

DESCRIPTION**TITLE OF INVENTION**

DRAWING DEVICE AND DRAWING METHOD

5 **TECHNICAL FIELD**

[0001]

The present invention relates to a drawing device and a drawing method for generating, from a given three-dimensional geographical feature information and an eyepoint position, a two-dimensional image which is viewed from the eyepoint position.

BACKGROUND ART

[0002]

As a method for drawing a three-dimensional geographical feature, a method of expressing the geographical shape with a group of polygons (this group is referred to as a polygon mesh), and generating an image by filling the inside of each of the polygons with a predetermined color after performing projective transformation on the coordinate values of the vertices of the polygons is known. In drawing of a three-dimensional geographical feature, a geographical feature which is seen at a long distance is drawn small, while a geographical feature which is seen at a short distance is drawn large. Therefore, both a polygon mesh having a high resolution and a polygon mesh having a low resolution are prepared, and when drawing a geographical feature located at a long distance, the drawing is performed after switching to the polygon mesh having a low resolution is performed, whereas when drawing a geographical feature located at a short distance, the drawing is performed after switching to the polygon mesh having a high resolution

is performed. According to such an operation, the number of polygons can be reduced while the resolution of the generated image is maintained.

[0003]

5 In the above method, there is a problem that when a polygon mesh having a high resolution and a polygon mesh having a low resolution are arranged adjacent to each other, discontinuity occurs in the boundary between the polygon meshes. To solve this problem, Patent Literature 1 discloses a method of preventing discontinuity from occurring in a boundary by
10 applying a special polygon pattern to a boundary portion of a target region in accordance with the resolution of the polygon mesh of another region adjacent to the target region.

CITATION LIST

15 PATENT LITERATURE

[0004]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. Hei 7-271999 (1995-271999)

SUMMARY OF INVENTION

20 TECHNICAL PROBLEM

[0005]

Conventional drawing devices are configured as above. In such a drawing device, it is necessary to change the polygon pattern of a boundary portion of a target region in accordance
25 with the resolution of the polygon mesh of another region adjacent to the target region. As the eyepoint position changes, the resolution of the polygon mesh is required to be changed in accordance with the change, and it is necessary to change the polygon patterns of boundary portions every time the
30 eyepoint position changes.

Here, note that, in the drawing of a three-dimensional geographical feature, a video image varying smoothly in accordance with the eyepoint position can be outputted by increasing the number of times that the drawing process is carried out per one second (in other words, the frame rate).
5 In order to increase the frame rate, a graphics processing unit (GPU) is used. In order to use the performance of the GPU efficiently, it is effective to reduce the number of times that vertex data are transferred between the central processing unit
10 (CPU) and the GPU. To this end, at least for a polygon mesh having a low resolution whose data amount is relatively low, by transferring the data about polygon mesh to the GPU in advance, the number of times that the vertex data are transferred can be reduced.

15 However, in this technique, there is a problem that every time the polygon pattern is changed in accordance with a change of the eyepoint position, it is necessary to re-transfer the vertex data from the CPU to the GPU, and it is therefore difficult to increase the frame rate.

20 [0006]

The present invention is made in order to solve the above-mentioned problem, and it is therefore an object of the present invention to provide a drawing device that prevents discontinuous lines and visually-discontinuous portions from
25 occurring in any boundary portion even when a plurality of geographical regions are drawn with different resolutions in accordance with the eyepoint position, and that does not have to make a correction to the polygon pattern in accordance with a change of the eyepoint position, and can reduce the transfer
30 amount of vertex data and increase the frame rate.

SOLUTION TO PROBLEM

[0007]

According to the present invention, there is provided a drawing device including: a polygon mesh generating unit for
5 generating, for each of a plurality of regions forming a three-dimensional geographical feature, both a high resolution polygon mesh in which each region is expressed with a high resolution, and a low resolution polygon mesh in which each
10 region is expressed with a lower resolution than the high resolution polygon mesh, and in which a peripheral portion of each region is generated to have enhanced-resolution in such a way that vertices constructing boundaries of each region have positions matching positions of vertices of the high resolution polygon mesh; a polygon mesh storage unit for storing the low
15 resolution polygon mesh and the high resolution polygon mesh which are generated by the polygon mesh generating unit; a projective transformation unit for selecting either the low resolution polygon mesh or the high resolution polygon mesh in accordance with a given eyepoint position, and performing
20 projective transformation of vertex coordinate values of vertices of the selected polygon mesh into two-dimensional coordinate values; and a smoothing unit for, when the projective transformation unit selects the low resolution polygon mesh as each of adjacent polygon meshes, correcting coordinate values
25 of a vertex constructing a boundary between the adjacent polygon meshes to be values obtained by interpolating between coordinate values of vertices adjacent to the vertex.

