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(54) Title: THREE-DIMENSIONAL DISPLAY SYSTEM AND METHOD

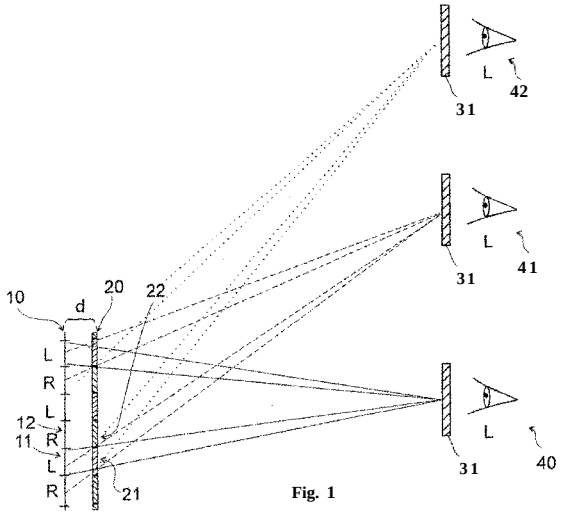


Fig. 1

(57) Abstract: The invention relates to a three-dimensional display system comprising a polarizing layer (20) located at a distance in front of the display surface (10), the polarizing layer comprising first sub regions (21) having a first direction of polarization, and second sub regions (22) having a second direction of polarization different from the first direction of polarization, the first sub regions (21) and second sub regions (22) being disposed in an alternating manner, and the display surface (10) has first display regions (11) adapted for displaying the left side image and second display regions (12) adapted for displaying the right side image, the first and second display regions being arranged to correspond, respectively, to the first sub regions (21) and to the second sub regions (22). The display system further comprises control means adapted to control the display based on the deviation of the current viewing direction from the optimum viewing direction. The invention further relates to a method implementing the functions of the display system.

THREE-DIMENSIONAL DISPLAY SYSTEM AND METHOD

TECHNICAL FIELD

The present invention relates to a display system for producing stereoscopic images, and a method corresponding thereto.

BACKGROUND ART

The objective of 3D visual presentation is to enable users to sense spatial shapes as a reality. The stereoscopic effect is achieved by conveying separate images to the left and right eyes, in the same way as the eyes sense spatial shapes from their respective different positions. A variety of different solutions have been developed for generating and sensing this double image (the so-called "stereo" image).

The simplest of these solutions involves simultaneously displaying the two images intended for the left and right eyes on a conventional display monitor, and generating the stereoscopic effect utilizing special glasses.

There exist, however, sophisticated and extremely expensive displays that do not require the use of glasses or any other auxiliary device, since the display itself provides stereoscopic view. These so-called "auto-stereoscopic" systems have earlier incorporated solutions for optimizing the 3D presentation corresponding to the current viewpoint of the user by "post-tuning" the display system mechanically or by modifying the displayed image information based on detecting the position of the user's head or eyes. Such a solution is disclosed for instance in the document US 7,190,518 B1.

The simplest and most widely used solutions for 3D display are systems based on separating the images simultaneously displayed at the same place by means of polarization. These systems are based on the principle of simultaneously displaying the images intended for the left and right eyes, and separating these two images by a polarization image separation means, a so-called 3D glasses, so that the left side portion thereof lets through only the image intended for the left eye, and the right side portion only the image intended for the right eye. Therefore, the essence of systems based on light polarization is that they produce differently polarized images for the left and right eyes, and separate these images by means

of polarization filters placed in front of each eye. Such a solution is disclosed for instance in the WO 2010/015868.

