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Display device with optical waveguide and projector

Abstract

A display device for use in displaying an augmented reality image of a real-world view or a virtual reality image. The display device comprises an optical waveguide having an input optical element for receiving an image and at least one output optical element for outputting the image, a projector for generating the image, the projector being physically coupled to the optical waveguide, and a projector housing containing at least some components of the projector. The projector housing is moveable with respect to the optical waveguide. The projector housing contains the at least some components of the projector so that the image generated by the projector is fixed relative to the projector housing. The projector includes an image processor to correct the image generated by the projector and received by the input optical element of the optical waveguide dependent on a position of the projector housing relative to the optical waveguide.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 17/561,081 filed Dec. 23, 2021, which claims priority to U.S. provisional patent application Ser. No. 63/199,427 filed Dec. 27, 2020, which are incorporated herein by reference in their entirety.

FIELD
(1) The present disclosure relates generally to a display device comprising a projector and a waveguide for displaying an augmented reality image of a real-world view or a virtual reality image to a user.
BACKGROUND
(2) Imaging waveguides can be used to present projected information to the eye of an observer in a head mounted display arrangement. In one instance where the waveguide is provided within an occluded housing, no light from the real-world is permitted to enter and pass through the waveguide. As such, in this configuration the waveguide would be considered as a virtual reality arrangement. Essentially the waveguide functions as a monitor or display with a relaxed viewing distance and a large eyebox.
(3) In another configuration a waveguide may be provided in an un-occluded housing, where light from the real-world can pass through the waveguide to the eye of a viewer. When no light is directed into the waveguide from the projector, a user would simply observe the real-world through the waveguide. When a projector actively introduces light into the waveguide, such introduced light may be mixed or combined with light from the real-world to form an augmented reality experience, in which a viewer will see projected images superimposed on the real-world.
(4) Prior art devices exist which either operate solely as virtual reality displays, such as for example

the Oculus Rift® from Facebook®, or solely as augmented reality displays, such as HoloLens® from Microsoft®, however no device can be user selectable to operate as either a virtual reality display or an augmented reality display.

SUMMARY

(5) The present invention provides a method and system as defined in the appended claims.

(6) In one aspect the present invention provides a display device for use in displaying an augmented reality image of a real-world view or a virtual reality image to a user, the display device comprising an optical waveguide having an input optical element for receiving an image and at least one output optical element for outputting the image, a projector for generating the image, the projector being physically coupled to the optical waveguide and a projector housing containing at least some components of the projector, the projector housing being relatively moveable with respect to the optical waveguide between a relative position in which a real-world view through the optical waveguide in the region of the at least one output optical element is occluded and a relative position in which the real-world view through the optical waveguide in the region of the at least one output optical element is not occluded.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) Various ones of the appended drawings merely illustrate example embodiments of the present invention and cannot be considered as limiting its scope.

(2) FIGS. **1**A and **1**B illustrate an optical waveguide configuration for use in an example display device;

(3) FIGS. **2**A and **2**B illustrate an alternative optical waveguide configuration for use in an example display device;

(4) FIGS. **3**A and **3**B illustrate a display device of a first display device arrangement in a virtual reality display mode;

(5) FIGS. **4**A and **4**B illustrate a display device of a first display device arrangement in a first augmented reality display mode;

(6) FIGS. **5**A and **5**B illustrate a display device of a first display device arrangement in a second augmented reality display mode;

(7) FIGS. **6**A, **6**B and **6**C illustrate orientations of the input image and the output image according to different arrangements of one display device configuration;

(8) FIGS. **7**A, **7**B and **7**C are schematic diagrams of the projector components in various display device configurations;

(9) FIGS. **8**A, **8**B and **8**C illustrate a display device of a second display device arrangement in a virtual reality display mode;

(10) FIGS. **9**A and **9**B illustrate a display device of a second display device arrangement in a first augmented reality display mode; and

(11) FIGS. **10**A, **10**B and **10**C illustrate a display device of a second display device arrangement in a second augmented reality display mode.

DETAILED DESCRIPTION

(12) The description that follows includes devices, methods, and techniques that embody illustrative embodiments of the present invention. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide an understanding of various embodiments of the inventive subject matter. It will be evident, however, to those skilled in the art that embodiments of the inventive subject matter may be practiced without these specific details. In general, well-known structures, and techniques have not been shown in detail.

(13) A generalized display device for use in displaying an augmented reality image of a real-world