ADVANTAGEOUS EFFECTS OF INVENTION

30 [0008]

According to the present invention, advantages of preventing visual discontinuity from occurring in any boundary and being able to perform a drawing process at a high speed can be achieved.

35 **BRIEF DESCRIPTION OF DRAWINGS**

[0009]

Fig. 1 is a configuration diagram showing a drawing device according to Embodiment 1 of the present invention;

Fig. 2 is a configuration diagram showing a three-dimensional geographical feature display system using the drawing device according to Embodiment 1 of the present invention;

Fig. 3 is a diagram for explaining three-dimensional geographical feature information;

Fig. 4 is a diagram for explaining a generation of a polygon mesh;

Fig. 5A and 5B are diagrams showing examples of polygon meshes;

Fig. 6A and 6B are diagrams showing examples of polygon meshes;

Fig. 7 is a diagram showing an example of a polygon mesh;

Figs. 8A to 8C are diagrams for explaining a smoothing process;

Fig. 9 is a diagram showing an example of a polygon mesh; and

Fig. 10 is a flow chart showing the details of processing performed by the drawing device according to Embodiment 1 of the present invention.

DESCRIPTION OF EMBODIMENTS

[0010]

Embodiment 1.

Fig. 1 is a diagram showing the configuration of a drawing device according to Embodiment 1 of the present invention. In Fig. 1, the drawing device 1, a polygon mesh generating unit 2, a polygon mesh storage unit 3, a projective transformation unit 4, a color filling unit 5, an image output unit 6, and a

smoothing unit 7 are shown.

[0011]

Fig. 2 is a diagram showing an example of the configuration of a three-dimensional geographical feature display system which uses the drawing device shown in Fig. 1. In Fig. 2, an auxiliary storage unit 8, an input unit 9, a display unit 10, a central processing unit (CPU) 11, a main storage unit 12, and a graphics processing unit (GPU) 13 are shown.

[0012]

Each of the components of the system shown in Fig. 2 will be explained hereafter.

1 denotes the drawing device shown in Fig. 1, and an example in which the drawing device 1 is configured using a personal computer (PC) will be shown hereafter. The system is configured by connecting the auxiliary storage unit 8, the input unit 9 and the display unit 10 to the PC main part constructing the drawing device 1. The PC includes the central processing unit (CPU) 11, the main storage unit 12 and the graphics processing unit (GPU) 13 therein. In the example shown in Fig. 2, each component of the drawing device shown in Fig. 1 is implemented by either one of the units disposed in the PC or cooperation between two or more of the units.

[0013]

The auxiliary storage unit 8 stores three-dimensional geographical feature information. The drawing device 1 reads information from this auxiliary storage unit 8 for using it.

The input unit 9 is configured by using, for example, a mouse, a keyboard, or the like. The system receives a user's instruction by using this input unit 9. When a user inputs an instruction to move the eyepoint position by using a mouse, a

keyboard or the like, the system makes a change in a projective transformation method in accordance with the instruction.

The display unit 10 displays a drawing result acquired by the drawing device 1 on the screen thereof.

5 [0014]

Next, a flow of processing performed by the drawing device 1 in this system will be explained with reference to Fig. 1.

As to the three-dimensional geographical feature information read from the auxiliary storage unit 8, the polygon mesh generating unit 2 generates two types of polygon meshes including a polygon mesh having a low resolution and a polygon mesh having a high resolution for each of regions which is partitioned by, for example, equally spaced latitude lines and equally spaced longitude lines.

