100**/**200** further includes projection screen **160**/**260** having first projection surface **162***a*/**262***a* on first side **261***a* of projection screen **160**/**260** and second projection surface **262***b* on second side **261***b* of projection screen **160**/**260** opposite to first side **261***a*.

It is noted that second projection unit **270***b* corresponds in general to second projection unit **170***b*, in FIG. **1**A. That is to say, second projection unit **170***b* may share any of the characteristics attributed to second projection unit **270***b* by the present disclosure, and vice versa. It is further noted that batteries **271***a* and **272***b*, in FIG. **2**B, correspond respectively in general to batteries **171***a* and **171***b*, in FIG. **1**A. Thus, batteries **271***a* and **271***b* may share any of the characteristics attributed to batteries **171***a* and **171***b* by the present disclosure, and vice versa. In addition, FIG. **2**B depicts second perspective **217***b* corresponding to second perspective **117***b* of floating image **116**, in FIG. **1**A.

Base **140**/**240** is shown to include motor **142**/**242**, and to be situated on surface **150**/**250**, which may be a floor or any other substantially horizontal surface. In addition, according to the exemplary implementation shown in FIG. **2**B, image display system **100**/**200** includes rotor **144**/**244** coupling base **140**/**240** to housing **101**/**201** and projection screen **160**/**260**. Also shown in FIG. **2**B are axis of rotation **258** of rotor **144**/**244**, and spin direction **256** of rotor **144**/**244**, housing **101**/**201**, first projection unit **170***a*/**270***a*, second projection unit **170***b*/**270***b*, and projection screen **160**/**260**. FIG. **2**B further shows thickness **266** of projection screen **160**/**260**, as well as horizontal axis **253** (hereinafter also "Y axis **253**") substantially parallel to surface **250** and perpendicular to each of horizontal X axis **252** and vertical Z axis **254**.

Rotor **144**/**244** is configured to spin housing **101**/**201**, first projection unit **170***a*/**270***a* and second projection unit **170***b*/**270***b* mounted on or otherwise secured to housing **101**/**201**, and projection screen **160**/**260** about axis of rotation **258** of rotor **244**, which is parallel to vertical Z axis **254**. As noted above, thickness **266** of projection screen **160**/**260** may be sufficiently thin to allow first projection surface **162***a*/**262***a* and second projection surface **262***b* opposite first projection surface **162***a*/**262***a* to be precisely aligned on axis of rotation **258**, and so as to be centered on axis of rotation **258**. For example, in some implementations, thickness **266** of projection screen **160**/**260** may be less, or substantially less, than 0.2 mm. Moreover, in some implementations, projection screen **160**/**260** may be laminated between transparent plastic films, such as acrylic or plexiglass films for example, adjacent each of first projection surface **162***a*/**262***a* and second projection surface **262***b*.

According to the exemplary implementation shown in FIG. 2B, each of first and second projection units **170***a*/**270***a* and **170***b*/**270***b* includes at least a projector projecting away from projection screen **160**/**260** and a mirror, and may further include a shutter situated between the projector and the mirror. Thus, first projection unit **170***a*/**270***a* includes at least first projector **272***a* configured to project away from projection screen **160**/**260** and having light emission source **278***a*, such as a projector lamp, for example, as well as first mirror **276***a*. In addition, in some implementations, first projection unit **170***a*/**270***a* may include first shutter **274***a* situated between first projector **272***a* and first mirror **276***a*. Second projection unit **170***b*/**270***b* includes at least second projector **272***b* opposite first projector **272***a*, and second mirror **276***b*. Second projector **272***b* having light emission source **278***b*, such as a projector lamp, for example, is also configured to project away from projection screen **160**/**260**. In addition, in some implementations, second projection unit **170***b*/**270***b* may include second shutter **274***b* situated between second projector **272***b* and second mirror **276***b*.

As shown in FIG. 2B, in some implementations, first projection unit **170***a*/**270***a* includes first mirror **276***a* configured to reflect first perspective **117***a*/**217***a* of floating image **116** projected by first projector **272***a* onto first projection surface **162***a*/**262***a* of projection screen **160**/**260**. Furthermore, and as also shown in FIG. 2B, in those implementations, second projection unit **170***b*/**270***b* includes second mirror **276***b* configured to reflect second perspective **117***b*/**217***b* of floating image **116** projected by second projector **272***b* onto second projection surface **262***b* of projection screen **160**/**260**.

In implementations in which first shutter **274***a* and second shutter **274***b* are included in respective first projection unit **170***a*/**270***a* and second projection unit **170***b*/**270***b*, first and second shutters **274***a* and **274***b* may be used to control when, for how long, and at what point in a rotation of rotor **144**/**244** respective first and second perspectives **117***a*/**217***a* and **117***b*/**217***b* of floating image **116** are displayed, for example by controlling the display interval of first and second projectors **272***a* and **272***b*. In other words, first and second shutters **274***a* and **274***b* may open during each display interval to enable first projector **272***a* to project first perspective **117***a*/**217***a* of floating image **116** to first mirror **276***a*, and to enable second projector **272***b* to project second perspective **117***b*/**217***b* of floating image **116** to second mirror **276***b*. Conversely, first and second shutters **274***a* and **274***b* may be closed during other intervals of the rotation of rotor **144**/**244**, first projector **272***a*, second projector **272***b*, and projection screen **160**/**260** about axis of rotation **258**.

