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(54) Title: WEARABLE OPTICAL SYSTEM

(57) Abstract: A wearable optical system allows a user to watch a large screen, such as a smartphone screen, in a wide field of view (FOV) with both eyes, the field superimposed on the real world. The screen displays two separate zones to be the data source for each eye. The system includes two projection optical subassemblies based on a pupil forming eye piece. The interpupillary distance (IPD) is adjusted by rotating each optical subassembly about a pivot, which is perpendicular to its specific display zone.


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WEARABLE OPTICAL SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to wearable optical systems, and particularly to such a system with a head-mounted display for a device screen, such as a smartphone.

BACKGROUND OF THE INVENTION

Many users of smartphones view the display of the smartphone while walking. This can lead to accidents and embarrassing situations, in which the user is not cognizant of his/her surroundings while viewing the smartphone display. The same holds true for virtual reality systems, such as OCULUS, which do not allow the user to see simultaneously the real world while watching data displayed on a smartphone.

SUMMARY OF THE INVENTION

The present invention seeks to provide a head-mounted display for a device screen, such as a smartphone, as is described more in detail herein below.

Without limitation, some embodiments of the head-mounted display (HMD) allow the user to see the real world while watching data displayed on a screen; have low weight; keep the center mass of gravity as close to the human head as possible, and provide a large field of view (FOV). In addition, the invention is economically attractive with a lower price.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the appended drawings in which:

Figs. 1 and 2 are simplified illustrations of a wearable optical system, constructed and operative in accordance with an embodiment of the present invention.

Fig. 3 is a simplified illustration of projection optics, including an eye-piece, a relay lens and a folding prism, in accordance with an embodiment of the present invention.

Figs. 4 and 5 are simplified illustrations of adjusting the distance between two eyes (Interpupillarity distance - IPD), wherein projection optics are rotated outwards to enlarge the IPD (Fig. 4) and inwards to reduce the IPD (Fig. 5).

Fig. 6 is a simplified perspective illustration of the embodiment of Figs. 1 and 2.

Fig. 7 is a simplified top view of a wearable optical system, constructed and operative in accordance with another embodiment of the present invention, in which the binocular FOV is enlarged by rotating each eye-piece around the optical axis of the relay
lens in opposite directions.

Fig. 8 is a simplified illustration of rotating a display zone, in accordance with an embodiment of the present invention.

Fig. 9 is a simplified schematic illustration of an eye-piece, in accordance with an embodiment of the present invention.

Fig. 10 is a simplified schematic illustration of a relay lens located at a stop of the eyepiece, in accordance with an embodiment of the present invention.

Fig. 11 is a simplified schematic illustration of adding a 90-60-30 prism above the relay lens, in accordance with an embodiment of the present invention.

Fig. 12 is a simplified schematic illustration of using a simple mirror in the system.

Fig. 13 is a simplified illustration of another embodiment showing a display screen facing the opposite of the user.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Reference is now made to Figs. 1 and 2, which illustrate a wearable optical system, constructed and operative in accordance with an embodiment of the present invention. Fig. 6 shows a perspective view of this first embodiment.

The wearable optical system includes three subassemblies

1. A main body 1 attached to the user's head
2. A display 2
3. Projection optics 3 - one for each eye

The main body 1 includes a rigid and convenient attachment to the user head, a fixture to hold display 2 (also called screen 2), and a mechanical fixture to allow each projection optics 3 to rotate around a pivot P perpendicular to the screen and located at the center of the FOV.

The display 2, which faces towards the user face (as indicated by arrow 4), can be any electronic display large enough to display two images for each eye, such as but not limited to, a cell phone screen, etc. The displayed zone for each eye can be a smaller part of a large screen like a smartphone's screen, or can be separate small display for each eye.

Each projection optics 3 is based on three subassemblies as can be seen in Fig. 3, including an eye-piece 31, a relay lens 32 and a folding prism 33.

The eye-piece 31 contains a semi-reflected mirror with optical power 39 and at least one semi-reflect surface 34 that enables superimposing the display image (screen) 35 onto the real-world 36. The relay lens 32 is located near the stop 37 of the projection
optics and relays the image 35 towards the eye-piece image plane.

The folding prism 33 is located between the relay lens 32 and the screen 35. This decreases the volume of the system and defines the proper orientation of the display with respect to the center line of sight (LOS).

**Interpupularity distance (IPD) adjustment**

It is well known that every person has a different IPD. The IPD range is between 52 to 78 mm. Since this optical arrangement is based on pupil forming optics, it is important to adjust each of the projection optics exit pupil to be coincident with the user eye’s pupil to reduce optical aberrations.

This can be achieved by lateral adjustment but in such a case one has to move the display zone respectively. Since the movement is about +7 mm, for each eye this would reduce the size of the display zone and thus reduce the total resolution for each eye.

In accordance with an embodiment of the invention, an easier solution is provided, namely, rotating each of the projection optics around a pivot P which is located in the middle of the FOV and perpendicular to the screen.

Reference is now made to Figs. 4 and 5, which illustrate adjusting the distance between two eyes (IPD). The projection optics for the right eye 41 and for the left eye 42 are rotated outwards to enlarge the IPD (Fig. 4) and inwards to reduce the IPD (Fig. 5).

Fig. 6 illustrates a perspective view of the first embodiment.

Fig 7 is a top view of another embodiment for an arrangement which makes it possible to enlarge the binocular FOV by rotating each eye-piece around the optical axis of the relay lens in opposite directions. In this embodiment, the overlap between both eyes decreases but the total FOV increases. In this case, the display zone 81 can also rotate, as shown in Fig. 8.