view or a virtual reality image to a user comprises an optical waveguide having an input optical element for receiving an image and at least one output optical element for outputting the image, a projector for generating the image, the projector being physically coupled to the optical waveguide, and a projector housing containing at least some components of the projector, the projector housing being relatively moveable with respect to the optical waveguide between a relative position in which a real-world view through the optical waveguide in the region of the at least one output optical element is occluded and a relative position in which the real-world view through the optical waveguide in the region of the at least one output optical element is not occluded.
(14) The projector housing serves two functions, namely housing most, if not all, of the components of the projector used to generate the image input to the input optical element, and acting as a screen or shutter to enable the display device to operate in two different modes: a virtual reality mode when the projector housing occludes the real-world view through the optical waveguide in the region of the at least one output optical element, and an augmented reality mode when the projector housing does not occlude the real-world view through the optical waveguide in the region of the at least one output optical element.
(15) The use of the projector housing avoids the need for additional components to provide for the occlusion of the real-world view and a simple relative movement between the optical waveguide and the projector housing provides a simple shutter mechanism.
(16) The display device may be arranged to have one or two output optical elements to provide a monocular or binocular display device.
(17) The projector may be contained within and comprise the projector housing and be rotatably attached to the optical waveguide and be relatively rotatable with respect to the optical waveguide between the relative position in which a real-world view through the optical waveguide in the region of the at least one output optical element is occluded and the relative position in which the real-world view through the optical waveguide in the region of the at least one output optical element is not occluded
(18) The relative position in which the real-world view through the optical waveguide in the region of the at least one output optical element is not occluded may be at 90°, 180° or 270° to the relative position in which a real-world view through the waveguide in the region of the at least one output optical element is occluded.
(19) The input optical element may be configured to receive the image from the projector independent of the orientation of the projector relative to the optical waveguide.
(20) The optical waveguide may extend in a plane, and the projector housing may lie substantially parallel to the plane of the optical waveguide. The projector housing may be relatively rotatable with the optical waveguide so that the projector housing lies to remain substantially parallel to the plane of the optical waveguide.
(21) The projector housing may contain the projector so that the image output from the projector is fixed relative to the projector housing. The projector may include an image processor to correct the orientation of the image generated by the projector and received by the input optical element of the optical waveguide dependent on the relative orientation of the projector housing and the optical waveguide.
(22) In an alternative arrangement, a projector output element of the projector is fixed to the optical waveguide separate to the projector housing, the projector housing rotates relatively to the projector output element, and at least one optical or electric coupling is provided between components in the projector housing and the projector output element.
(23) The optical waveguide and the projector housing may be configured to enable the projector housing to relatively move with respect to the optical waveguide by translation so that they can relatively slide across one another. In such an arrangement, the projector output element of the projector may be fixed to the optical waveguide separate to the projector housing. The projector housing can then translate relatively to the projector output element, and at least one optical or

electric coupling can be provided between components in the projector housing and the projector output element.
(24) The optical waveguide may extend in a plane, and the optical waveguide and the projector housing may be configured to enable the projector housing to relatively rotate with respect to the optical waveguide around an axis substantially parallel to the plane. In such an arrangement, the projector output element of the projector may be fixed to the optical waveguide separate to the projector housing. The projector housing can then rotate relatively to the projector output element, and at least one optical or electric coupling can be provided between components in the projector housing and the projector output element.
(25) When a projector includes a projector output element separate to the projector housing, it may include an optical image generator element, and the coupling provided between components in the projector housing and the projector output element may comprise at least one electrical coupling.
(26) When a projector includes a projector output element separate to the projector housing, it may include at least one optical component, and the coupling provided between components in the projector housing and the projector output element may comprise at least one optical coupling.
(27) The projector housing may be coupled to the optical waveguide to rotate about the input optical element.
(28) At least one of the input optical element and the output optical element may be a surface relief diffractive element.
(29) The at least one output optical element may be adapted to output the image in an expanded form compared with the form of the image input to the input optical element from the projector.
(30) The optical waveguide may include a least one intermediate optical element to receive the image from the input optical element and to output the image in an expanded form to the output optical element, the output image is in an expanded form compared with the form of the image input to the input optical element from the projector.
(31) The projector may be arranged to input the image to the input optical element on a first side of the optical waveguide, and the output optical element may be arranged to output the image on a second side opposed the first side.
(32) The display device may act in a virtual reality display mode when the projector housing is relatively positioned to occlude a real-world view through the optical waveguide in the region of the at least one output optical element, and in an augmented reality display mode when the projector housing is relatively positioned to not occlude a real-world view through the optical waveguide in the region of the at least one output optical element.
(33) The display device can comprise a head-mounted display device incorporated into for example, a helmet or a frame, such as glasses of googles, to be worn by a user so that the output optical element is arranged to lie a short distance from the eye of the viewer, so that the viewer can view the real world through the output optical element of the optical waveguide, as well as overlaid displayed image elements, in an augmented reality mode when not occluded by the projector housing. The optical waveguide allows light from the real world to pass through the output optical element when not occluded.
(34) The use of the projector housing as an occlusion or shutter to block the light reaching the output optical element in the display device performs additional occlusion functions. The occlusion of the ambient light from the real-world view avoids distracting background image information when not required when the display device is operating in a virtual reality mode. The occlusion to avoid the ambient light also increases contrast for the viewing of the displayed image from the output optical element. Further, since the image is output from the output optical element in both directions (sides) from the optical waveguide, the occlusion of the face of the waveguide away from the intended viewing direction of the image by the viewer, blocks the output of the image to reduce the likelihood of any third party viewing the image. This improves security and confidentiality for sensitive information in the viewed image.