Some commercially available displays are factory-prepared for polarization-type three-dimensional display. These displays are configured such that the display surface thereof consists of first display regions adapted for displaying the left side image, and second display regions adapted for displaying the right side image. The first and second display regions are disposed in an alternating manner on the display surface. In most cases the individual display regions are implemented as one pixel-high horizontal lines, which implies that the first and second display regions are disposed alternatingly in the vertical direction. These displays are called line-interleaved 3D displays. Separation of polarized images is achieved in this type of display by placing a polarizing layer having oppositely polarized sub regions disposed alternately in front of neighbouring display regions (pixel lines). Therefore, the left and right side images, respectively, may be displayed in the odd and even lines of the display screen, and the polarizing layer, consisting of differently polarized stripes (preferably having perpendicular linear polarization or opposite circular polarization), allows that the left and right side images may be separated by image separation means worn by the user.

Due to limitations of manufacturing technology (the glass plate present in LCD displays), all line-interleaved 3D displays have the common characteristics that the polarizing layer disposed in front of the display surface cannot be placed on the display surface without a spacing, The polarizing layer is disposed in front of the display surface always with a spacing, which causes a quality deterioration of the three-dimensional display in case the individual display regions do not fall right behind the corresponding sub regions of the polarizing layer as seen from the viewpoint of the user.

The prior art solution to this problem - in connection with the above type of display - consists in including in the user manual a warning that the display should always be viewed from a direction which is facing the display. However, according to the experiences, users frequently view three-dimensional displays from positions different from the ideal one, without receiving any feedback from the display system warning them of their incorrect viewing position. Usually the problem is not even recognised by the users, who only notice the quality

deterioration of the three-dimensional display, or the appearance of image ghosting.

We have recognised that in case the viewing direction is detected and the angular deviation between the current and the optimum direction(s) is determined, warnings may be given to the user based on the measured deviation, and/or display parameters may be modified to improve the quality of the three-dimensional image.

DISCLOSURE OF THE INVENTION

The objective of the present invention is therefore to provide a display system and corresponding method that reduces or eliminates the above described problems related to prior art solutions to the greatest possible extent. A further objective of the invention is to provide a display system and method that allows the simple and efficient modification of the displayed image based on the current viewing direction of the user such that the quality of three-dimensional display is preserved to the greatest possible extent. Another objective of the invention is to provide a simple display system and method that can be implemented with low costs.

The objectives according to the present invention have been fulfilled by providing a display system according to claim 1, and a method according to claim 9. Preferred embodiments of the invention are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be explained below referring to the accompanying drawings, in which

Fig. 1 is a schematic drawing illustrating the problem to be solved by the system and method according to the present invention,

Fig. 2 is a schematic drawing illustrating the hardware components of a preferred embodiment, and

Fig. 3 shows the structural block diagram of the core part of a preferred embodiment of the system.

MODES FOR CARRYING OUT THE INVENTION

The three-dimensional display system shown in Figs. 1 and 2 comprises a display surface 10 adapted for simultaneously displaying a left side image and a right side image, and further comprises image separation means 30 having a left side portion 31 adapted for separating, by means of polarization, the left side image for viewing by the left eye, and a right side portion 32 adapted for separating, by means of polarization, the right side image for viewing by the right eye.

A polarizing layer 20 is disposed at a distance d in front of the display surface 10, said layer comprising first sub regions 21 having a first direction of polarization, and second sub regions 22 having a second direction of polarization different from the first one. The first and second sub regions 21, 22 are disposed in an alternating manner, forming a pattern providing alternating polarization directions.

The display surface 10 has first display regions 11 adapted for displaying the left side image and second display regions 12 adapted for displaying the right side image, the first and second display regions being arranged to correspond, respectively, to the first sub regions 21 and to the second sub regions 22. According to the preferred embodiment illustrated in the drawings, the first display regions 11, as well as the second display regions 12 are implemented as one-pixel high horizontal pixel lines of the display surface 10, that is, a line-interleaved 3D display is applied.