15 [0015]

Fig. 3 is a diagram showing the three-dimensional geographical feature information. For example, the three-dimensional geographical feature information is provided by defining points arranged to form a grid on the basis of latitudes and longitudes, and describing the altitude value of each of the points, as shown in Fig. 3. Fig. 4 is a diagram explaining the generation of a polygon mesh. The polygon mesh generating unit 2 expresses a region enclosed by four grid points H11, H12, H21 and H22 shown in Fig. 3 with, for example, two triangles, as shown in Fig. 4. By similarly and repeatedly performing this process on other regions, the polygon mesh generating unit generates, for each of the regions in a certain area, a polygon mesh in which the shape of the geographical feature is expressed by a group of polygons.

30 In the example shown in Fig. 4, a region enclosed by four

grid points is represented by using two triangles. However, this embodiment is not limited to this example. As an alternative, a region enclosed by four grid points can be expressed by using a single rectangle.

5 [0016]

Fig. 5A and 5B are diagrams showing some examples of polygon meshes. Fig. 5A shows an example of a polygon mesh having a high resolution, and Fig. 5B shows an example of a polygon mesh having a low resolution. As shown in Fig. 5B, in
10 the polygon mesh having a low resolution, the mesh of only a peripheral portion is subdivided to enhance the resolution thereof.

[0017]

More specifically, the polygon mesh generating unit 2
15 generates, for each of a plurality of regions forming a three-dimensional geographical feature, both a high resolution polygon mesh in which the region is expressed with a high resolution, and a low resolution polygon mesh in which the region is expressed with a lower resolution than that of the
20 high resolution polygon mesh, and in which a peripheral portion of the region has an enhanced-resolution in such a way that the vertices constructing the boundaries of the region have positions matching those of the vertices constructing the boundaries of the high resolution polygon mesh.

25 [0018]

Fig. 6A and 6B are diagrams showing examples in which polygon meshes are arranged adjacent to each other. Fig. 6A shows an example in which a polygon mesh having a high resolution and a polygon mesh having a low resolution are arranged adjacent
30 to each other. As a result of subdividing and

resolution-enhancing of the mesh of a peripheral portion of each polygon mesh having a low resolution as shown in Fig. 5B, even when a polygon mesh having a high resolution and a polygon mesh having a low resolution are arranged adjacent to each other, as shown in Fig. 6A, the vertices on the boundary match each other between the adjacent polygon meshes, and no discontinuity occurs at the boundary.

In contrast, Fig. 6B shows an example in which polygon meshes having a low resolution are arranged adjacent to each other. Even when polygon meshes with low resolution are arranged adjacent to each other in this way, the vertices on the boundary match each other between the polygon meshes so that no discontinuity occurs at the boundary. However, because an area having a high resolution occurs only in a part of boundary portions, visual discontinuity occurs. This discontinuity is avoided by performing a smoothing process which will be described later.

[0019]

Next, the polygon mesh storage unit 3 transfers data of the polygon mesh having a low resolution and data of the polygon mesh having a high resolution, which are generated as described above, from the CPU 11 to the GPU 13 which are shown in Fig. 2, and stores the data in a storage area of the GPU 13. When the memory capacity of the GPU 13 is limited, the polygon mesh storage unit stores only the polygon mesh having a low resolution in the GPU 13. The polygon mesh storage unit 3 stores the polygon mesh having a high resolution only in a storage area of the CPU 11, and transfers only the data about polygon meshes with high resolution which are required in accordance with a change of the eyepoint position to the GPU 13 and stores the

data in the GPU 13.

[0020]

The projective transformation unit 4 applies a projective transformation matrix which is determined in accordance with the eyepoint position to the coordinate values of each vertex of each acquired polygon mesh, thereby acquiring a polygon mesh projected onto a two-dimensional coordinate system.

At this time, the drawing device determines either one of the polygon mesh having a high resolution or the polygon mesh having a low resolution as a data to be used for each region which is a target for drawing. The drawing device carries out this determination by, for example, comparing, as to each region, a predetermined distance and the distance between the current eyepoint position and the region. When the latter distance is longer than the former distance, the drawing device uses the polygon mesh having a low resolution, whereas when the latter distance is shorter than or equal to the former distance, the drawing device uses the polygon mesh having a high resolution.

[0021]

Next, the drawing device performs a smoothing process, which will be described later, on the data about the selected polygon mesh. The smoothing process is performed in a case where the polygon mesh of a target region to be processed has a low resolution, and a polygon mesh of another region adjacent to the target region has similarly a low resolution.