(35) The display device in various arrangements can thus act as a hybrid virtual reality and augmented reality display device.
(36) Specific embodiments will now be described with reference to the figures.
(37) In general, a display device in accordance with an embodiment requires an optical waveguide with an input optical arrangement to couple the input image from a projector into the optical waveguide and at least one output optical arrangement to output the image to at least one eye of a viewer or user in an expanded form. Any optical configuration that provides an input coupling for a projector and an expanded output can be used. The optics required for the projector output will depend on the orientation of the generated image, i.e. the orientation of the light emitting elements of the projector, and the optical components required can include one or more lenses, one or more prisms and/or one or more mirrors i.e. the requisite refractive and reflective optical elements to take the image generated by light emitting elements to the surface of the input optical element of the optical waveguide.
(38) In one arrangement the input optical element of the optical waveguide may be a surface relief diffractive element and the at least one output optical element may also be a surface relief diffractive element, as for example described in GB2529003, the disclosure of which is hereby incorporated in its entirety.
(39) Different forms of waveguides for use with the display device, will now be considered before describing various display device configurations.
(40) FIGS. **1**A and **1**B and FIGS. **2**A and **2**B illustrate two different waveguide configurations will now be described.
(41) FIG. **1**A is a perspective view and FIG. **1**B is a front view of an optical waveguide **10**. Such an optical waveguide **10** is shown in the prior art in WO2008/081070, the disclosure of which is hereby incorporated in its entirety.
(42) The optical waveguide **10** has an input grating **11** to couple an input image from a projector into the optical waveguide **10** and an output grating **13** to output the image to an eye of a viewer **15** in an expanded form compared with the form of the image input to the input grating **11** from a projector. A crossed grating **12** is provided in the optical path between the input and output gratings **11** and **13**. The crossed grating **12** includes two overlapping gratings with grooves at 90° to one another. Light travels by total internal reflection from the input grating **11** towards the crossed grating **12**. When light from the input grating **11** encounters the crossed grating **12** it is simultaneously diffracted in opposite directions, which are mutually orthogonal to the input light beam from the input grating **11** but are within the plane of the optical waveguide **10**. The light is then diffracted again in the crossed grating **12** so that it can extend towards the output grating **13**. In this way, the crossed grating **12** can provide expansion of the input light in two opposite directions.
(43) Light is output by the crossed grating **12** within the plane of the optical waveguide and travels towards the output grating **13**. When the input light encounters the output grating **13** it is either transmitted or diffracted. The transmitted portion of the beam extends within the output grating **13**, and the diffracted portion of the beam is coupled out of the optical waveguide **10** towards the viewer **15**.
(44) Any transmitted portions of the beam can then be diffracted out of the waveguide **10** by later grooves of the output grating **13**. Thus, a first dimension of expansion is provided by the crossed grating **12** and a second dimension of expansion is provided by the output grating **13**. In order for this to be effective, the grating periods are selected specifically to prevent any out-coupling of light by the crossed grating **12**. Thus, the only out-coupling of light from the optical waveguide is by the output grating **13**.
(45) The optical waveguide **10** comprises an optical material extending in a plane from the input grating **11** to the output grating **13**. It has a thickness to provide for total internal reflection to guide the light from the input grating **11** to the output grating **13**.

(46) In the arrangement illustrated in FIGS. **1**A and **1**B, the image input to the input grating **11** can be input on either side and likewise the image output from the output grating **13** is output on both sides. In the illustration the image is input to the input grating **11** on one side of the optical waveguide **10** and the image is shown output from the output grating on the other side of the optical waveguide **10**. This configuration is illustrated for convenience of design as a head-mounted display since the output image is output to the eye of a wearer and there is little room on that side for the projector in a conventional arrangement. Further, in the display devices in accordance with embodiments, the provision of the projector on the other side of the optical waveguide **10** enables the use of the projector housing to occlude the side of the optical waveguide **10** away from the image output.
(47) The arrangement illustrated in FIGS. **1**A and **1**B is an optical waveguide configuration that receives an input image from a projector at the input grating **11** and generates an expanded image output from the output grating **13**. The output image is expanded compared with the form of the image input to the input grating **11** from the projector The optical configuration of the waveguide hence can meet the optical requirements for the display device. However, the need for the crossed grating **12** as an intermediate optical element to expand the image is not the most optically efficient arrangement.
(48) FIGS. **2**A and **2**B illustrate an alternative optical waveguide configuration, in which an intermediate optical element is not required.
(49) FIG. **2**A is a perspective view and FIG. **2**B is a front view of an optical waveguide **20**. Such an optical waveguide **20** in shown in the prior art in GB2529003, the disclosure of which is hereby incorporated in its entirety.
(50) The optical waveguide **20** has an input grating **21** to couple an input image from a projector into the optical waveguide **20** and an output grating **23** to output the image to an eye of a viewer **25** in an expanded form compared with the form of the image input to the input grating **21** from the projector. Light output by the input grating **21** travels by total internal reflection towards the output grating **23**.
(51) The output grating **23** includes two overlapping gratings with grooves at angles to one another. When light from the input grating **21** encounters the output grating **23** it is simultaneously diffracted in opposite directions, which are at an angle to the input light beam from the input grating **21** within the plane of the optical waveguide **20**. It is also diffracted out of the waveguide **20**. In this way, the output grating **23** can provide expansion of the input light in two opposite directions as well as outputting the light from the optical waveguide **20** towards the viewer **25**.
(52) Although the output grating **23** is shown as two separated angled gratings in FIGS. **2**|A and **2**B, an any form of grating structure or optical element can be used that provides for both image expansion and image output.
(53) The optical waveguide **20** comprises an optical material extending in a plane from the input grating **21** to the output grating **23**. It has a thickness to provide for total internal reflection to guide the light from the input grating **21** to the output grating **23**.
(54) A first display device arrangement will now be described with reference to FIGS. **3**A, **3**B, **4**A, **4**A **5**A and **5**B. FIG. **3**A is a perspective view and FIG. **3**B is a plan view of the display device in a virtual reality display mode, in which the view of the real-world by the viewer **38** is occluded.
(55) An optical waveguide **31** comprises a waveguide as described with reference to FIGS. **1**A and **1**B or FIGS. **2**A and **2**B and as a minimum it has an input optical element **35** and an output optical element **32**. If the arrangement of FIGS. **1**A and **1**B is used, an intermediate optical element can be used (not shown). The input optical element **35** and the output optical element **32** are spaced along the plane of the optical waveguide **31**. The input optical element **35** is arranged to receive an input image from a projector housing **30**. The optical output element **32** is arranged to provide an output expanded image to the eye of a viewer **38**, wherein the output image is expanded compared with the form of the image input to the input optical element from the projector.