According to the invention, a sensor system is applied for detecting the current viewing direction determined by the image separation means 30, and thereby detecting the deviation of the current viewing direction from the optimum direction determined by the first display regions 11, the second display regions 12, the first sub regions 21 and the second sub regions 22. By optimum direction we mean a set of those viewing directions where the first display regions 11 exactly overlap with the first sub regions 21, and also the second display regions 12 exactly overlap with the second sub regions 22. In the embodiment illustrated in the figures the set of optimum directions lies in a horizontal plane and the deviation is the angle between this plane and the current direction. In case a chequerboard-like pattern is applied, the set of optimum directions is a straight line

perpendicular to the centre of the display surface 10, the deviation being constituted by the angle between this line and the current direction.

In the display system according to Fig. 1 a position 40 illustrated in the drawing corresponds to one of the optimum viewing directions. In this position 40 the left eye of the user views the lines L corresponding to the left side image, that is, the first display regions 11, through the left side portion 31 of the image separation means 30. This visibility and the exclusion of the lines corresponding to the right side image, is provided by the identical direction of polarization of the first sub regions 21 of the polarizing layer 20 and of the left side portion 31. Identical polarization direction is illustrated by identical Crosshatch pattern. The lines R displaying the right side image correspond to the second display regions 12.

In case the viewpoint of the user is displaced from position 40 to position 41, in addition to the first display regions 11 (lines L) intended to constitute the left side image, also the second display regions 12 (lines) corresponding to the right side image become visible to the user through the first subregions 21 of the polarizing layer 20, to the extent that they make up half of the picture seen from position 41. In practice this will lead to the so-called "image ghosting", a phenomenon where to certain extent each eye is able to view the image intended for the other eye. In case the viewpoint of the user is moved to position 42, as it is visible on the figure, the right eye will be able to see almost exclusively the first display regions 11 corresponding to the left side image, that is, the images intended for the respective eyes are exchanged.

The above described problem arises because the polarizing layer 20 is disposed in front of the display surface 10 at a distance (or gap) d. The present invention offers a solution to this problem.

In the simplest case the user is informed of the necessity of moving the image separation means 30 in a direction reducing the deviation of the viewing direction from the optimum. The indication to the user may for instance include indicating that the user's viewpoint is outside the optimal or near-optimal region, or may include an indication of the direction of the required movement. Thereby the user receives a warning from the display system before the quality of 3D display would begin to deteriorate significantly.

According to a preferred embodiment, the image displayed on the display surface 10 is modified based on the detected deviation. A preferred way of modifying the displayed image involves computing the amount of image ghosting based on the detected deviation, and modifying the displayed image information to decrease or eliminate ghosting. Modifying the displayed image information preferably involves adding to the image intended for one eye the reduced-intensity negative of the image intended for the other eye.

The above described preferred solution for ghost-image cancellation allows improving the properties of three-dimensional display for viewing directions that only slightly differ from the optimum direction. In case the deviation from the optimum direction reaches the position 41 exemplified in Fig. 1, that is, each eye views the image intended for it and the image intended for the other eye to an equal extent, the image becomes "greyed" due to the above described ghost-image cancellation. This "greying" indicates to the user that the display surface 10 is being viewed from an incorrect viewpoint.

According to a further preferred embodiment, modifying the displayed image involves a shifting of the first display regions 11 and the second display regions 12 over the display surface 10 by an identical amount in the same direction. It may be conceived that the first and second display regions 11, 12 adapted for displaying, respectively, the left and right side images, are implemented as columns instead of lines, or they may also be arranged according to any arbitrary alternating pattern. An example of the latter may be a chequerboard-like arrangement. In case the height or width of a display region exceeds one pixel, the problem of ghosting or interchanged left and right side images may be solved by shifting the first and second display regions along the display surface by a suitable extent determined by detecting the viewing direction. Such a shifting should be implemented such that the first and second display regions 11, 12 become located to the greatest possible extent behind the first and second sub regions 21, 22.

For position 42 of Fig. 1 a preferable solution may be modifying the displayed image by exchanging the first display regions 11 and the second display regions. 12 of the display surface 10. In such a case, therefore, the first display regions 11 will correspond to the right eye, and the second display regions 12

correspond to the left eye. Thereby, the problem posed by a viewing direction extremely different from the optimum direction may be solved by electronic/software means.

