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Method and apparatus for texture data

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(56) Related Art

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ABSTRACT OF THE DISCLOSURE

A system for reading texture data from a memory without need to use a cache unit in such a manner that the read speed is not affected by the size of the memory, wherein a memory address is supplied to a memory address comparing unit, a memory address comparing unit compares the memory address of the current pixel and the memory address of the immediately preceding adjacent pixel, the compared result being supplied as information to a compared result storing unit which stores the information. A memory accessing unit receives a memory address different from the memory address of the adjacent pixel and reads texture data the corresponding address in a memory, the texture data being stored in a texture data storing unit. A texture data restructuring unit reads texture data from the texture data storing unit corresponding to the information read from the compared result storing unit and restructures the texture data accordingly.

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COMPLETE SPECIFICATION

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Applicant(s):

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Invention Title:

METHOD AND APPARATUS FOR TEXTURE DATA

The following statement is a full description of this invention, including the best method of performing it known to me/us:

METHOD AND APPARATUS FOR TEXTURE DATA

This application claims priority under the International Convention based upon Japanese Patent Application No. P08-249133, filed August 30, 1996.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a new and improved method and apparatus for reading and rendering texture data for use with a texture mapping technique that substantially improves expression in a three-dimensional computer graphics system. In particular, the present invention can be applied for a variety of fields such as CAD (Computer Aided Designing) systems and game machines.

Description of the Related Art

Texture mapping is used to place texture data such as pattern or natural images on an object in computer graphics. This object is typically formed using a plurality of polygons, such as a triangle polygon or a square polygon. Therefore, by using texture mapping, a realistic picture can be generated. For example, consider the state wherein an object in square form mapped texture data is rotating. As mentioned above, since generally an object is formed from a plurality of polygons such as triangles, texture data is mapped as each polygon unit. With respect to such texture data mapping, the texture data is stored in a memory beforehand, and the texture mapping is performed by reading texture data from the memory in accordance with calculated memory addressing.

An example of a conventional texture mapping operation is as follows:

1) Texture coordinates (S1, T1, Q1), (S2, T2, Q2), and (S3, T3, Q3) are designated to vertexes of a triangle.

2) By linearly interpolating the texture coordinates of the vertexes of the triangle, texture coordinates (S, T, Q) of an inner point of the triangle are obtained.

3) By performing dividing operations of U = S/Q and V = T/Q, a memory address (U, V) is obtained.

4) Texture data is then read from the memory with the memory address obtained in step 3 and is placed on the triangle.

In a conventional computer graphics system, texture data is mapped in such a manner that a texture data reading apparatus reads texture data from a conventional memory. However, since the read speed of texture data from the memory is not satisfactorily high, the performance of the texture mapping apparatus is restricted.

To solve such a problem, a cache unit that temporarily stores texture data may be disposed between the texture data reading apparatus and the memory. In this case, the data reading apparatus can read texture data from the cache unit at high speed.

In such a structure, when the size of texture data is smaller than the storage capacity of the cache unit, the texture data can be read at high speed. However, when the size of the texture data is larger than the storage capacity of the cache unit, to change texture data in the cache unit, texture data should be read from the memory and then written to the cache unit. Thus, the cache unit does not effectively work as a means for sending capture data at high speed.

In addition, since the circuit scale of the cache unit is large, when it is used, a small scale texture mapping unit cannot be accomplished.

Accordingly, there has been a long existing need for improved methods and apparatus for texture data reading and rendering which obviates the aforedescribed difficulties encountered with systems heretofore available. The present invention clearly fulfills this need.

SUMMARY OF THE INVENTION

According to one aspect, this invention provides a texture data reading apparatus for reading texture data to be mapped from a memory, including:

texture data reading means for comparing the memory address of texture data associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

means for accessing the memory address of texture data associated with the current pixel;

means for reading new texture data only when the memory address of texture data associated with the current pixel is different from the memory address of texture data associated with an adjacent pixel; and

means for reusing stored texture data rather than reading new texture data from the memory when the memory address of texture data associated with the current pixel is the same as the memory address of texture data associated with an adjacent pixel, thereby enhancing efficiency.

Another aspect of the invention provides a texture data reading apparatus for reading texture data to be mapped from a memory, including:

memory address comparing means for comparing the

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memory address of texture data associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

compared result storing means for storing information, in response to a compared result of said memory address comparing means, that indicates that texture data newly read from the memory is to be used, or texture data previously read from the memory is to be reused;

memory accessing means for accessing the memory corresponding to the compared result of said memory address comparing means, and for reading texture data from the memory;

texture data storing means for storing the texture data that has been read from the memory by said memory accessing means; and

texture data restructuring means for reading desired texture data from said texture data storing means corresponding to the information stored in said compared result storing means,

whereby when the memory address of texture data associated with a pixel is the same as the memory address of texture data associated with an adjacent pixel, texture data is not read from the memory, instead texture data with the same address is reused, thereby increasing efficiency.