Because the peripheral portion of each polygon mesh having a low resolution is resolution-enhanced as described above, when polygon meshes having a low resolution are adjacent to each other, a high resolution region is generated in a boundary portion, and a visually-discontinuous area occurs.

The drawing device can prevent such a discontinuous area from occurring by performing the smoothing process.

[0022]

The color filling unit 5 carries out a process of filling
5 the inside of each polygon, which is enclosed by vertices being acquired as a result of the projective transformation, with a predetermined color.

[0023]

The image output unit 6 writes an acquired draw result
10 in a storage unit called a frame buffer, and transfers the image to the display unit 10 via a video image cable or the like. This image is displayed by the display unit 10.

[0024]

Next, the process carried out by the smoothing unit 7 will
15 be explained.

Figs. 7 and 8 are diagrams for explaining the smoothing process carried out by the smoothing unit 7. In Fig. 7, vertices pointed by arrows are added when the peripheral portion is resolution-enhanced in performing the process of generating a
20 polygon mesh (only some of the added vertices are pointed by arrows). The smoothing unit 7 performs the smoothing process on these vertices as required.

[0025]

Concretely, the smoothing unit performs a process as
25 shown in Figs. 8A to 8C. Fig. 8A shows a part of a polygon mesh before the smoothing unit performs the smoothing process. A point (middle point) intermediate between the both end points of a lower side shown in the diagram is an added vertex. The added vertex has an altitude value at the coordinate values of
30 the vertex itself. Therefore, the line connecting, via the

middle point, between the both end points of the lower side shown in the diagram is bent at the middle point, and is not straight.

[0026]

To solve this problem, the smoothing unit changes the altitude value at the coordinate values of this added vertex to an altitude value which the smoothing unit acquires by interpolating between the altitude values at the coordinate values of the two vertices adjacent to the added vertex, as shown in Fig. 8B. As a result, the lower side shown in the diagram is changed to a straight side which is not bent at the middle point. Therefore, as shown in Fig. 8C, the smoothing unit can delete this middle point and can put the data of the polygon mesh back into the data before the addition of the vertex.

[0027]

At this time, as shown in an upper part of Fig. 8C, the whole of the area shown in the diagram can be expressed as a single rectangle. As shown in a lower part of Fig. 8C, the whole of the area shown in the diagram can be expressed alternatively as two triangles. Therefore, the smoothing unit can select whether to use either of them in accordance with the states of other areas adjacent to the target area.

[0028]

Fig. 9 shows an example in which polygon meshes having a low resolution are arranged adjacent to each other after the smoothing unit performs the above-described smoothing process. It can be seen from a comparison with Fig. 6B that no visually-discontinuous area having a high resolution is not generated in a boundary portion in which the polygon meshes are adjacent to each other, so that it is understood that a visually-continuous polygon mesh is obtained.

[0029]

Note that, the smoothing process can be performed before the projective transformation in the GPU 13. Therefore, it is not necessary to re-transfer the vertex data from the CPU every
5 time when the smoothing process is performed, so that the drawing device can perform the processing at a high speed. Further, the frame rate of the display can be increased.

[0030]

Fig. 10 is a diagram showing a flow chart of the
10 above-mentioned operation.

[0031]

The drawing device according to Embodiment 1 is configured as above.

According to this configuration, the polygon mesh
15 generating unit 2 generates a polygon mesh having a high resolution and a polygon mesh having a low resolution in such a way that the vertices of the low-resolution polygon mesh and the vertices of the high-resolution polygon mesh are matched with each other on the boundary therebetween by enhancing the
20 resolution of the peripheral region of the low-resolution polygon mesh, and when the polygon mesh having a low resolution is adjacent to another polygon mesh having a low resolution, the smoothing unit 7 smooths the coordinate values of vertices constructing a boundary portion between the polygon mesh and
25 the other polygon mesh, there is provided an advantage of preventing occurrence of any discontinuous area in a boundary portion between regions, without changing the polygon meshes stored in the polygon mesh storage unit 3 every time the eyepoint position is changed.

30 **INDUSTRIAL APPLICABILITY**

[0032]

As mentioned above, the drawing device according to the present invention can be applied to a device or the like to which three-dimensional geographical feature information and an
5 eyepoint position are given, and that generates an image which is viewed from the given eyepoint position.