The arrangement shown in Fig. 2 constitutes a preferred embodiment where the viewing direction determined by the image separation means 30 is detected by optical sensors 50, 51 arranged on the display (implemented in this embodiment as a monitor). Direction detection is accomplished by transmitters 52, 53 arranged on the image separation means 30. Direction detection may for instance be performed according to the solution disclosed in WO 2010/10051 1. In the illustrated embodiment, therefore, the display surface 10 is implemented as the screen of a conventional LCD monitor, with the polarizing layer 20 being implemented as a polarization foil adhering to the LCD screen. For detecting the viewing direction a single sensor is sufficient, which may even be a simple USB web camera. Applying two sensors provides higher reliability. In case of horizontal line-interleaved 3D displays, for detecting the deviation of the viewing direction from the optimum it is sufficient to detect the viewing direction on the vertical axis.

Fig. 3 shows the schematic connection diagram of a control means 60 according to the present invention. The invention involves determining the deviation of the current viewing direction from the optimum direction utilizing the signals of the sensors 50, 51, and modifying the displayed image applying the control means 60 as described above. The control means 60 is expediently implemented as a software module adapted for receiving and processing the signals of the sensors 50, 51, and for modifying the image information displayed on the display surface 10 based on the results of signal processing.

The invention may therefore be advantageously applied for commercially available line-interleaved 3D displays, which usually provide a stereo image of sufficient quality in a narrow vertical zone of 10-20 centimetres. The display system and method according to the invention allows that the user may be kept inside this zone, and/or that display parameters may be tuned and corrected taking into account the user's viewing position.

The invention may be equally applied for systems operating with linear and circular polarization. In the display system according to the invention the first and second display regions are statically assigned to the same respective eye (except

for eventual interchanges), and thereby it is not required to alternate the displayed images. In case of line-interleaved 3D displays the human eye is unable to discern individual pixels located one under the other, and thereby the efficiency of ghost image cancellation is not deteriorated by the fact that the reduced-intensity negative of one of the images is displayed at the location intended for the other image, i.e. shifted by one line.

The parallax problem arising from the presence of a distance d between the display surface 10 and the polarizing layer 20 may therefore be eliminated applying the above described solution. The smaller the distance d, the wider the region is from where good-quality stereo images can be seen. However, this region shrinks as image resolution is increased. The invention may thereby be advantageously applied in conjunction with today's popular high-definition displays.

The present invention is not limited to the preferred embodiments presented above in details but further modifications, variations, and further improvements are possible within the scope defined by the claims. In the context of the present invention, the term "image" refers both to static and moving images. Depending on the arrangement pattern of the first and second display regions, the sets of viewing directions corresponding to the optimum direction may extend along straight lines or in planes.

CLAIMS

1. A three-dimensional display system comprising

- a display surface (10) adapted for simultaneously displaying a left side image and a right side image, and
- an image separation means (30) comprising a left side portion (31) adapted for separating, by means of polarization, the left side image for viewing by the left eye, and a right side portion (32) adapted for separating, by means of polarization, the right side image for viewing by the right eye,

characterised by further comprising

- a polarizing layer (20) located at a distance in front of the display surface (10), the polarizing layer comprising first sub regions (21) having a first direction of polarization, and second sub regions (22) having a second direction of polarization different from the first direction of polarization, the first sub regions (21) and second sub regions (22) being disposed in an alternating manner, and the display surface (10) has first display regions (11) adapted for displaying the left side image and second display regions (12) adapted for displaying the right side image, the first and second display regions being arranged to correspond, respectively, to the first sub regions (21) and to the second sub regions (22),
- a sensor system adapted for detecting the current viewing direction determined by the image separation means (30), and thereby detecting the deviation of the current viewing direction from an optimum direction determined by the first display regions (11), the second display regions (12), the first sub regions (21) and the second sub regions (22), and
- a control means (60) adapted for controlling display based on the detected deviation.