Another aspect of the invention provides a rendering apparatus, including:

a plurality of memories; and

a plurality of texture data reading units for reading texture data from said memories, said texture data reading units being connected to said memories in parallel, texture data of a plurality of pixels being read from said memories,

each of said texture data reading units:

compares the memory address of texture data

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associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

accesses the memory with the memory address of texture data associated with the current pixel;

reads new texture data only when the memory address of texture data associated with the current pixel is different from the memory address of texture data associated with adjacent pixel; and

reuses stored texture data, rather than reading new texture data from the memory, when the memory address of texture data associated with the current pixel is the same as the memory address of texture data associated with an adjacent pixel, thereby increasing efficiency.

Another aspect of the invention provides a method for reading texture data to be mapped from a memory, including the steps of:

comparing the present memory address of texture data associated with a current pixel to be read, with a previous memory address of texture data associated with adjacent pixel; and

restructuring texture data, in response to a result of said comparing step, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data, read in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address.

Another aspect of the invention provides an apparatus for reading texture data to be mapped from a memory, including:

a first memory for storing texture data;

a comparator for comparing the present memory address of texture data associated with a current pixel with a previous memory address of texture data associated

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with an adjacent pixel, thereby providing a compared result; and

a restructuring device for restructuring texture data, in response to said compared result, by reading texture data from said memory, in accordance with the present memory address, whenever the present memory address is different from the previous sequential memory address, or by reusing texture data, read in accordance with the previous memory address, whenever the present memory address is same as the previous memory address.

Another aspect of the invention provides a rendering apparatus for generating drawing image data, including:

a coordinate processing unit for receiving vertex data of a polygon including coordinates of the vertices, and for generating coordinate data representing coordinates in the polygon from the coordinates of the vertices of the polygon;

a color value processing unit for receiving vertex data of the polygon including color values of the vertices and for generating color values in the polygon from the color values of the vertices of the polygon;

a texture memory for storing texture memory;

a texture address generating unit for receiving vertex data of the polygon including texture coordinates of the vertices and for generating texture addresses in the polygon from the texture coordinates of the vertices of the polygon, said texture addresses referring to texture data in said texture memory;

a texture data rendering unit for reading texture data from said texture memory in accordance with each texture address; and

a blending unit for blending the color values and texture data and generating new color data;

a comparator for comparing the present memory address of texture data associated with a current pixel

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and a previous memory address of texture data associated with an adjacent pixel to thereby provide a compared result, wherein the present memory address and the previous memory address being provided by said texture address generating unit; and

a restructuring device for restructuring texture data, in response to said compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data read, in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address,

whereby said coordinate data and said new color data are transmitted for drawing an image.

Another aspect of the invention provides a rendering apparatus for generating drawing image data, including:

a plurality of rendering units disposed in parallel for receiving vertices data of a polygon and for generating data for drawing an image each rendering unit including a texture memory and a reading unit for reading texture data from said texture memory; and wherein

each reading unit includes:

a comparator for comparing the present memory address of texture data associated with a current pixel with a previous memory address of texture data associated and an adjacent pixel, the present memory address and the previous memory address being provided from a texture address generating unit, to thereby provide a compared result; and

a restructuring device for restructuring texture data, in response to said compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or

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by reusing texture data, read in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address.

Another aspect of the invention provides a rendering method for generating drawing image data, including the steps of:

receiving vertex data of a polygon including coordinates of the vertices;

generating coordinate data representing coordinates in the polygon from the coordinates of the vertices of the polygon;

receiving vertex data of the polygon including color values of the vertices;

generating color values in the polygon from the color values of the vertices of the polygon;

receiving vertex data of the polygon including texture coordinates of the vertices;

generating texture addresses in the polygon from the texture coordinates of the vertices of the polygon, said texture addresses referring to texture data in a texture memory;

reading texture data from said texture memory in accordance with each texture address; and

comparing the present memory address of texture data associated with a current pixel and a previous memory address of texture data associated with an adjacent pixel, to thereby provide a compared result;

restructuring texture data, in response to said compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data read, in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address; and

blending the color values and texture data and

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generating new color data.