First and second shutters **274***a* and **274***b* may be implemented using any type of shutter that is sufficiently fast and lightweight. In some implementations, first and second shutters **274***a* and **274***b* may be electronic shutters, such as liquid-crystal, electrochromic, or ferroelectric shutters, for example. In other implementations, first and second shutters **274***a* and **274***b* may be implemented as mechanical shutters. In one exemplary implementation, first and second shutters **274***a* and **274***b* may be implemented as twisted nematic field effect (TN) liquid-crystal shutters in order to minimize mechanical wear and to provide fast switching speeds.

In implementations in which first shutter **274***a* and second shutter **274***b* are omitted from first projection unit **170***a*/**270***a* and second projection unit **170***b*/**270***b*, first and second light emission sources **278***a* and **278***b* of respective first and second projectors **272***a* and **272***b* may be used to control the display interval of first and second projectors **272***a* and **272***b*. For example, first and second light emission sources **278***a* and **278***b* may be selectively illuminated during each display interval to enable first projector **272***a* to project first perspective **117***a*/**217***a* of floating image **116** to first mirror **276***a*, and to enable second projector **272***b* to project second perspective **117***b*/**217***b* of floating image **116** to second mirror **276***b*.

Conversely, first and second light emission sources **278***a* and **278***b* may be selectively extinguished during other intervals of the rotation of rotor **144**/**244**, first projector **272***a*, second projector **272***b*, and projection screen **160**/**260** about axis of rotation **258**. In other words, first and second light emission sources **278***a* and **278***b* may be gated or strobed to enable projection of first perspective **117***a*/**217***a* of floating image **116** to first mirror **276***a* and projection of second perspective **117***b*/**217***b* of floating image **116** to second mirror **276***b* only during predetermined display intervals.

It is noted that whether such a display interval is controlled using first and second shutters **274***a* and **274***b*, or through use of first and second light emission sources **278***a* and **278***b* of respective first and second projectors **272***a* and **272***b*, there may be multiple display intervals, such as two, three, or more display intervals, during each rotation of rotor **144**/**244**, first projection unit **170***a*/**270***a* including first projector **272***a*, second projection unit **170***b*/**270***b* including second projector **272***b*, and projection screen **160**/**260**.

FIG. **2**C shows a side view of exemplary image display system **100**/**200** along perspective lines **2**C-**2**C in FIG. **2**A, according to another implementation. It is noted that the features identified in FIG. **2**C by reference numbers identical to reference numbers shown in FIG. **2**A correspond respectively to those previously described features and may share any of the characteristics attributed to those corresponding features by the present disclosure, and vice versa.

Like the implementation shown in FIG. **2**B, according to the implementation shown in FIG. **2**C, rotor **144**/**244** is configured to spin housing **101**/**201**, first and second projection units **170***a*/**270***a* and **170***b*/**270***b* mounted on or otherwise secured to housing **101**/**201**, and projection screen **160**/**260** about axis of rotation **258**, which is parallel to vertical Z axis **254**. As noted above, thickness **266** of projection screen **160**/**260** may be sufficiently thin to allow first projection surface **162***a*/**262***a* and second projection surface **262***b* opposite first projection surface **162***a*/**262***a* to be precisely aligned on axis of rotation **258**, and so as to be centered on axis of rotation **258**. For example, in some implementations, thickness **266** of projection screen **160**/**260** may be less, or substantially less, than 0.2 mm. Moreover, in some implementations, projection screen **160**/**260** may be laminated between transparent plastic films, such as acrylic or plexiglass films for example, adjacent each of first projection surface **162***a*/**262***a* and second projection surface **262***b*.

However, in contrast to the implementation shown in FIG. 2B, according to the exemplary implementation shown in FIG. **2**C, each of first and second projection units **170***a*/**270***a* and **170***b*/**270***b* includes at least a projector projecting directly onto projection screen **160**/**260**, and may further include a shutter situated between the projector and projection screen **160**/**260**. Thus, in the implementation shown by FIG. **2**C, first projection unit **170***a*/**270***a* includes first projector **272***a* configured to project first perspective **117***a*/**217***a* of floating image **116** directly onto first projection surface **162***a*/**262***a* of projection screen **160**/**260**. Moreover, and as also shown in FIG. **2**C, in that implementation, second projection unit **170***b*/**270***b* includes second projector **272***b* configured to project second perspective **117***b*/**217***b* of floating image **116** directly onto second projection surface **262***b* of projection screen **160**/**260**.

In implementations in which first shutter **274***a* and second shutter **274***b* are included in respective first projection unit **170***a*/**270***a* and second projection unit **170***b*/**270***b*, first and second shutters **274***a* and **274***b* may be used to control when, for how long, and at what point in a rotation of rotor **144**/**244** respective first and second perspectives **117***a*/**217***a* and **117***b*/**217***b* of floating image **116** are projected directly onto projection screen **160**/**260**, for example by controlling the display interval of first and second projectors **272***a* and **272***b*, as described above. In other words, first and second shutters **274***a* and **274***b* may open during each display interval to enable first projector **272***a* to project first perspective **117***a*/**217***a* of floating image **116** directly onto first projection surface **162***a*/**262***a*, and to enable second projector **272***b* to project second perspective **117***b*/**217***b* of floating image **116** directly onto second projection surface **262***b*. Conversely, first and second shutters **274***a* and **274***b* may be closed during other intervals of the rotation of rotor **144**/**244**, first projector **272***a*, second projector **272***b*, and projection screen **160**/**260** about axis of rotation **258**.