(56) The projector in this arrangement is arranged in a projector housing **30** that lies in a substantially parallel to the plane of the optical waveguide **31** and lying adjacent to a side or face of the optical waveguide **30** away from the viewer **38** and on the opposite side from the side of the optical waveguide that the optical output element **32** outputs the expanded image. The projector housing **30** contains the components of the projector, including the electronic components and the optical components as will be described in more detail hereinafter.
(57) The projector housing **30** is coupled to the optical waveguide **31** between the opposed faces in the region of the input optical element **35** by a rotatable coupling **33** that allows relative rotation of the projector housing **30** and the optical waveguide **31** about an axis substantially perpendicular to the plane of the optical waveguide **31** and centered on the optical input element **35**. The rotatable coupling **33** permits the projector housing **30** to be rotated relatively to the optical waveguide **31** through a range of angles.
(58) In this arrangement light is projected through the internal hollow **34** of the coupling **33**, so that the projector within the housing **30** inputs an image onto the face of the input optical element **35** of the optical waveguide **31**.
(59) In this configuration, the projector housing **30** lies across the rear face of the optical waveguide **31** in the region of the output optical element **32** to occlude a real-word view of the viewer **38** by occluding and preventing light passing through the optical waveguide **31** in the region of the output optical element **32** for mixing with the generated image from the projector.
(60) Hence, in this arrangement, the projector housing **30** occludes the face of the optical waveguide **31** in the region of the output optical element **32** and hence a viewer **38** does not see a real-world view combined with the image output from the output optical element **32**. The display device is therefore operating in a virtual reality display mode.
(61) In some embodiments a prism (not shown) may be provided at the interface between the projector and input optical element **35**. The prism may be fixedly attached to either the projector or on a rotatable element attached to the waveguide, such that light from the projector is always directed at the same face of the prism regardless of the rotational position of the projector housing **30** relative to the optical waveguide **31**. A prism enables the projector light output element to lie orthogonal to the face of the input optical element **35**. This allows for a design where the projector can extend across the plane of the projector housing **30**. In an alternative configuration, the output of the light emitting element of the projector is substantially parallel to the face of the input optical element **35**.
(62) FIGS. **4**A and **4**B illustrate the configuration of FIGS. **3**A and **3**B in an arrangement after the relative rotation of the projector housing **30** and the optical waveguide **31** through and angle of 90° or 270°.
(63) As can be seen in FIGS. **4**A and **4**B, the projector housing **30** now lies orthogonal to the optical waveguide **31** but still substantially parallel to the optical waveguide **31** and the projector housing **30** no longer lies on a rear face of the optical waveguide **31** in the region of the output optical element **32**. The bulk of the projector housing **30** now lies away from the optical waveguide **31** in a region above the optical waveguide **31**.
(64) Hence, in this arrangement, the projector housing **30** does not occlude the face of the optical waveguide **31** in the region of the output optical element **32** and hence a viewer **38** sees a real-world view combined with the image output from the output optical element **32**. The display device is therefore operating in an augmented reality display mode.
(65) FIGS. **5**A and **5**B illustrate the configuration of FIGS. **3**A and **3**B in an arrangement after the relative rotation of the projector housing **30** and the optical waveguide **31** through and angle of 180°.
(66) As can be seen in FIGS. **5**A and **5**B, the projector housing **30** now lies extending away from the output optical element **32** of optical waveguide **31**, but still substantially parallel to the optical waveguide **31**. Hence the projector housing **30** no longer lies on a rear face of the optical

waveguide **31** in the region of the output optical element **32**. The bulk of the projector housing **30** now lies away from the optical waveguide **31** in a region to the side of the optical waveguide **31**.
(67) Hence, in this arrangement, the projector housing **30** does not occlude the face of the optical waveguide **31** in the region of the output optical element **32** and hence a viewer **38** sees a real-world view combined with the image output from the output optical element **32**. The display device is therefore operating in an augmented reality display mode.
(68) In the display device configuration illustrated in FIGS. **3**A, **3**B, **4**A, **4**B, **5**A and **5**B the optical waveguide **31** can be attached to a housing, which may be an armature (not shown) that can attach the optical waveguide **31** to a head worn support, such as for example a helmet or a frame, such as glasses or goggles.
(69) In the display device configuration illustrated in FIGS. **3**A, **3**B, **4**A, **4**B, **5**A and **5**B the projector housing **30** can contain all of the components of the projector, so that the coupling **33** simply comprises a mechanical coupling between the projector housing **30** and the optical waveguide **31**. However, in such a simple arrangement, the light emitting arrangement of the projector that generates the image for viewing by the viewer **38** will rotate relatively to the optical waveguide **31**.
(70) FIGS. **6**A, **6**B and **6**C illustrate orientations of the input image and the output image according to different arrangements of the display device configuration described with reference to FIGS. **3**A, **3**B, **4**A, **4**B, **5**A and **5**B.
(71) FIG. **6**A illustrates the rotational configuration of the input image **63***a* to the input optical element **31** of the waveguide **30**, the theoretical orientation of the image **64***a* communicated from the input optical element **31** to the output optical element **32**, and the orientation of the output image **65***a* for the operation of the arrangement of FIGS. **3**A and **3**B. It can be seen that the orientation of the output image **65***a* is correct for viewing by the viewer.
(72) FIG. **6**B illustrates the rotational configuration of the input image **63***b* to the input optical element **31** of the waveguide **30**, the theoretical orientation of the image **64***b* communicated from the input optical element **31** to the output optical element **32**, and the orientation of the output image **65***b* for the operation of the arrangement of FIGS. **4**A and **4**B. It can be seen that the orientation of the output image **65***b* is not correct for viewing by the viewer. It is relatively rotated by the degree of rotation of the projector housing **30** and the optical waveguide **31**.
(73) FIG. **6**C illustrates the rotational configuration of the input image **63***c* to the input optical element **31** of the waveguide **30**, the theoretical orientation of the image **64***c* communicated from the input optical element **31** to the output optical element **32**, and the orientation of the output image **65***c* for the operation of the arrangement of FIGS. **4**A and **4**B. It can be seen that the orientation of the output image **65***c* is not correct for viewing by the viewer. It is relatively rotated by the degree of rotation of the projector housing **30** and the optical waveguide **31**.
(74) To overcome the problem of incorrectly orientated output images due to the relative rotation of the projector housing **30** containing all the components of the projector, image processing can be performed on the image to be generated by the image generator as the input image to the input optical element, to correct for the relative rotation of the projector housing **30** and the optical waveguide **31** by relatively rotating the image generated. Hence, for example for the arrangement of FIGS. **4**A and **4**B the image processing in the projector will generate an image that is rotated by 90° or 270°, and for the arrangement of FIGS. **5**A and **5**B the image processing in the projector will generate an image that is rotated by 180°.
(75) To perform the required image processing, the display device can be provided with an arrangement to perform this automatically. This can comprise a sensor (not shown) to detect the relative rotation of the projector housing **30** to the optical waveguide **31** when the rotation is performed manually. The output of the sensor can be received within the projector and used to control the image processing as required. This arrangement is based on a manual switching between the virtual reality display mode and the augmented reality display mode. In an alternative