The eye-piece is now described with reference to Fig. 9. The eyepiece has a large FOV by using a concave mirror 90 with a radius equivalent to the distance from the exit pupil 91 to the concave mirror 90. In this case, all field angles are perpendicular to the surface of the concave mirror 90. This means there are no aberrations due to the field of view. The focal plane 92 is located at half of the mirror radius of curvature and also has a radius of curvature which is half that of the mirror curvature. A flat beam-splitter 93 reflects the rays and forms an image 94 of the exit pupil 91 which will finally be the stop of the system.

This type of eye-piece is very lightweight and has almost no field aberrations (slight aberration may be seen due to the beam-splitter thickness).
Fig. 10 illustrates a relay lens 101 located at a stop 102 of the eyepiece. Relay lens 101 relays at least a portion of a smartphone screen 103 onto a focal plane 104 of a concave mirror 105.

Fig. 11 illustrates adding a 90-60-30 prism 111 above the relay lens 101. Some advantages of adding the 90-60-30 prism 111 are as follows:

1. The prism is not sensitive to rotation, so that the viewed image does not rotate while rotating the projection optics around its mechanical pivot.
2. This reduces the thickness 112 of the system.
3. This reduces the distance 113 of the center mass of gravity (CMG) 114 of the system compared to using just a simple mirror 121 as shown in Fig. 12.
4. Ergonomically shaping of the system as can be seen in Fig. 3.

Another embodiment is described in Fig. 13, which includes a mirror 131, which replaces the prism 111 described in Fig 11. In this embodiment, the display 133 is located closer to the user 134, facing the opposite direction 132 of the user and also has the same advantages as described above for Fig. 11.
What is claimed is:

1. A wearable optical system comprising:
   a body attachable to a user's head, a fixture in which a screen with two display zones one for each eye, is mounted facing the said user, and two projection optical subassemblies, each said optical subassembly being rotatable about a pivot perpendicular to the screen and located at a center of said display zone for each respective optical subassembly.

2. The system according to claim 1, wherein each optical subassembly comprises an eye-piece, a relay lens and a folding prism.

3. The system according to claim 2, wherein said eye-piece comprises at least one semi-reflected concave mirror and a beam-splitter for superimposing said display zone onto real-world.

4. The system according to claim 2, wherein said relay lens is located near a stop of the projection optics and relays said display zone towards an image plane of said eye-piece.

5. The system according to claim 2, wherein said folding prism is located between the relay lens and said display zone.

6. A wearable optical system comprising:
   a body attachable to a user's head, a fixture in which a screen with two display zones, one for each eye, is mounted facing away from said user and two projection optical subassemblies, each said optical subassembly being rotatable about a pivot perpendicular to said screen and located at a center of said display zone for each respective optical subassembly.

7. The system according to claim 6, wherein each optical subassembly comprises an eye-piece, a relay lens and a folding mirror.

8. The system according to claim 7, wherein said eye-piece comprises at least one semi-reflected concave mirror and a beam-splitter for superimposing said display zone onto real-world.

9. The system according to claim 7, wherein said relay lens is located near a stop of the projection optics and relays said display zone towards an image plane of said eye-piece.

10. The system according to claim 7, wherein said folding mirror is located between the relay lens and said display zone.
A. CLASSIFICATION OF SUBJECT MATTER

INV. G02B7/12 G02B27/01

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>Y</td>
<td>US 2009/303315 A1 (CHARLESWOPJH CHARLES NICOLAS [GB]) 10 December 2009 (2009-12-10) paragraphs [0095] - [0116]; figures 1-9</td>
<td>1,2,4,5</td>
</tr>
<tr>
<td>Y</td>
<td>JP 2010 145690 A (PANASONIC CORP) 1 July 2010 (2010-07-01) figures 1-8</td>
<td>1,2,4-7,</td>
</tr>
<tr>
<td>Y</td>
<td>EP 0 636 916 A1 (CANON KK [JP]) 1 February 1995 (1995-02-01) figure 20</td>
<td>9,10</td>
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Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search

3 February 2016

Date of mailing of the international search report

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Name and mailing address of the ISA/

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Baur, Christoph
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>CN 203 278 946 U (ZHOU LIANGYONG) 6 November 2013 (2013-11-06) figures 1-12</td>
<td>1,2,4,5</td>
</tr>
<tr>
<td>Y</td>
<td>CN 203 786 407 U (CHENGDU IDEALSEE TECHNOLOGY CO LTD) 20 August 2014 (2014-08-20) figures 1-4</td>
<td>6,7,9,10</td>
</tr>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
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<td>JP 2009527964 A</td>
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<td>US 2009303315 AI</td>
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<td></td>
<td></td>
<td>WO 2007096619 A2</td>
</tr>
<tr>
<td>US 2004004584 AI</td>
<td>08-01-2004</td>
<td>NONE</td>
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<tr>
<td>JP 2010145690 A</td>
<td>01-07-2010</td>
<td>NONE</td>
</tr>
<tr>
<td>EP 0636916 AI</td>
<td>01-02-1995</td>
<td>EP 0636916 AI</td>
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<td>US 5672862 A</td>
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<td>US 2014130148 AI</td>
<td>08-05-2014</td>
<td>CN 103810409 A</td>
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<td>JP 2014092941 A</td>
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<td>US 2014130148 AI</td>
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<tr>
<td>CN 203278946 U</td>
<td>06-11-2013</td>
<td>NONE</td>
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<tr>
<td>CN 203786407 U</td>
<td>20-08-2014</td>
<td>NONE</td>
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<td>US 2014152531 AI</td>
<td>05-06-2014</td>
<td>NONE</td>
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<td>JP H02281891 A</td>
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