2. The display system according to claim 1, characterised in that it comprises control means (60) adapted for modifying the image displayed on the display surface (10) based on the detected deviation.

3. The display system according to claim 2, characterised in that it comprises control means (60) adapted for computing image ghosting based on the deviation and for modifying the displayed image to decrease or eliminate image ghosting.

4. The display system according to claim 3, characterised in that the modification of the displayed image involves the addition of the image intended for one eye to a reduced-intensity negative of the image intended for the other eye.

5. The display system according to claim 2, characterised in that the modification of the displayed image involves the shifting of the first display regions (11) and the second display regions (12) on the display surface (10) by an identical amount in the same direction.

6. The display system according to claim 2, characterised in that the modification of the displayed image involves exchanging the first display regions (11) and the second display regions (12) on the display surface (10).

7. The display system according to claim 1, characterised in that it comprises control means (60) adapted for indicating to the user the necessity of moving the image separation means (30) in a direction reducing the deviation.

8. The display system according to any one of claims 1-7, characterised in that the first display regions (11) and the second display regions (12) are implemented as one-pixel high horizontal pixel lines of the display surface (10).

9. A method for a three-dimensional display system, comprising the steps of

- displaying a left side image and a right side image on a display surface (10), and
- separating, by means of polarization, the left side image to be viewed by a left eye from the right side image to be viewed by a right eye by applying an image separation means (30),

characterised by

- applying a polarizing layer (20) at a distance in front of the display surface (10), the polarizing layer comprising first sub regions (21) having a first direction of polarization, and second sub regions (22) having a second direction of polarization different from the first direction of polarization, the first sub regions (21) and second sub regions (22) being disposed in an alternating manner, and forming on the display surface (10) first display regions (11) adapted for displaying the left side image and second display regions (12) adapted for displaying the right side image, the first and second display regions being arranged to correspond, respectively, to the first sub regions (21) and to the second sub regions (22), and
- detecting the current viewing direction determined by the image separation means (30), and thereby determining the deviation of the current viewing direction from an optimum direction determined by the first display regions (11), the second display regions (12), the first sub regions (21) and the second sub regions (22), and
- displaying the image on the basis of the detected deviation.

10. The method according to claim 9, characterised by modifying the image displayed on the display surface (10) on the basis of the detected deviation.

11. The method according to claim 10, characterised by computing the image ghosting corresponding to the detected deviation and modifying the displayed image to decrease or eliminate image ghosting.

12. The method according to claim 11, characterised by reducing the image ghosting by adding the image intended for one eye to a reduced-intensity negative of the image intended for the other eye.

13. The method according to claim 10, characterised by that modifying the displayed image involves the shifting of the first display regions (11) and the second display regions (12) on the display surface (10) by an identical amount in the same direction.

14. The method according to claim 10, characterised by that modifying the displayed image involves exchanging the first display regions (11) and the second display regions (12) on the display surface (10).

15. The method according to claim 9, characterised by indicating to the user the necessity of moving the image separation means (30) in a direction reducing the deviation.

16. The method according to any one of claims 9-15, characterised by implementing the first display regions (11), and the second display regions (12) as one-pixel high horizontal pixel lines of the display surface (10).