arrangement, the switching arrangement can be performed electronically. A motor can be provided to relatively rotate the projector housing **30** and the optical waveguide **31** to switch between the virtual reality display mode and the augmented reality display mode. The control to the motor to perform the rotation can also be used to control the image processing as required.

(76) The configuration of FIGS. **3**A, **3**B, **4**A, **4**B, **5**A and **5**B is based on all the projector components being contained in the projector housing **30** and this rotating relative to the optical waveguide **31** and this then only requires a simple mechanical rotational coupling **33**. However, compensating optical image processing is required. In an alternative configuration, within the rotational coupling **33** an optical component of the projector can be arranged that is fixed relative to the optical waveguide **31**. This fixed optical component can comprise any components necessary to ensure that the input image remains in the correct orientation with respect to the input optical element **35** of optical waveguide **31** and avoids the need for image processing compensation. The optical components may comprise the image generating element of the projector and the rotational coupling **33** will therefore include electrical connections from other electronic components of the projector in the projector housing **31** that rotates relative to the optical waveguide **31**.

(77) FIGS. **7**A, **7**B and **7**C are schematic diagrams of the projector components in various display device configurations.

(78) FIG. **7**A illustrates a projector configuration in which the projector **70***a* comprises optical components **71***a*, an optical drive circuit **72***a*, an image processor **73***a* and a wireless interface **74***a*. In this configuration the optical components **71***a* can comprise the light emitting elements and other optical components such as refractive and/or reflective optical elements. The optical drive circuit **72***a* generates the required drive signals to drive the light emitting elements under the control of the image processor **73***a*. The wireless interface **74***a* can comprise any form of conventional wireless interface, such as WiFi, Zigbee®, or Bluetooth® and enables connection of the display device with a remote device such as a computer, mobile device/telephone, or tablet for the transmission of information for display and for receiving information from the display device.

(79) FIG. **7**B illustrates an alternative projector configuration in which the projector **70***b* comprises optical components **71***b*, an optical drive circuit **72***b*, an image processor **73***b* and a physical connector **75***b*. In this configuration the optical components **71***b* can comprise the light emitting elements and other optical components such as refractive and/or reflective optical elements. The optical drive circuit **72***b* generates the required drive signals to drive the light emitting elements under the control of the image processor **73***b*. The physical connector **75***b* enables connection of the display device with a remote device such as a computer, mobile device/telephone, or tablet for the transmission of information for display and for receiving information from the display device.

(80) FIG. **7**C illustrates another projector configuration in which the projector **70***c* comprises optical components **71***c*, an optical drive circuit **72***c*, and a wireless interface **74***a*. In this configuration the optical components **71***c* can comprise the light emitting elements and other optical components such as refractive and/or reflective optical elements. The optical drive circuit **72***c* generates the required drive signals to drive the light emitting elements under the control of information received remotely. The wireless interface **74***c* can comprise any form of conventional wireless interface, such as WiFi, Zigbee®, or Bluetooth® and enables connection of the display device with a remote device such as a computer, mobile device/telephone, or tablet for the transmission of information for display and for receiving information from the display device.

(81) It can be seen from the described configurations for the display device that it can either include on board image processing for the preparation of image data for image generation or it can be required to receive this image data from a remote device over a wireless or physical link.