As noted above, first and second shutters **274***a* and **274***b* may be implemented using any type of shutter that is sufficiently fast and lightweight. In some implementations, first and second shutters **274***a* and **274***b* may be electronic shutters, such as liquid-crystal, electrochromic, or ferroelectric shutters, for example. In other implementations, first and second shutters **274***a* and **274***b* may be implemented as mechanical shutters. In one exemplary implementation, first and second shutters **274***a* and **274***b* may be implemented as TN liquid-crystal shutters in order to minimize mechanical wear and to provide fast switching speeds.

In implementations in which first shutter **274***a* and second shutter **274***b* are omitted from first projection unit **170***a*/**270***a* and second projection unit **170***b*/**270***b*, first and second light emission sources **278***a* and **278***b* of respective first and second projectors **272***a* and **272***b* may be used to control the display interval of first and second projectors **272***a* and **272***b*. For example, first and second light emission sources **278***a* and **278***b* may be selectively illuminated during each display interval to enable first projector **272***a* to project first perspective **117***a*/**217***a* of floating image **116** directly onto first projection surface **162***a*/**262***a*, and to enable second projector **272***b* to project second perspective **117***b*/**217***b* of floating image **116** directly onto second projection surface **262***b*.

Conversely, first and second light emission sources **278***a* and **278***b* may be selectively extinguished during other intervals of the rotation of rotor **144**/**244**, first projector **272***a*, second projector **272***b*, and projection screen **160**/**260** about axis of rotation **258**. In other words, first and second light emission sources **278***a* and **278***b* may be gated or strobed to enable projection of first perspective **117***a*/**217***a* of floating image **116** directly onto first projection surface **162***a*/**262***a* and projection of second perspective **117***b*/**217***b* of floating image **116** directly onto second projection surface **262***b* only during predetermined display intervals.

In the implementations shown by each of FIGS. **2**B and **2**C, the use of first and second shutters **274***a* and **274***b* or first and second light emission sources **278***a* and **278***b* to control the display interval of first and second projectors **272***a* and **272***b* effectively increases the frame rate of image display system **100**/**200**, by turning on and off mid frame to allow only a narrow range of viewing for each of observers **168***a* and **168***b*. As known in the art, the term "frame rate" refers to the rate or frequency with which a new frame can be rendered on a display surface, such as first and second projection surfaces **162***a*/**262***a* and **262***b*, expressed in frames per second (fps). Thus, frame rate is to be distinguished from refresh rate, which is the rate or frequency with which the same frame can be redrawn for display.

By controlling first and second shutters **274***a* and **274***b* or first and second light emission sources **278***a* and **278***b* based upon input from P/R sensor(s) **130** and/or rotational tracking module **131**, image display system **100**/**200** ensures that first and second perspectives **117***a*/**217***a* and **117***b*/**217***b* of floating image **116** are enabled and disabled at appropriate times during the rotation of rotor **144**/**244**, first projection unit **170***a*/**270***a* including first projector **272***a*, second projection unit **170***b*/**270***b* including second projector **272***b*, and projection screen **160**/**260**. First and second shutters **274***a* and **274***b* or first and second light emission sources **278***a* and **278***b* have the added benefit of reducing motion-blur, i.e., translational blur as well as rotational blur, by providing a narrow temporal window for viewing first and second perspectives **117***a*/**217***a* and **117***b*/**217***b* of floating image **116**.

The operation of first and second shutters **274***a* and **274***b* or strobed first and second light emission sources **278***a* and **278***b* can be readily understood by considering a two observer use case, e.g., observers **168***a* and **168***b*. When motor **142**/**242** spins rotor **144**/**244**, first projection unit **170***a*/**270***a* including first projector **272***a*, second projection unit **170***b*/**270***b* including second projector **272***b*, and projection screen **160**/**260** at a spin rate of 3600 rpm, for example, and controller **110** outputs a new display frame to each of first and second projectors **272***a* and **272***b* during a single rotation (i.e., an independent graphics channel to each of first and second projectors **272***a* and **272***b*), each of first and second projectors **272***a* and **272***b* is dedicated to one of observers **168***a* and **168***b*.

