



## Movement-compensated visual display

### Field of the invention

The present invention relates to a visual display device, and to a method for generating an image in such a device.

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### Background of the invention

Popular visual display units such as televisions are meant for an audience made up of several persons. Each individual gets a different angle of view which depends on the person's position to the screen. However, only at certain  
10 angles can the viewers see the images best. Such systems are not optimised for personalised viewing.

By contrast, portable or hand held visual display equipment such as portable televisions, Personal Digital Assistants (PDAs), laptop PCs, gameboys, portable VCDs/DVDs, handy phones, etc. are meant for single users. As a result, they  
15 usually have very small screens. The small screens make reading or watching the screens difficult when held by persons on constantly moving or vibrating floors.

### Summary of the invention

The present invention aims to provide a new and useful display unit, and a new  
20 and useful method for displaying an image.

This invention proposes in a first aspect a display unit comprising: display means for displaying an image; at least one sensor for detecting changes in a position of the display unit; and means by which the images displayed are modified in response to changes in the position of the display unit.

25 In a second aspect the invention proposes a method of displaying an image in which a position of a display unit is calculated and in which the images displayed by the display unit are modified in response to changes in the position of the display unit.



In either case, the change in position can be absolute (i.e. relative to notional fixed axes), or relative to some other object, most particularly a person's head.

The modifications in the image may be to vary it (e.g. in size or position on a screen) to compensate for the changes of the position, so that a viewer sees a  
5 stable image.

#### Brief description of the figures

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

Figure 1 is composed of Fig. 1(a) and Fig. 1(b), and illustrates an embodiment  
10 of this invention in the form of a Personal Digital Assistant (PDA);

Figure 2 is a block diagram of the mechanism of the embodiment shown in Figure 1;

Figure 3 illustrates the position and size of a display image relative to the display screen in the x-y horizontal plane, as is typical for the embodiment  
15 illustrated in Figure 2;

Figure 4 illustrates the position of a display image, relative to a rotational displacement of the display screen in the x-y horizontal plane, as is typically experienced by the embodiment illustrated in Figure 2;

Figure 5, which is composed of Fig. 5(a) and Fig. 5(b), illustrates the  
20 dimensions of the display image, relative to a rotational displacement of the display screen in the z-x plane, as is typically experienced by the preferred embodiment illustrated in Figure 2;

Figure 6 is a block diagram of a control mechanism in the embodiment illustrated in Figure 2;

25 Figure 7 illustrates a variation of the embodiment which uses accelerometers and gyroscopes as sensors.

Figure 8 illustrates another variation of the embodiment which uses a camera as a sensor.

#### Description of the embodiment

Fig. 1(a) illustrates an embodiment of the invention which is a PDA with a small  
5 screen 100 for display, a button 110 for working state selection and a small  
camera 120, which, besides other functions, is used to determine the relative  
position of a viewer's head to the display screen 100. Line 130 indicates the  
direction of a line in the display image when the PDA screen 100 is at a certain  
position. Fig.1(b) shows the same PDA rotated to a second position. The line  
10 140 is included as a static reference line so that Fig.1(a) and 1(b) can be  
compared. Line 140 shows that the PDA has been turned through an angle  $\theta$   
between Fig. 1(a) and Fig.1(b). Due to display control in this embodiment, the  
display content remains as in its original attitude relative to the viewer and does  
not turn with the device. The line 130 in Fig. 1(a) is parallel to line 150 in  
15 Fig.1(b). Although Fig 1 illustrates compensation for a rotational movement to  
PDA, the compensation can actually be processed in response to any relative  
movement between the viewer and the display. The display control not only  
keeps the display contents stable against random movements of the screen but  
also eliminates or attenuates changes in attitude between the display  
20 orientation and the viewer's head. If the viewer is stationary the device can be  
thought of as offering a stabilisation effect, and if the viewer is continuously  
moving the device can be thought of as using a tracking function to re-position  
constantly the image to the viewer.

There are two kinds of content to be displayed: pictures and text. For displaying  
25 a picture, an image which is larger than the actual display screen is generated.