(82) An alternative display device configuration will now be described with reference to FIGS. **8**A, **8**B, **8**C, **9**A, **9**B, **10**A, **10**B and **10**C. In this configuration part of the projector, a projector output element, is separate to the projector housing and fixed to the optical waveguide at the location of the input optical element to act as a pivot point for the projector housing to rotate about an axis A

substantially parallel to the plane of the optical waveguide.
(83) FIG. **8**A is a perspective view, FIG. **8**B is a plan view, and FIG. **8**C is a rear view of a display device in a virtual reality display mode, in which the view of the real-world by the viewer **88** is occluded.
(84) An optical waveguide **81** comprises a waveguide as described with reference to FIGS. **1**A and **1**B or FIGS. **2**A and **2**B and as a minimum it has an input optical element and an output optical element **82**. If the arrangement of FIGS. **1**A and **1**B is used, an intermediate optical element can be used (not shown). The input optical element and the output optical element **82** are spaced along the plane of the optical waveguide **81**. The input optical element is arranged to receive an input image. The optical output element **82** is arranged to provide an output expanded image to the eye of a viewer **88**, where the output image is expanded compared with the form of the image input to the input optical element from the projector.
(85) In this arrangement, a projector housing **80** lies substantially parallel to the plane of the optical waveguide **81** and lies adjacent to a side or face of the optical waveguide **81** away from the viewer **88** and on the opposite side from the side of the optical waveguide **81** that the optical output element **82** outputs the expanded image that is expanded compared with the form of the image input to the input optical element from the projector. The projector housing **80** contains some of the components of the projector, including the electronic components and possibly some of the optical components.
(86) A projector output element **83** is fixed to a rear face of the optical waveguide **81** at a position over the input optical element of the optical waveguide **81**. The projector output element **83** is shown as a cube shape sitting within a cut out portion of the projector housing **80**. The projector output element **83** comprises optical elements required to output the image as the input image to the input optical element of the optical waveguide **81** in a fixed manner. The input optical element is hence within the footprint on the optical waveguide **81** of the shown cube of the projector output element **83**. The input image is represented by the element **84**.
(87) The projector housing **80** is coupled to the projector output element **83** by a hinge coupling **85***a* and **85***b* that allows relative rotation of the projector housing **80** and the optical waveguide **31** about an axis A substantially parallel to the plane of the optical waveguide **81**. The hinged coupling **85***a* and **85***b* permits the projector housing **80** to be rotated relatively to the optical waveguide **81** through a range of angles. The hinged coupling **85***a* and **85***b* also provides a route for electrical and/or optical couplings between projector components in the projector housing **80** and the optical components in the projector output element **83** by passing the couplings through a hollow centre of the hinged coupling **85***a* and **85***b*.
(88) In this configuration, the projector housing **80** lies across the rear face of the optical waveguide **81** in the region of the output optical element **82** to occlude a real-word view of the viewer **88** by occluding and preventing light passing through the optical waveguide **81** in the region of the output optical element **82** for mixing with the generated image from the projector.
(89) Hence, in this arrangement, the projector housing **80** occludes the face of the optical waveguide **81** in the region of the output optical element **82** and hence a viewer **88** does not see a real-world view combined with the image output from the output optical element **82**. The display device is therefore operating in a virtual reality display mode.
(90) FIGS. **9**A and **9**B illustrate the configuration of FIGS. **8**A, **8**B and **8**C in an arrangement after the relative movement of the projector housing **80** and the optical waveguide **81** through and angle of 90°.
(91) As can be seen in FIGS. **9**A and **9**B, the projector housing **80** now lies orthogonal to the plane of the optical waveguide **81** and the projector housing **80** no longer lies on a rear face of the optical waveguide **81** in the region of the output optical element **82**. The bulk of the projector housing **80** now extends orthogonally away from the optical waveguide **81**.
(92) Hence, in this arrangement, the projector housing **80** does not occlude the face of the optical

waveguide **81** in the region of the output optical element **82** and hence a viewer **88** sees a real-world view combined with the image output from the output optical element **82**. The display device is therefore operating in an augmented reality display mode.

(93) FIGS. **10**A, **10**B and **10**C illustrate the configuration of FIGS. **8**A, **8**B and **8**C in an arrangement after the relative movement of the projector housing **80** and the optical waveguide **81** through and angle of 180°.

(94) As can be seen in FIGS. **10**A, **10**B and **10**C, the projector housing **80** now lies extending away from the output optical element **82** of optical waveguide **81**, substantially parallel to the optical waveguide **81**. Hence the projector housing **80** no longer lies on a rear face of the optical waveguide **81** in the region of the output optical element **82**. The bulk of the projector housing **80** now lies away from the optical waveguide **81** in a region to the side of the optical waveguide **81**.

(95) Hence, in this arrangement, the projector housing **80** does not occlude the face of the optical waveguide **81** in the region of the output optical element **82** and hence a viewer **88** sees a real-world view combined with the image output from the output optical element **82**. The display device is therefore operating in an augmented reality display mode.

(96) In the display device configuration illustrated in FIGS. **8**A, **8**B, **8**C, **9**A, **9**B, **10**A, **10**B and **10**C the optical waveguide **81** can be attached to a housing, which may be an armature (not shown) that can attach the optical waveguide **81** to a head worn support, such as for example a helmet or a frame, such as glasses or goggles.

(97) In a modification of the arrangement of FIGS. **8**A, **8**B, **8**C, **9**A, **9**B, **10**A, **10**B and **10**C, the projector can be mounted in the projector housing **80** and the projector output element **83** can comprise a prism or mirror that rotates from a first position in the arrangement of FIGS. **8**A, **8**B and **8**C to a second position in the arrangement of FIGS. **10**A, **10**B and **10**C. The prism or mirror directs the image output from the projector in a plane substantially parallel to the plane of the optical waveguide **81** through a 90° angle onto the input optical element of the optical waveguide **81**. In this configuration, there is an optical coupling with between the projector housing **80** to couple the projector and the prism or mirror. The prism or mirror can be rotated using a mechanical coupling with the hinged coupling **85***a* and **85***b*, so as to rotate as a result of the rotation about the hinged coupling **85***a* and **85***b*. Alternatively, a motor can be provided to rotate the prism or mirror, which is controlled by an electrical connection from drive electronics in the projector housing **80**.