Let us assume that first projector **272***a* is dedicated to observer **168***a* while second projector **272***b* is dedicated to observer **168***b*. Let us further assume that observers **168***a* and **168***b* are positioned 180° apart on opposite sides of a horizontal circle surrounding floating image **116**. When first perspective **117***a*/**217***a* (e.g., a face-to-face or frontal view of floating image **116**) from first projector **272***a* is displayed to observer **168***a* on first projection surface **162***a*/**262***a* of projection screen **160**/**260**, first shutter **274***a* is open or light emission source **278***a* is strobed on, nominally for 1.0 ms or less. Concurrently, second shutter **274***b* is open or light emission source **278***b* is strobed on, also for 1.0 ms or less, to permit observer **168***b* to see second perspective **117***b*/**217***b* (backside view of floating image **116**) displayed on the opposite, second projection surface **262***b* of projection screen **160**/**260**. It is noted that first and second shutters **274***a* and **274***b* are closed or first and second light emission sources **278***a* and **278***b* are strobed off at all other times during each rotation of rotor **144**/**244**, preventing observers **168***a* and **168***b* from viewing images other than those which are appropriate to their location and perspective of floating image **116**.

With faster image generation and projector update rates, additional observers can be added, with first and second shutters **274***a* and **274***b* being open or first and second light emission sources **278***a* and **278***b* being strobed on during multiple display intervals each rotation. For example, with graphics generator and projector update rates of one hundred and eighty hertz (180 Hz), each of first and second projection units **170***a*/**270***a* and **170***b*/**270***b* can display up to three unique images per 3600 rpm (60 Hz) rotation cycle, (where each shutter or light emission source turns on briefly at three, equally spaced positions around the rotation perimeter) such that six observers can perceive a one of six different perspectives of floating image **116**.

It is noted that the illusion of floating image **116** as a three-dimensional (3D) floating image is created by the rapid spin rate of rotor **144/244**, first projection unit **170***a*/**270***a* including first projector **272***a*, second projection unit **170***b*/**270***b* including second projector **272***b*, and projection screen **160/260**. One advantage of using first and second projection units **170***a*/**270***a* and **170***b*/**270***b*, and two-sided projection screen **160/260** having thickness **266**, is that images projected on opposite first and second projection surfaces **162***a*/**262***a* and **262***b* of projection screen **160/260** are both essentially situated on axis of rotation **258**, greatly reducing motion-blur created by offset of projection screen **160/260** from the exact center of rotation. In contrast, a typical flat panel display has a substantially larger thickness due to the integration of electronics in the housing of such a display. It is noted that even a few millimeters of flat panel display screen thickness can create unacceptable motion-blur due to the fact that a rotating display surface that is offset from the axis of rotation of the display surface creates an effective translational blur in addition to the motion-blur due purely to rotation (i.e., rotational blur). Thus, the use of the rotating projection system as described herein is advantageous over the use of rotating transmissive flat panel display solutions that attempt to achieve a similar floating image effect.

FIG. **3** shows an exemplary use case for image display system **100/200** according to one implementation. FIG. **3** shows image display system **300***a* implemented in local venue **370** utilized by local users **368***a*, **368***b*, **368***c*, and **368***d* (hereinafter "local users **368***a*-**368***d*"), as well as remote image display system **300***b* implemented in remote venue **311** utilized by remote users **369***a*, **369***b*, **369***c*, and **369***d* (hereinafter "remote users **369***a*-**369***d*"). It is noted that local venue **370** corresponds in general to the venue local to image display systems **100/200** described above, while remote venue **311** corresponds in general to remote venue **111** in FIG. **1**A. Moreover, local users **368***a* and **368***b* correspond in general to observers **168***a* and **168***b*, in FIG. **1**A.

As shown in FIG. **3**, each of image display system **300***a* and remote image display system **300***b* includes base **340**, housing **301**, and projection screen **360**. As further shown in FIG. **3**, image display system **300***a* and remote image display system **300***b* each includes rotor **344** coupling base **340** to housing **301** and projection screen **360**. In addition, FIG. **3** shows floating image **316** of remote venue **111/311**, generated by image display system **300***a*. Also shown in FIG. **3** are audio-visual data **359***b* including image data **357***b* corresponding to remote venue **111/311**, local audio-visual data **359***a* including local image data **357***a* of local venue **370**, and wireless communication link **361** between image display system **300***a* and remote image display system **300***b*.

Image display system **300***a* and remote image display system **300***b* correspond in general to image display system **100/200**, in FIGS. **1**A, **2**A, **2**B, and **2**C. As a result, image display system **300***a* and remote image display system **300***b* may share any of the characteristics attributed to image display system **100/200** by the present disclosure, and vice versa. For example, like image display system **100/200**, image display system **300***a* and remote image display system **300***b* may include sensor network **120** bridging base **340** and housing **301**. In addition, rotor **344** and base **340** correspond in general to rotor **144/244** and base **140/240** in FIGS. **1**A, **2**A, **2**B, and **2**C. Thus, rotor **344** and base **340** may share any of the characteristics attributed to rotor **144/244** and base **140/240** by the present disclosure, and vice versa. That is to say, although not explicitly shown in FIG. **3**, base **340** includes motor **142/242**.

Moreover, housing **301** and projection screen **360** correspond respectively in general to housing **101/201** and projection screen **160/260**, in FIGS. **1**A, **2**A, **2**B, and **2**C. Thus, housing **301** and projection screen **360** may share any of the characteristics attributed to respective housing **101/201** and projection screen **160/260** by the present disclosure, and vice versa. In other words, although not explicitly shown in FIG. **3**, housing **301** may include features corresponding respectively to computing platform **102** including transceiver **104**, controller **110** having CPU **112**, GPU(s) **113**, and DSP **114**, as well as system memory **106** storing software code **108**. In addition, computing platform **102** of housing **101/301** may be communicatively coupled to one or more of audio system **115**, 360° degree camera **118**, and laser **119**. Furthermore, housing **301** may include first and second projection units corresponding respectively to first and second projection units **170***a*/**270***a* and **270***b*/**270***b* situated on opposite sides of projection screen **160/260/360** and configured to rotate with rotor **144/244/344**, housing **101/201/301**, and projection screen **160/260/360**.