REFERENCE SIGNS LIST

[0033]

1 drawing device, 2 polygon mesh generating unit, 3 polygon mesh
10 storage unit, 4 projective transformation unit, 5 color filling unit, 6 image output unit, 7 smoothing unit, 8 auxiliary storage unit, 9 input unit, 10 display unit, 11 central processing unit (CPU), 12 main storage unit, and 13 graphics processing unit (GPU).

15

CLAIMS

1. A drawing device comprising:

a polygon mesh generating unit for generating, for a plurality of regions forming a three-dimensional geographical feature, both a plurality of high resolution polygon meshes each of which expresses a corresponding one of the plurality of regions with a high resolution, and a plurality of low resolution polygon meshes each of which expresses a corresponding one of the plurality of regions with a lower resolution than those of the plurality of high resolution polygon meshes, each of the plurality of low resolution polygon meshes expressing a peripheral portion of the corresponding region with enhanced-resolution in such a way that vertices of the corresponding low resolution polygon mesh constructing boundaries of the corresponding region have positions matching respective positions of vertices of the corresponding high resolution polygon mesh;

a polygon mesh storage unit for storing the plurality of low resolution polygon meshes and the plurality of high resolution polygon meshes, both of which are generated by the polygon mesh generating unit;

a projective transformation unit for selecting either at least one of the plurality of low resolution polygon meshes or at least one of the plurality of high resolution polygon meshes, each of the at least one low resolution polygon mesh and the at least one high resolution polygon mesh expressing a corresponding one of the plurality of regions in accordance with a given eyepoint position, and performing projective transformation of vertex coordinate values of vertices of the selected polygon mesh into two-dimensional coordinate values; and

a smoothing unit for, when the projective transformation unit selects the low resolution polygon mesh as each of adjacent polygon meshes, correcting coordinate values of a vertex constructing a boundary between the adjacent polygon meshes to be values obtained by interpolating between coordinate values of vertices adjacent to the vertex.

2. The drawing device according to claim 1, wherein the polygon mesh storage

unit comprises:

a main storage unit for storing the plurality of low resolution polygon meshes and the plurality of high resolution polygon meshes, both of which are generated by the polygon mesh generating unit; and

5 a storage area of a graphics processing unit for storing the plurality of low resolution polygon meshes which are stored in and transmitted from the main storage unit.

3. The drawing device according to claim 1 or claim 2, further comprising: a
10 color filling unit for generating an image in which inside of each polygons enclosed by the vertex coordinate values acquired by the projective transformation unit is filled with a predetermined color; and

an image output unit for outputting the image acquired by the color filling unit to a display unit.

15

4. A drawing method comprising:

a polygon mesh generating step for generating, for a plurality of regions forming a three-dimensional geographical feature, both a plurality of high resolution polygon meshes each of which expresses a corresponding one of the plurality of
20 regions with a high resolution, and a plurality of low resolution polygon meshes each of which expresses a corresponding one of the plurality of regions with a lower resolution than those of the plurality of high resolution polygon meshes, each of the plurality of low resolution polygon meshes expressing a peripheral portion of the corresponding region with enhanced-resolution in such a way that vertices of the
25 corresponding low resolution polygon mesh constructing boundaries of the corresponding region have positions matching respective positions of vertices of the corresponding high resolution polygon mesh;

a polygon mesh storing step for storing the plurality of low resolution polygon meshes and the plurality of high resolution polygon meshes, both of which are
30 generated by the polygon mesh generating step;

a projective transformation step for selecting either at least one of the plurality of low resolution polygon meshes or at least one of the plurality of high resolution polygon meshes, each of the at least one low resolution polygon mesh and the at least one high resolution polygon mesh expressing a corresponding one of the plurality of regions in accordance with a given eyepoint position, and performing projective transformation of coordinate values of vertices of the selected polygon mesh into two-dimensional coordinate values; and

a smoothing step for, when the low resolution polygon mesh is selected as each of adjacent polygon meshes at the projective transformation step, correcting coordinate values of a vertex constructing a boundary between the adjacent polygon meshes to be values obtained by interpolating between coordinate values of vertices adjacent to the vertex.