Fig. 2 is a block diagram of the embodiment of this invention, which is a PDA  
having a portable display 200 which is a planar display screen which defines an  
x-y plane, such as an LCD screen. A driver unit 210, which typically employs  
commonly used methods by LCD display drivers such as the Direct Addressing  
30 Matrix Display Method [1], amplifies display signals in the x and y directions and  
subsequently sends processed images to the screen 200. A sensor unit 220

detects movements of the display screen. The measurements by the sensor unit 220 are processed in a de-coupling unit 230 so that any movement is de-coupled, interpreted and expressed in a 3-axes system describing three dimensional space by axes x, y and z.

- 5 There are three controllers 240, 250, 260, in the embodiment. Each controller process the display signals in reaction to movements along each of the axes x, y, z, respectively, i.e. controller 240 for the x-axis, controller 250 for the y-axis and controller 260 for the z-axis.

10 Any movement along the z-axis which results in a visual effect in the x-y plane is processed by the controller 260. The resultant image on the screen in the x-y plane by effect of the controller 260 has a dimension and size which are compensated for any change in screen position along the z-axis.

For a text display, the display driver 210 may have a text wrap function working with the input from display controls 240, 250 and 260 so that the text strings  
15 flow continuously in the display screen. That is, when the image moves relative to the screen so that certain words disappear from the edge of the screen, they are regenerated at a new edge position on the screen.

Fig. 3 and Fig. 4 each show the screen, the image on the screen and the control scope on the display plane (x-y plane).

20 Control scope means the limits to which an image displayed on the screen can be moved: the boundary of the image does not cross into the screen display area. Conversely, one can imagine the screen positioning itself in a static image area, the positioning of the screen to the static image representing position of the physical world relative to the image. In Fig. 3, an image 300 is generated  
25 which is larger than display plane 310. The difference in length and breath of the image 300 and the length and breath of the screen 310 defines the control scope:  $\Delta x$  and  $\Delta y$  in the x and y directions respectively.

The display image is continually re-positioned within the control scope limits to compensate for movements of the screen in the x-y plane. This provides image

stability against random movements of the display screen in the directions of the x-y plane.  $\Delta x$  and  $\Delta y$  define the displacement tolerance level.

Fig. 4 shows the effect of the driver and controllers on the image 400 attitude when the screen 420 experiences a rotation in the x-y plane. The figure shows a maximum turning angle  $\theta$  between the turned screen 410 and the original screen position 420, but that the image 400 has not rotated.

Fig. 5 illustrates how any movement in the z-direction such as a rotation of the PDA about the y-direction affects the image dimensions in the x-y plan. The z-axis represents the distance of the screen to viewer 550. In Fig.5(a), the display plane 510 turns by an angle  $\delta$  from the horizontal position 500 in the x-z plane around an axis at the centre of the cross section of the device. The resultant visual effect is shown in Fig. 6. When the screen 530 is turned away from the viewer to the left side as shown in Fig.5(a), the image 520 is enlarged on the left side as demonstrated by 540. As the right side of the screen 530 turns towards the viewer, the compensated image 540 is made smaller on the right side. Thus, the viewer 550 sees a display which appears to remain constant in size regardless of the movements of the screen in the z direction, or of any movements of the screen in the x-y plane.

For controlling movements along any of the axes, the respective control for that direction can be developed as a cascaded structure as shown in Fig. 6. The feedback signals indicate a position  $y$ , a velocity  $v$  and an acceleration  $a$ , which are input correspondingly to a position controller 610, a velocity controller 620 and an acceleration controller 630.

Unit 640 is a model of the display driver, in which  $M$  is the mass of the PDA, and the first-order lag with time constant  $\tau$  represents the display delay. Units 650 and 660 are integrators describing the physical relationships between acceleration and velocity as well as velocity and position.

In the cascaded control, there are three feedback control loops cascaded from the inner loop to the outer loop: one acceleration control loop 670, one velocity control loop 680 and one position control loop 690. The most important feature

of cascaded control is that the signals of the loops are separated in the frequency domain and processing can be carried out one by one from the inner loop 670 to the outer loop 690 [2].

5 The movements of the PDA can be movements of the PDA relative to a fixed coordinate system, and/or movements of the PDA relative to the viewer's head which may also be moving. These two frameworks in which the PDA's movements may be defined provide further variations of the embodiment within the scope of the invention of which two are given as examples in the following.