It is noted that floating image **316** of remote venue **111/311** corresponds to floating image **116**, in FIG. **1**A, and those corresponding features may share any of the characteristics attributed to either of floating image **116** and floating image **316** by the present disclosure. Each of local venue **370** and remote venue **111/311** may correspond to a video conferencing venue in an office complex, hospital, university, or hotel business center, for example. Alternatively, each of local venue **370** and remote venue **111/311** may correspond to a residential venue enabling remote located family members to enjoy a virtual family reunion.

As yet another alternative, each of local venue **370** and remote venue **111/311** may correspond to a gaming venue enabling participation in a multi-player video game by remote users **369***a*-**369***d* as well as local users **368***a*-**368***d*. In implementations in which local venue **370** and remote venue **111/311** are gaming venues, for example, local users **368***a*-**368***d* may correspond to local players of a multi-player video game, while remote users **369***a*-**369***d* may correspond to remote players of the multi-player video game.

According to the exemplary implementation shown in FIG. **3**, image data **357***b* of remote venue **111/311** including remote users **369***a*-**369***d*, as well as audio data generated at remote venue **111/311**, may be received by image display system **300***a* at local venue **370** as audio-visual data **359***b* via wireless communication link **361**. The audio data included in audio-visual data **359***b* may be broadcast to local users **368***a*-**368***d* by audio system **115**, while image data **357***b* corresponding to remote venue **111/311** is displayed on projection screen **160/260/360** of image display system **300***a*. As a result, and due to spinning of rotor **144/244/344**, housing **101/201/301**, and projection screen **160/260/360**, as described above, floating image **116/316** of remote venue **111/311** may appear to local users **368***a*-**368***d* as 3D interactive floating image **116/316** of remote venue **111/311** including remote users **369***a*-**369***d*.

Substantially concurrently with spinning of rotor **144/244/344**, housing **101/201/301**, and projection screen **160/260/360** of image display system **300***a* to generate floating image **116/316**, local image data **357***a* of local venue **370** including local users **368***a*-**368***d* may be obtained by image display system **300***a* using one or more of camera(s) **138***b*, 360° camera **118**, laser **119**, and laser sensor **122***f*. Local image data **357***a*, along with local audio data obtained using microphone(s) **124**, for example, may be transmitted to remote image display system **300***b* at remote venue **111**/**311** as local audio-visual data **359***a* via wireless communication link **361**.

As another example use case, image display system **100**/**200**/**300***a* and remote image display system **300***b* can be used for social or business interactions in a number of different exemplary implementations. For example, in one implementation, each of local users **368***a*-**368***d* could view remote venue **111**/**311** from a perspective substantially matching their individual locations within local venue **370**, reduced in size to fit projection screen **160**/**260**/**360** of image display system **100**/**200**/**300***a*.

FIG. **4** shows a top view of a multi-perspective image viewing environment including image display system **400** including rotor **444** configured to spin housing **401**. It is noted that projection screen **160**/**260**/**360**, first and second projection units **170***a*/**270***a* and **170***b*/**270***b*, internal features of housing **401**, and base **140**/**240**/**340** including motor **142**/**242** are not shown in FIG. **4** in the interests of conceptual clarity.

As shown in FIG. **4**, the multi-perspective image viewing environment also includes circle **472** of exemplary locations **474***a*, **474***b*, **474***c*, **474***d*, **474***e*, **474***f*, **474***g*, and **474***h* (hereinafter "locations **474***a*-**474***h*") from which to observe floating image **116**, in FIG. **1**A. Also shown in FIG. **4** are observer **468***a* viewing first perspective **417***a* of floating image **116**, and observer **468***b* viewing second perspective **417***b* of floating image **116**. It is noted that circle **472** including exemplary locations **474***a*-**474***h* for viewing different perspectives of floating image **116** is substantially concentric with rotor **444**.

Image display system **400** including rotor **444** and housing **401** corresponds in general to image display system **100**/**200**/**300***a* and to remote image display system **300***b* in FIGS. **1**A, **2**A, **2**B, **2**C, and **3** (hereinafter "image display system **100**/**200**/**300***a*/**300***b*"). Thus, image display system **400**, rotor **444**, and housing **401** may share any of the characteristics attributed to respective image display system **100**/**200**/**300***a*/**300***b*, rotor **144**/**244**/**344**, and housing **101**/**201**/**301** by the present disclosure, and vice versa. In addition, observer **468***a*, observer **468***b*, first perspective **417***a*, and second perspective **417***b* correspond respectively in general to observer **168***a*, observer **168***b*, first perspective **117***a*, and second perspective **117***b*, in FIG. **1**A. In addition, first perspective **417***a* and second perspective **417***b* correspond respectively in general to first perspective **217***a* and second perspective **217***b* in FIGS. **2**A, **2**B, and **2**C.