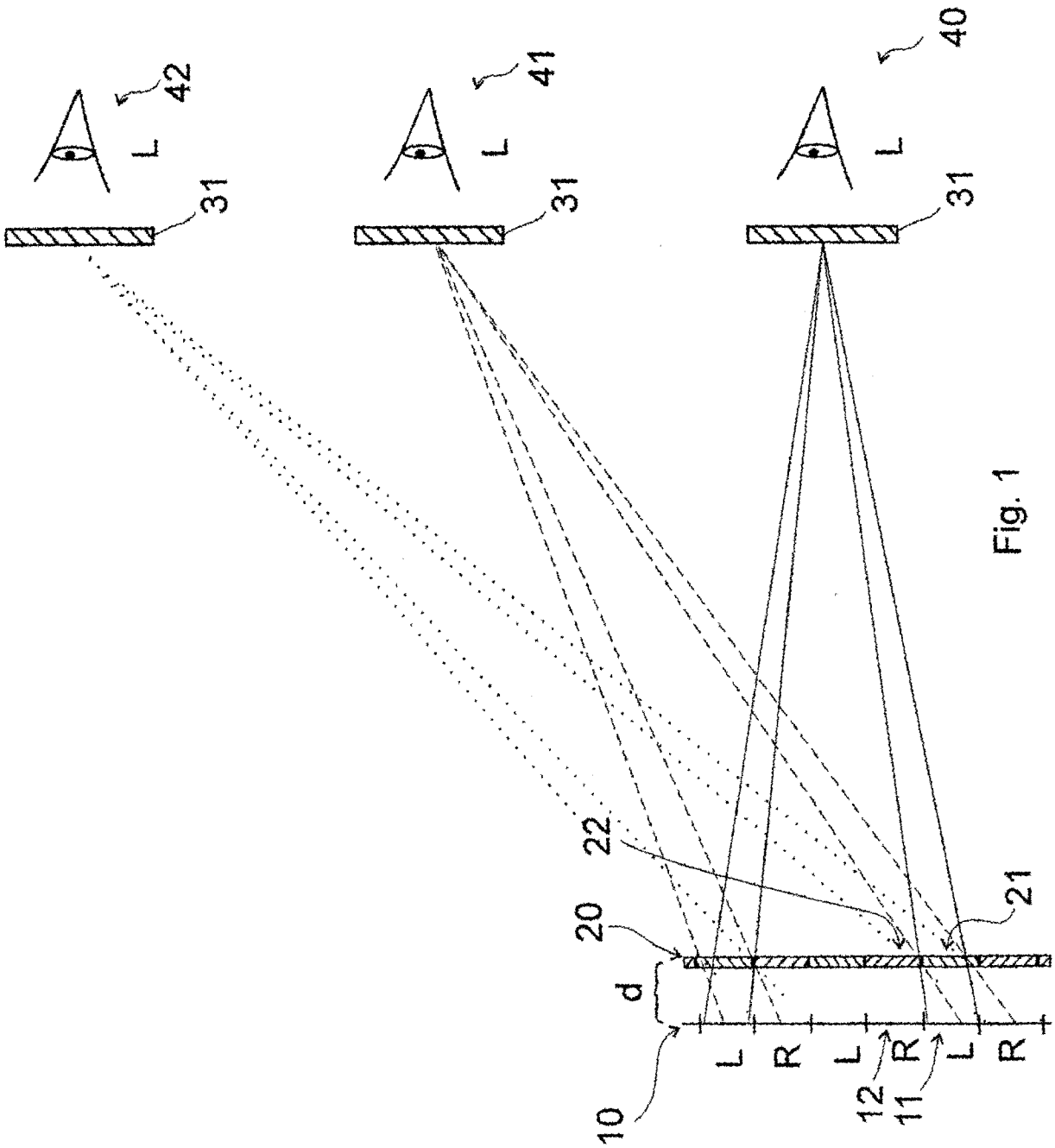
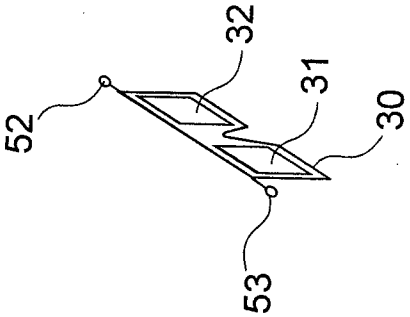


