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(54) Title: METHOD FOR REDUCING COMPUTER CALCULATIONS WHEN GENERATING VIRTUAL IMAGES

(57) Abstract

This invention relates to a method for reducing the computer calculations when generating virtual images. The invention is based on the principle that image details which are redundant as regards the function of the vision are neither calculated nor displayed. This is achieved by taking the following steps. The direction of the eyes of an observer is sensed and used as a basis for calculating the observer’s momentary point of fixation in the image. At least one zone of the image is defined with the point of fixation as centre point, and if a plurality of zones are defined, these zones are of gradually increasing size. The image information in the smallest zone is calculated and generated with high resolution, and the image information in each larger zone is calculated and generated with lower and lower resolution, the image information in the image outside the largest zone being finally calculated and generated with the lowest resolution.
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FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.
Method for Reducing Computer Calculations When Generating Virtual Images

The present invention relates to a method for reducing the computer calculations when generating virtual images.

As a rule, virtual images are generated with the same resolution over the whole image, which requires a computer of considerable calculating capacity. In many cases, however, the human eye and the human brain are incapable of taking in all this image information as it is being displayed on a display device.

When produced, computer-generated images are normally built up of a number of surfaces in the form of polygons. These surfaces may have different colours or shades as well as different densities. The more details in the image, the more polygons per image area.

This invention is based on the principle that image details which are redundant as regards the function of the vision are neither calculated nor displayed. As a result, the number of calculations required to produce virtual video images can be drastically reduced. However, this method implies that there is only one observer in front of the display device, since it is the observer's point of fixation, i.e. the centre of the observer's visual field, that controls the resolution and, hence, the exactitude of the calculations. This means that the detail resolution of the displayed image is a function of the resolution characteristics of the eye.

The application presenting itself immediately bears upon simulators of the type "virtual reality" (also referred to as "cyberspace"), where the user wears a helmet on his head, covering his eyes and ears. The user may also carry a number of sensors on different parts of his body, sensing his movements and position. With the aid of the information obtained from the sensors, the computer creates the illusion of an artificial world in the form of images (optionally three-dimensional ones) which are projected in front of the user's eyes by means of display devices, as well as stereo sound through earphones. This technique has been developed by, inter alia, the US airforce and NASA. One purpose of virtual reality is to create realistic simulators.

The present invention solves the problem of how to reduce considerably the computer calculations required when generating images by providing a method having the distinctive features recited in the appended independent claim.
In the following, the invention will be described in more detail with reference to the accompanying drawings, in which

Fig. 1 illustrates the visual acuity of an eye at high luminance as a function of the horizontal angular distance from the fovea, and a three-step approximation thereof,

Fig. 2 is a three-dimensional view of the approximation, presenting three zones, and

Fig. 3 shows an example of the surface exactitude in a generated image with respect to the point of observation of the eye.

The invention makes use of the fact that the human eye has a gradually poorer capacity to distinguish details in visual impressions according to their angular distance from visual impressions falling straight at the area of the highest visual acuity, the fovea. In Fig. 1, the visual acuity is shown as a function of the horizontal angular distance from the fovea. It appears from this Figure that the eye is highly sensitive to spatial distinction within an area corresponding to ±1 degree in the horizontal direction of the visual field. This approximately goes for the vertical direction as well.

When the invention is brought to use, the visual field is therefore divided into a number of areas, in which the eye has varying capacities to distinguish details. The number of areas may vary, depending on the degree of accuracy with which one wishes to follow the acuity curve. For exemplifying purposes, Fig. 1 thus includes a three-step approximation of the visual acuity. In the following, these three areas will be referred to as zone 1, zone 2 and zone 3.

Further, Fig. 2 illustrates how these three zones are distributed three-dimensionally when the observer's point of fixation is located at the centre of the image. The "empty" space in the cube represents redundant image details. As appears from this Figure, a vast amount of image details need not be calculated or displayed.

The method according to the invention presupposes that the point of fixation of the eye in a projected image can be detected. There exists today various equipment for performing the detection. The observer may then sit in front of some kind of display device. It is particularly simple to detect the point of fixation when the user is wearing a helmet of the type employed in connection with "virtual reality". This helmet is a natural attachment for the detection apparatus. In addition, this disposes of the
source of error that may arise in systems where the apparatus is not fixed to the user's head.

Supposing that an image is projected in front of the user in such a manner as to take up his entire visual field, i.e. 185° in the horizontal direction and 155° in the vertical direction. In front of each eye, there is thus projected an image taking up approximately 120° in the horizontal direction. It appears from Fig. 1 that the eye has a perfect capacity to distinguish details in an area of up to a few degrees round the point of fixation. This means that the computer has to calculate details with full resolution in this area only.