In one exemplary use case, observer **168***a*/**468***a* may be at location **474***a* corresponding to a zero crossing of circle **472**, i.e., 0° or 360° along the circumference of circle **472**, as detectable using sensor network **120**. From that location, observer **168***a*/**468***a* may face a front side of floating image **116**, for example, and view floating image **116** displayed by image display system **100**/**200**/**300***a*/**300***b*/**400** from frontal first perspective **117***a*/**217***a*/**417***a*. By contrast, observer **168***b*/**468***b* located so as to face a backside of floating image **116** from location **474***e*, i.e., a location 180° apart from location **474***a* of observer **168***a*/**468***a*, would view floating image **116** as if from backside second perspective **117***b*/**217***b*/**417***b*. In other words, in an exemplary use case in which floating image **116** is observable from two locations corresponding to location **474***a* and **474***e*, image display system **100**/**200**/**300***a*/**300***b*/**400** may display two perspectives of floating image **116**.

In other use cases, however, more perspectives of floating image **116** may be displayed. For example, in one implementation, circle **472** may include four locations for viewing floating image **116** that are 90° apart with respect to circle **472**, e.g., locations **474***a*, **474***c*, **474***e*, and **474***g*. In that implementation, first and second perspectives **117***a*/**217***a*/**417***a* and **117***b*/**217***b*/**417***b* may once again be respective frontal and backside perspectives of floating image **116**, while the perspectives viewable from locations **474***c* and **474***g* may be opposing side views of floating image **116** (i.e. left and right side view perspectives).

As another example, in implementations in which circle **472** includes six locations for viewing floating image **116**, e.g., locations **474***a*-**474***h*, each of those locations may be 60° apart with respect to circle **472**. In that implementation, image display system **100**/**200**/**300***a*/**300***b*/**400** may be configured to display six distinct perspectives of floating image **116** that correspond respectively to locations **474***a*-**474***h*. It should be understood, that with an increasing spin rate and an increasing number of alternating and distinct views (e.g. up to 360 distinct views), up to 360° holographic view of floating image **116** may be achieved.

The functionality of image display system **100**/**200**/**300***a*/**300***b*/**400** will be further described by reference to FIG. **5**. FIG. **5** shows flowchart **580** of an exemplary method for use by an image display system for generating multiple perspectives of a floating image free of motion-blur. With respect to the method outlined in FIG. **5**, it is noted that certain details and features have been left out of flowchart **580** in order not to obscure the discussion of the inventive features in the present application.

Referring to FIG. **5** in combination with FIGS. **1**A, **2**A, **2**B, **3**, and **4**, flowchart **580** begins with using motor **142**/**242** to cause rotor **144**/**244**/**344**/**444** to spin projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* about axis of rotation **258** (action **582**). Referring to FIG. **1**A, in some implementations, controller **110** may be configured to utilize motor **142**/**242** to cause rotor **144**/**244**/**344**/**444** to spin projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* about axis of rotation **258**. In some implementations, CPU **112** of controller **110** may execute software code **108** to control motor **142**/**242** so as to cause rotor **144**/**244**/**344**/**444** to spin projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* about axis of rotation **258**.

Flowchart **580** continues with displaying first perspective **117***a*/**217***a*/**417***a* of floating image **116** on first projection surface **162***a*/**262***a* of projection screen **160**/**260**/**360** using first projector **272***a* while projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* spin about axis of rotation **258** by rotor **144**/**244**/**344**/**444** (action **584**). Display of first perspective **117***a*/**217***a*/**417***a* of floating image **116** on first projection surface **162***a*/**262***a* of projection screen **160**/**260**/**360** may be performed by controller **110**. For example, in some implementations, controller **110** may utilize a first GPU of GPU(s) **113** to generate first perspective **117***a*/**217***a*/**417***a* of floating image **116** for display using first projector **272***a*.

As shown in FIG. **2**B, in some implementations, first projector **272***a* may project first perspective **117***a*/**217***a*/**417***a* away from first projection surface **162***a*/**262***a* and toward first mirror **276***a*. In those implementations, first mirror **276***a* is configured to reflect first perspective **117***a*/**217***a*/**417***a* onto first projection surface **162***a*/**262***a* of projection screen **160**/**260**/**360** in action **584**. Alternatively, and as shown in FIG. **2**C, in some implementations, first mirror **276***a* may be omitted, and first projector **272***a* may project first perspective **117***a*/**217***a*/**417***a* directly onto first projection surface **162***a*/**262***a*.

In addition, and as discussed above, one of first shutter **274***a* and light emission source **278***a* of first projector **272***a* may be utilized to control a display interval of first projector **272***a* to precisely control when, for how long, and at what point in the rotation of projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* about axis of rotation **258** the display of first perspective **117***a*/**217***a*/**417***a* on first projection surface **162***a*/**262***a* occurs. Depending on the spin rate of rotor **144**/**244**/**344**/**444**, projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* about axis of rotation **258**, the display interval of first projector **272***a* that is controlled using one of first shutter **274***a* and light emission source **278***a* of first projector **272***a* may be less than or equal to 1.0 ms, such as 0.5 ms, or less, for example.