Fig. 1



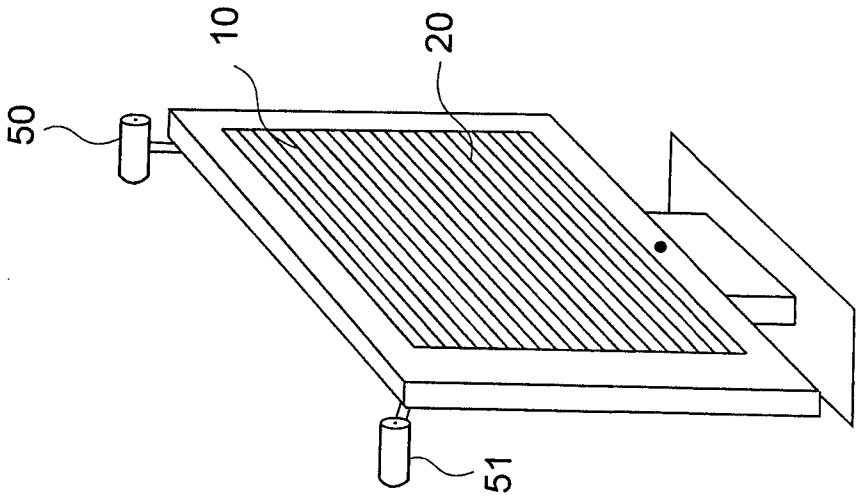


Fig. 2

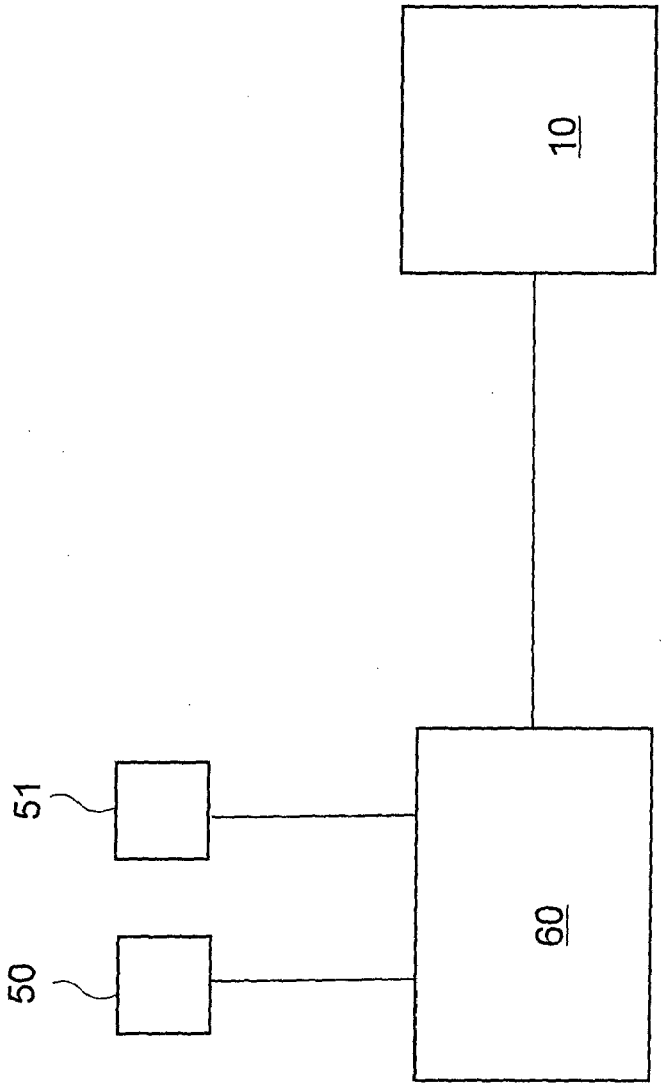


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/HU2013/000002

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N13/04
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)
H04N

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 6 791 570 B1 (SCHWERDTNER ARMIN [DE] ET AL) 14 September 2004 (2004-09-14) column 5, line 66 - column 6, line 39; figures 2,3	1-6, 8-14, 16
X	WO 2011/036827 A1 (PANASONIC CORP [JP] ; INOUE KAZUNORI) 31 March 2011 (2011-03-31) the whole document	1,7,9,15

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
7 May 2013	15/05/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tillier, Christophe

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/HU2013/000002

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