10 Fig. 7 illustrates a hardware configuration of one of the variations of the embodiment of the invention. The embodiment is a PDA which comprises a display driver 710 and a display screen 720. This variation monitors the relative movements of the PDA to a fixed coordinate system. Thus the control system functions as a regulation system. Unit 700 is a digital signal processor (DSP), which functionally receives a reference signal 701, and comprises a controller  
15 702 and an information-processing element 703. The controller 702 aims to stabilise the PDA images with respect to the fixed coordinates. The reference signal 701 is a constant zero input from the button 110 in Fig. 1. Three controllers such as those illustrated in Fig. 2 for the directions  $x$ ,  $y$ ,  $z$  are implemented in controller 702. The de-coupling unit of Fig. 2 corresponds to  
20 element 703 in Fig. 7. The embodiment comprises a unit 730 made up of accelerometers which measure acceleration signals and a unit 740 made up of gyroscopes which monitor angular velocity signals. Small MEMS accelerometers and gyroscopes are preferably used for the sake of keeping the embodiment small and handy. Screen positions can be approximated from the  
25 acceleration and the velocity signals by integration in DSP 700.

Fig. 8 illustrates another variation of the embodiment of the invention. This variation monitors the movements of the PDA relative to the viewer's head. It is likely that the viewer's head may also be moving. The embodiment now functions as a tracking system. Unit 800 is a digital signal processor (DSP),  
30 which receives a reference signal 801, and comprises a controller 802 and an information-processing element 803. The system comprises a display driver 810

and a display screen 820. The sensor in this variation is preferably a camera 830, which corresponds to the sensor 120 shown in Fig. 1, and which monitors the position of the viewer's head. For obtaining positional information, any image processing methods in visual servo control can be used, for example, the  
 5 commonly used feature-based or correlation-based visual tracking methods [3]. The acceleration signals and the velocity signals can be obtained by differentiating the position signals or by a state observer implemented in the DSP unit 800.

The above description of the invention is intended to be illustrative and not  
 10 limiting. Various changes or modifications in the embodiments described may occur to those skilled in the art without departing from the scope of the invention. For example, although the sensors used in the present embodiment have been described as accelerometers, gyroscopes and cameras, other types of sensors can also be used. The invention allows viewers' eyes to be less  
 15 subject to fatigue by stabilising the display contents. The viewer can adjust his attitude to the screen while the displayed content tracks the movement of the viewer's head and adjusts the position of the images accordingly. Such method and apparatus can be used without too many additional hardware components.

### References

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- [2] W. Loehard, *Control of Electrical Drivers*, second edition, Springer-Verlag, 1996.
- 25 [3] S. Hutchison, G.D. Hager, and P.I. Corke, "A tutorial on visual servo control," *IEEE Trans. Robot. Automat.*, vol. 12, no. 5 pp. 651-670, Oct. 1996.

Claims

1. A display unit comprising: a display means for displaying images; at least one sensor for detecting changes in a position of the display unit; and means by which the images displayed are modified in response to changes in the position of the display unit.  
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2. A display unit according to claim 1 which the sensor includes detection means to detect the viewer, said position being the relative position of the user and display unit.
3. A display unit according to claims 2 in which said detection means uses digital signal processing techniques to detect the viewer.  
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4. A display unit according to any of claim 2 or 3 in which the sensor is a camera.
5. A display unit according to claim 1 in which the sensors include at least one accelerometer and/or gyroscope.
- 15 6. A display unit according to claim 1 which is a hand held display device.
7. A method of displaying an image using a display unit which comprises determining position of the display unit, and modifying the images displayed in response to changes in the position of the display unit.
8. A method according to claim 7 in which the display unit's position is relative to the viewer.  
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9. A method according to claim 7 in which the display unit's position is relative to a fixed coordinate system of three axes representing three-dimensional space.
10. A method according to any of claims 7 to 9 which, upon the movements of a part the display unit along the directions towards or backwards from the viewer, the dimensions of the image are modified accordingly.  
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11. A method according to any of claims 7 to 10 which, upon lateral movements of the display unit in any direction perpendicular to the direction towards the viewer, the positions of the image are modified to compensate for said movements.