For exemplifying purposes, the visual field in the Figures referred to in this application has been divided into three zones. In actual practice, use may conveniently be made of more than three zones. The area with full resolution is roughly described by zone 1, taking up 10°x 10° of the image (see Figs 1 and 2). At a certain distance outside this area, the capacity to distinguish details is much poorer. This latter area is roughly described by zone 2, taking up 40°x 40° of the image, minus the area of zone 1. In zone 2, the computer is obliged to calculate details with a 1/16 surface exactitude. In the remainder of the image, i.e. the image minus zones 1 and 2, which is referred to as zone 3, the computer is obliged to calculate details with a 1/256 surface exactitude.

Although the zones described in this example are square, they may also, when use is made of refined techniques, be round or oval so as to better suit the function of the eye.

With the aid of four illuminated toroids placed at different locations in an image, Fig. 3 illustrates how the surface exactitude can be reduced with an increasing distance to the point of fixation. The image in the Figure takes up 120° x 75° of the visual field. The computer produces these toroids with different degrees of resolution, depending on where the toroids are located in relation to the point of fixation of the eye. Those parts of the toroids that are situated in zone 1 are rendered in great detail, those parts of the toroids that are situated in zone 2 are rendered in less detail, and those parts of the toroids that are situated in zone 3 are rendered in least detail.

As is customary in the generation of virtual images, the computer contains information on the "objects" that are to be rendered in the virtual image, their positions,
shapes, sizes, colours, manner of illumination, and so forth. On the basis of this
information, the computer calculates the appearance of the image. In all generation
of virtual images, the computer is able to calculate the image with a varying wealth
of detail. The more detailed the rendition is, the longer the time it takes for the com-
puter to calculate the details. The new thing about the invention is that, in the
generation of an image, the computer calculates the image with a varying wealth of
detail in different parts, as controlled by the observer's momentary point of fixation.

Thus, the basic idea is that the details of the image are calculated only in as far as
they can be perceived by the observer. An example thereof will now be described
with reference to Fig. 3.

1. The computer calculates the entire image with the resolution according to zone
   3 and stores this information (part image 3) in an image memory.

2. The computer calculates the image described by zone 2 (including zone 1) with
   the resolution according to zone 2 and stores this information (part image 2) in
   an image memory.

3. The computer calculates the image described by zone 1 with the resolution
   according to zone 1 and stores this information (part image 1) in an image
   memory.

4. The computer generates a new image of these three part images, in which part
   image 1 takes precedence over part image 2, which in turn takes precedence
   over part image 3.

It may furthermore be assumed that the capacity to distinguish different density
levels decreases in a manner similar to that of the detail vision. This fact may be
used for reducing the number of steps of the grey scales employed. Likewise, the
number of levels in the definition of various colour components may also be
reduced.

If use is made of, say, 256 levels in the grey scale of zone 1, 64 levels in zone 2
and 16 levels in zone 3 may suitably be employed.
Claims

1. A method for reducing computer calculations when generating virtual images, characterized in that
   the direction of the eyes of an observer is sensed and used as a basis for calculating the observer's momentary point of fixation in the image,
   at least one zone of the image is defined with the point of fixation as centre point and, if a plurality of zones are defined, these zones are of gradually increasing size, and
   the image information in the smallest zone is calculated and generated with high resolution and, for each larger zone, is calculated and generated with lower and lower resolution and, finally, in the image outside the largest zone is calculated and generated with the lowest resolution.

2. A method as claimed in claim 1, characterized in that a smaller zone which is calculated and generated with high resolution is not also calculated and generated with lower resolution as part of a larger zone.

3. A method as claimed in claim 1 or 2, characterized in that the number of density levels is reduced from a smaller zone to a larger zone.

4. A method as claimed in any one of claims 1-3, characterized in that the number of levels in the definition of different colour components is reduced from a smaller zone to a larger zone.

5. A method as claimed in any one of claims 1-4, characterized in that each zone round the point of observation has a substantially oval shape.

6. A method as claimed in any one of claims 1-4, characterized in that each zone round the point of observation has a substantially circular shape.
Relative visual acuity

100%

50%

40%

30%

20%

10%

zone 1

zone 2

zone 3

Degrees from fovea

Fovea

Degrees from fovea

FIG 1


INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G06T 11/00
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)

IPC6: G06T

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

SE,DK,FI,NO classes as above

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

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Date of mailing of the international search report: 04/06/96

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