(98) In a further alternative configuration of the display device, instead of relatively rotating the projector housing and the optical waveguide, they can be translationally moved by sliding the components relative to each other. A projector output element can be fixed to a rear face of the optical waveguide at a position over the input optical element of the optical waveguide. The projector output element can be a cube shape sitting within a cut out portion of the projector housing. The projector output element comprises optical elements required to output the image as the input image to the input optical element of the optical waveguide in a fixed manner. The projector output element can comprise a translational coupling with the projector housing so that the projector housing can slide relative to the fixed projector output element so that the projector housing can slide either along a long axis of the waveguide or a short axis of the waveguide to cover the output optical element of the optical waveguide for the virtual reality display mode and to uncover the output optical element of the optical waveguide for the augmented reality display mode. Electrical and/or optical connections can be provided between the projector housing and the projector output element, which remain operationally coupled during the process of sliding the projector housing relative to the optical waveguide.

(99) In the configurations discussed above, only one output optical element is discussed. This is appropriate for a monocular display device. For a binocular display device two output optical elements are provided. These can be provided as two outputs optical elements at opposed ends of an optical waveguide with the input optical element arranged between them. In such an arrangement the input image is directed from the same input optical element in two opposed

directions through the optical waveguide. In an alternative configuration, two separate identical optical waveguides could be provided, each receiving the same input image from a single projector of from separate synchronized projectors.

(100) Throughout this specification, plural instances may implement or replace components, operations, or structures described as a single instance. Although individual operations of one or more methods are illustrated and described as separate operations, one or more of the individual operations may be performed concurrently, and nothing requires that the operations be performed in the order illustrated. Structures and functionality presented as separate components in example configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements fall within the scope of the subject matter herein.

(101) Certain embodiments are described herein as including logic or a number of components, modules, or mechanisms. Modules may constitute either software modules (e.g., code embodied on a machine-readable medium or in a transmission signal) or hardware modules. A "hardware module" is a tangible unit capable of performing certain operations and may be configured or arranged in a certain physical manner. In various example embodiments, one or more computer systems (e.g., a standalone computer system, a client computer system, or a server computer system) or one or more hardware modules of a computer system (e.g., a processor or a group of processors) may be configured by software (e.g., an application or application portion) as a hardware module that operates to perform certain operations as described herein.

(102) In some embodiments, a hardware module may be implemented mechanically, electronically, or any suitable combination thereof. For example, a hardware module may include dedicated circuitry or logic that is permanently configured to perform certain operations. For example, a hardware module may be a special-purpose processor, such as a field programmable gate array (FPGA) or an ASIC. A hardware module may also include programmable logic or circuitry that is temporarily configured by software to perform certain operations. For example, a hardware module may include software encompassed within a general-purpose processor or other programmable processor. It will be appreciated that the decision to implement a hardware module mechanically, in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations.

(103) Accordingly, the phrase "hardware module" should be understood to encompass a tangible entity, be that an entity that is physically constructed, permanently configured (e.g., hardwired), or temporarily configured (e.g., programmed) to operate in a certain manner or to perform certain operations described herein. As used herein, "hardware-implemented module" refers to a hardware module. Considering embodiments in which hardware modules are temporarily configured (e.g., programmed), each of the hardware modules need not be configured or instantiated at any one instance in time. For example, where a hardware module comprises a general-purpose processor configured by software to become a special-purpose processor, the general-purpose processor may be configured as respectively different special-purpose processors (e.g., comprising different hardware modules) at different times. Software may accordingly configure a processor, for example, to constitute a particular hardware module at one instance of time and to constitute a different hardware module at a different instance of time.

(104) Hardware modules may provide information to, and receive information from, other hardware modules. Accordingly, the described hardware modules may be regarded as being communicatively coupled. Where multiple hardware modules exist contemporaneously, communications may be achieved through signal transmission (e.g., over appropriate circuits and buses) between or among two or more of the hardware modules. In embodiments in which multiple hardware modules are configured or instantiated at different times, communications between such hardware modules may be achieved, for example, through the storage and retrieval of information

in memory structures to which the multiple hardware modules have access. For example, one hardware module may perform an operation and store the output of that operation in a memory device to which it is communicatively coupled. A further hardware module may then, at a later time, access the memory device to retrieve and process the stored output. Hardware modules may also initiate communications with input or output devices, and may operate on a resource (e.g., a collection of information).
(105) The various operations of example methods described herein may be performed, at least partially, by one or more processors that are temporarily configured (e.g., by software) or permanently configured to perform the relevant operations. Whether temporarily or permanently configured, such processors may constitute processor-implemented modules that operate to perform one or more operations or functions described herein. As used herein, “processor-implemented module” refers to a hardware module implemented using one or more processors.
(106) Similarly, the methods described herein may be at least partially processor-implemented, a processor being an example of hardware. For example, at least some of the operations of a method may be performed by one or more processors or processor-implemented modules. Moreover, the one or more processors may also operate to support performance of the relevant operations in a “cloud computing” environment or as a “software as a service” (SaaS). For example, at least some of the operations may be performed by a group of computers (as examples of machines including processors), with these operations being accessible via a network (e.g., the Internet) and via one or more appropriate interfaces (e.g., an application program interface (API)).
(107) The performance of certain of the operations may be distributed among the one or more processors, not only residing within a single machine, but deployed across a number of machines. In some example embodiments, the one or more processors or processor-implemented modules may be located in a single geographic location (e.g., within a home environment, an office environment, or a server farm). In other example embodiments, the one or more processors or processor-implemented modules may be distributed across a number of geographic locations.
(108) Although an overview of the inventive subject matter has been described with reference to specific example embodiments, various modifications and changes may be made to these embodiments without departing from the broader scope of embodiments of the present invention. Such embodiments of the inventive subject matter may be referred to herein, individually or collectively, by the term “invention” merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept if more than one is, in fact, disclosed.
(109) The embodiments illustrated herein are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed. Other embodiments may be used and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. The Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.
(110) As used herein, the term “or” may be construed in either an inclusive or exclusive sense. Moreover, plural instances may be provided for resources, operations, or structures described herein as a single instance. Additionally, boundaries between various resources, operations, modules, engines, and data stores are somewhat arbitrary, and particular operations are illustrated in a context of specific illustrative configurations. Other allocations of functionality are envisioned and may fall within a scope of various embodiments of the present invention. In general, structures and functionality presented as separate resources in the example configurations may be implemented as a combined structure or resource. Similarly, structures and functionality presented as a single resource may be implemented as separate resources. These and other variations, modifications, additions, and improvements fall within a scope of embodiments of the present