Flowchart **580** can conclude with, concurrently with displaying first perspective **117***a*/**217***a*/**417***a* of floating image **116** on first projection surface **162***a*/**262***a* of projection screen **160**/**260**/**360** using first projector **272***a*, displaying second perspective **117***b*/**217***b*/**417***b* of floating image **116** on second projection surface **262***b* of projection screen **160**/**260**/**360** using second projector **272***b* while projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* spin about axis of rotation **258** by rotor **144**/**244**/**344**/**444** (action **586**). Display of second perspective **117***b*/**217***b*/**417***b* of floating image **116** on second projection surface **262***b* of projection screen **160**/**260**/**360** may be performed by controller **110**. For example, in some implementations, controller **110** may utilize a second GPU of GPU(s) **113** to generate second perspective **117***b*/**217***b*/**417***b* of floating image **116** for display using second projector **272***b*.

As shown in FIG. 2B, in some implementations, second projector **272***b* may project second perspective **117***b*/**217***b*/**417***b* away from second projection surface **262***b* and toward second mirror **276***b*. In those implementations, second mirror **276***b* is configured to reflect second perspective **117***b*/**217***b*/**417***b* onto second projection surface **262***b* of projection screen **160**/**260**/**360** in action **586**. Alternatively, and as shown in FIG. 2C, in some implementations, second mirror **276***b* may be omitted, and second projector **272***b* may project second perspective **117***b*/**217***b*/**417***b* directly onto second projection surface **262***b*.

In addition, and as discussed above, one of second shutter **274***b* and light emission source **278***b* of second projector **272***b* may be utilized to control a display interval of second projector **272***b* to precisely control when, for how long, and at what point in the rotation of projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* about axis of rotation **258** the display of second perspective **117***b*/**217***b*/**417***b* on second projection surface **262***b* occurs. Depending on the spin rate of rotor **144**/**244**/**344**/**444**, projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* spin about axis of rotation **258**, the display interval of second projector **272***b* that is controlled using one of second shutter **274***b* and light emission source **278***b* of second projector **272***b* may be less than or equal to 1.0 ms, such as 0.5 ms, or less, for example.

In implementations in which the display interval of first projector **272***a* and second projector **272***b* are controlled using respective first and second shutters **274***a* and **274***b*, controller **110** may further determine a substantially optimum timing for opening and closing first and second shutters **274***a* and **274***b*. In one such implementation, for example, controller **110** may receive P/R data from one or more of P/R sensor(s) **130**, such as Hall effect sensor **134***b*, and may determine a substantially optimum timing for opening and closing first and second shutters **274***a* and **274***b* based on the P/R data. In that implementation, controller **110** may then control first and second shutters **274***a* and **274***b* based on the deterrmined timing.

It is noted that although the display interval of first projector **272***a* and the display interval of second projector **272***b* will typically share the same time duration, they may not always coincide. For example, referring to FIGS. **1**A and **4**, if observers of floating image **116** are positioned at locations **474***a*, **474***c*, and **474***e* on circle **472**, the display intervals for frontal first perspective **117***a*/**217***a*/**417***a* and backside second perspective **117***b*/**217***b*/**417***b* of floating image **116** being displayed to respective observers **468***a* and **468***b* may coincide. However, only one of first projector **272***a* or second projector **272***b* need be utilized to display a side perspective of floating image **116** to the observer at location **474***c*, while no opposite perspective of floating image **116** need be displayed for viewing from vacant location **474***g*. In general, the display interval of first projector **272***a* and the display interval of second projector **272***b* will coincide when image display system **100**/**200**/**300***a*/**300***b*/**400** generates an even number of perspectives of floating image **116** for display to observers symmetrically located on circle **472**, i.e., at locations **474***a*, **474***c*, **474***e*, and **474***g*, or at locations **474***b*, **474***d*, **474***f*, and **474***h*, or at locations **474***a*-**474***h*.

It is further noted that the spin rate at which rotor **144**/**244**/**344**/**444**, projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b*, spin about axis of rotation **258** may depend in part on the frame rate of image display system **100**/**200**/**300***a*/**300***b*/**400**. In addition to the frame rate of image display system **100**/**200**/**300***a*/**300***b*/**400**, the spin rate with which rotor **144**/**244**/**344**/**444**, projection screen **160**/**260**/**360**, first projector **272***a*, and second projector **272***b* spin or rotate about axis of rotation **258** may be based on the number of perspectives of floating image **116** being displayed by image display system **100**/**200**/**300***a*/**300***b*/**400**.

Thus, the present application discloses systems and methods for displaying multiple perspectives of a floating image that are substantially free of motion-blur, using spinning projectors. By using projectors to display different perspectives of an image on opposite projection surfaces of a projection screen while spinning the projection screen and the projectors using a motor and a rotor, the systems and methods disclosed by the present application enable the generation of multiple perspectives of the image as an apparently 3D floating image. Moreover, by substantially centering the projection surfaces on an axis of rotation of the rotor while precisely controlling a display interval during which the projectors can display the perspectives on the opposite projection surfaces, the present solution advantageously enables generation of the multiple perspectives of the 3D floating image having no perceptible rotational or translational blur. As a result, the image display solution disclosed by the present application advantageously enables realistic, engaging, and immersive group interactions among group participants whether those participants are present in a common venue or are physically remote from one another.