invention as represented by the appended claims and equivalents thereof. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

Claims

1. A display device for use in displaying an augmented reality image of a real-world view or a virtual reality image to a user, the display device comprising: an optical waveguide having an input optical element for receiving an image; a projector for generating the image, the projector being physically coupled to the optical waveguide; and a projector housing containing at least some components of the projector, the projector housing being moveable with respect to the optical waveguide, the projector housing containing the at least some components of the projector so that the image generated by the projector is fixed relative to the projector housing, the projector including an image processor to correct the image generated by the projector and received by the input optical element of the optical waveguide dependent on a position of the projector housing relative to the optical waveguide.
2. The display device of claim 1, wherein the projector housing: is rotatably attached to the optical waveguide; and is rotatable with respect to the optical waveguide between a first relative position and a second relative position.
3. The display device of claim 2, wherein the projector housing is coupled to the optical waveguide to rotate about the input optical element.
4. The display device of claim 2, wherein the optical waveguide extends in a plane, and the projector housing is rotatable about an axis substantially normal to the plane of the optical waveguide.
5. The display device of claim 4, wherein the image processor correcting the image comprises correcting an orientation of the image.
6. The display device of claim 4, wherein the projector housing extends substantially parallel to the optical waveguide, and the projector housing is rotatable relative to the optical waveguide so that the projector housing remains substantially parallel to the optical waveguide.
7. The display device of claim 4, wherein the projector housing is rotatable about an axis substantially parallel to the plane of the optical waveguide.
8. The display device of claim 2, wherein the first relative position is at 90°, 180°, or 270° to the second relative position.
9. The display device of claim 2, wherein; a projector output element of the projector is fixed to the optical waveguide separate from the projector housing; the projector housing rotates relative to the projector output element; and at least one optical coupling is provided between components in the projector housing and the projector output element.
10. The display device of claim 9, wherein the projector output element includes at least one optical component.
11. The display device of claim 1, wherein the optical waveguide and the projector housing are configured to enable the projector housing to move with respect to the optical waveguide by translation.
12. The display device of claim 11, wherein: a projector output element of the projector is fixed to the optical waveguide separate from the projector housing; the projector housing translates relative to the projector output element; and at least one optical coupling is provided between components in the projector housing and the projector output element.
13. The display device of claim 12, wherein the projector output element includes at least one optical component.
14. The display device of claim 1, wherein the optical waveguide includes an output optical element configured to output the image.
15. The display device of claim 14, wherein at least one of the input optical element and the output

optical element is a surface relief diffractive element.

16. The display device of claim 14, wherein the output optical element is adapted to output the image in a form that is expanded compared with a form of the image input to the input optical element from the projector.

17. The display device of claim 14, wherein the optical waveguide includes a least one intermediate optical element to receive the image from the input optical element and to output the image in an expanded form to the output optical element, where the output image is expanded compared with the form of the image input to the input optical element from the projector.

18. The display device of claim 14, wherein the projector is arranged to input the image to the input optical element on a first side of the optical waveguide, and the output optical element is arranged to output the image on a second side opposed the first side.

19. A method of displaying an augmented reality image of a real-world view or a virtual reality image to a user, the method comprising: generating an image using a projector based on image data; receiving the image at an input optical element of an optical waveguide; outputting the image from at least one output optical element of the optical waveguide, the at least one output optical element occupying a region of the optical waveguide, the optical waveguide being physically coupled to the projector; moving a projector housing with respect to the optical waveguide from a first relative position to a second relative position, the projector housing containing at least some components of the projector; and processing the image data to correct the image generated by the projector and received by the input optical element of the optical waveguide dependent on a position of the projector housing relative to the optical waveguide.

20. A device for displaying an augmented reality image of a real-world view or a virtual reality image to a user, comprising: a projector for projecting an image; an optical waveguide having an input optical element and at least one output optical element occupying a region of the optical waveguide, the optical waveguide being configured to receive the image and to output the image from the at least one output optical element; and a projector housing containing at least some components of the projector, the projector housing being moveable with respect to the optical waveguide, the projector housing containing the at least some components of the projector so that the image generated by the projector is fixed relative to the projector housing, the projector including an image processor to correct the image generated by the projector and received by the input optical element of the optical waveguide dependent on a position of the projector housing relative to the optical waveguide.