From the above description it is manifest that various techniques can be used for implementing the concepts described in the present application without departing from the scope of those concepts. Moreover, while the concepts have been described with specific reference to certain implementations, a person of ordinary skill in the art would recognize that changes can be made in form and detail without departing from the scope of those concepts. As such, the described implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present application is not limited to the particular implementations described herein, but many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

What is claimed is:

1. An image display system comprising:
   a motor configured to spin a rotor;
   a first projector;
   a second projector;
   a projection screen having a first projection surface on a first side of the projection screen and a second projection surface on a second side of the projection screen opposite to the first side; and
   a controller configured to:
      cause the motor to spin the rotor that spins the projection screen, the first projector, and the second projector about an axis;
      display a first perspective of an image on the first projection surface of the projection screen using the first projector while the projection screen, the first projector, and the second projector spin about the axis by the rotor; and
      concurrently with displaying the first perspective of the image on the first projection surface of the projection screen using the first projector, display a second perspective of the image on the second projection surface of the projection screen using the second projector.

2. The image display system of claim **1**, wherein the first projector and the second projector are configured to project the respective first and second perspectives of the image directly onto the projection screen.

3. The image display system of claim **2**, further comprising a first shutter situated between the first projector and the projection screen, and a second shutter situated between the second projector and the projection screen, wherein a display interval of the first projector and the second projector is controlled using the first shutter and the second shutter.

4. The image display system of claim **1**, further comprising a first mirror configured to reflect the first perspective of the image onto the first projection surface, and a second mirror configured to reflect the second perspective of the image onto the second projection surface.

5. The image display system of claim **4**, further comprising a first shutter situated between the first projector and the first mirror, and a second shutter situated between the second projector and the second mirror, wherein a display interval of the first projector and the second projector is controlled using the first shutter and the second shutter.

6. The image display system of claim **1**, wherein a display interval of the first projector and the second projector is controlled using respective first and second shutters, and wherein the controller is further configured to:
   receive at least one of position or rotation data from a sensor of the image display system;
   determine a timing for opening and closing the first and second shutters based on the at least one of position or rotation data; and
   control the first and second shutters based on the determined timing.

7. The image display system of claim **1**, wherein a display interval of the first projector and the second projector is controlled using a light emission source of the first projector and a light emission source of the second projector.

8. The image display system of claim **1**, wherein a display interval of the first projector and the second projector is less than or equal to one millisecond (≤1.0 ms).

9. The image display system of claim **1**, wherein the image display system is configured to generate one of four perspectives of the image observable 90° apart with respect to a circle concentric with the rotor, and six perspectives of the image observable 60° apart with respect to the circle concentric with the rotor.

10. The image display system of claim **1**, wherein the image appears to be a three-dimensional (3D) image floating in space.

11. A method for use by an image display system including a motor configured to spin a rotor that spins a first projector, a second projector, and a projection screen having a first projection surface on a first side of the projection screen and a second projection surface on a second side of the projection screen opposite to the first side, the method comprising:
   causing the motor to spin the rotor that spins the projection screen, the first projector, and the second projector about an axis;
   displaying a first perspective of an image on the first projection surface of the projection screen, using the first projector, while the projection screen, the first projector, and the second projector spin about the axis by the rotor; and
   concurrently with displaying the first perspective of the image on the first projection surface of the projection screen using the first projector, displaying a second perspective of the image on the second projection surface of the projection screen, using the second projector.

12. The method of claim **11**, wherein the first and second perspectives of the image are displayed by being projected directly onto the projection screen.

13. The method of claim **12**, further comprising using a first shutter situated between the first projector and the projection screen, and a second shutter situated between the second projector and the projection screen to control a display interval of the first projector and the second projector.

14. The method of claim **11**, wherein the first perspective of the image is displayed by being reflected onto the first projection surface by a first mirror, and the second perspective of the image is displayed by being reflected onto the second projection surface by a second mirror.

15. The method of claim **14**, further comprising using a first shutter situated between the first projector and the first mirror, and a second shutter situated between the second projector and the second mirror to control a display interval of the first projector and the second projector.

16. The method of claim **11**, wherein a display interval of the first projector and the second projector is controlled using respective first and second shutters, and wherein the method further comprises:
   receiving at least one of position or rotation data from a sensor of the image display system;
   determining a timing for opening and closing the first and second shutters based on the at least one of position or rotation data; and
   controlling the first and second shutters based on the determined timing.

17. The method of claim **11**, wherein a display interval of the first projector and the second projector is controlled

using a light emission source of the first projector and a light emission source of the second projector.

18. The method of claim **11**, wherein a display interval of the first projector and the second projector is less than or equal to one millisecond (≤1.0 ms).

19. The method of claim **11**, wherein the method generates one of four perspectives of the image observable 90° apart with respect to a circle concentric with the rotor, and six perspectives of the image observable 60° apart with respect to the circle concentric with the rotor.

20. The method of claim **11**, wherein the image appears to be a three-dimensional (3D) image floating in space.

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