Another aspect of the invention provides a method for reading texture data, including the steps of:

comparing a present memory address of texture data associated with a current data point with a previous memory address of texture data associated with an adjacent data point, to thereby produce a compared result; and

restructuring the texture data, in response to the compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data read, in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of an embodiment of the present invention;

Figs. 2A and 2B are schematic diagrams for explaining an example of the operation of the embodiment of the present invention;

Figs. 3A and 3B are schematic diagrams for explaining the operation of a four-point interpolating process according to an embodiment of the present invention;

Fig. 4 is a block diagram illustrating a rendering apparatus with a texture data reading apparatus, all according to an embodiment of the present invention;

Fig. 5 is a block diagram showing a rendering apparatus with a plurality of texture data reading apparatuses according to another embodiment of the present invention;

Figs. 6A-6D are schematic diagrams for explaining the general concepts of texture mapping; and

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Figs. 7A and 7B are block diagrams showing the structure of a conventional texture data reading apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the accompanying drawings, like reference numerals denote like or corresponding parts throughout the drawing figures.

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The structure and operation of a conventional texture data mapping, reading and rendering system is illustrated in Figures 6, 7A and 7B of the drawings.

Texture mapping is used to place texture data such as pattern or natural images onto an object in computer graphics. This object is typically formed using a plurality of polygons, such as a triangle polygon or a square polygon. Therefore, by using texture mapping, a realistic picture can be generated. For example, consider the state wherein an object in square form mapped texture data is rotating. As previously mentioned, generally an object is formed from a plurality of polygons such as triangles, texture data is mapped as each polygon unit. With respect to such texture data mapping, the texture data is stored in a memory beforehand, and the texture mapping is performed by reading texture data from the memory in accordance with calculated memory addressing.

An example of a conventional texture mapping operation is as follows:

1) Texture coordinates (S1, T1, Q1), (S2, T2, Q2), and (S3, T3, Q3) are designated to vertexes of a triangle.

2) By linearly interpolating the texture coordinates of the vertexes of the triangle, texture coordinates (S, T, Q) of an inner point of the triangle are obtained.

3) By performing dividing operations of U = S/Q and V = T/Q, a memory address (U, V) is obtained.

4) Texture data is then read from the memory with the memory address obtained in step 3 and is placed on the triangle.

In a conventional computer graphics system, texture data is mapped in such a manner that a texture

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data reading apparatus 51 reads texture data from a conventional memory 52. However, since the read speed of texture data from the memory 52 is not satisfactorily high, the performance of the texture mapping apparatus is restricted.

To solve such a problem, as shown in Fig. 7B, a cache unit 53 that temporarily stores texture data may be disposed between the texture data reading apparatus 51 and the memory 52. In this case, the data reading apparatus 51 can read texture data from the cache unit 53 at high speed.

In such a structure, when the size of texture data is smaller than the storage capacity of the cache unit, the texture data can be read at high speed. However, when the size of the texture data is larger than the storage capacity of the cache unit, to change texture data in the cache unit, texture data should be read from the memory and then written to the cache unit. Thus, the cache unit does not effectively work as a means for sending capture data at high speed.

In addition, since the circuit scale of the cache unit is large, when it is used, a small scale texture mapping unit cannot be accomplished.

In computer graphics, when an image is drawn, it is divided into scan lines and drawn in the order of the scan lines. Hence, the typical triangle polygon is divided into the successive scan lines for the display. Next, in accordance with the invention, the case of which texture data of one scan line is read from a memory will be described.

As best observed in Fig. 1, the apparatus reads texture data from a memory. The apparatus shown in Fig.

1 is composed of a texture data reading apparatus and a memory 14. The texture data reading apparatus 12 is composed of a memory address comparing unit 15, a compared result storing unit 16, a memory accessing unit 17, a texture data storing unit 18, and a texture data restructuring unit 19. A memory address (U, V) is supplied to the memory address comparing unit 15 through an input terminal 11.

The memory address comparing unit 15 is a memory address comparator that compares the present memory address of texture data associated with a pixel and the previous memory address of texture data associated with an adjacent pixel to determine whether or not to read texture data from the memory 14. The compared result is provided by the compared result storing unit 16. Furthermore, the memory address comparing unit 15 selects only the memory address (U, V) of the texture data which should be read from the memory 14, in accordance with the compared result, and then provides the memory accessing unit 17 with the selected memory address (U, V). That is, if the present memory address of texture data associated with the present pixel is different to the previous memory address of texture data associated with an adjacent pixel, the present memory address of texture data associated with the present pixel is provided to the memory accessing unit 17. Furthermore, the information representing the result is simultaneously provided to the compared result storing unit 16. On the other hand, if the present memory address of texture data associated with the present pixel is the same as the previous memory address of texture data associated with an adjacent pixel, the present memory address of texture data associated with the present pixel is not provided to the memory accessing unit 17. Instead, only the information representing the result is provided to the compared result storing unit 16.

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The compared result storing unit 16 is a compared result memory that stores the information representing the result provided by the memory address comparing unit 15. This information indicates whether texture data which is newly read from the memory is used, or texture data which was previously read from the memory is re-used.

The memory accessing unit 17 is a memory accessing device that accesses the memory 14 and reads texture data C (U, V) from the memory 14 in accordance with the memory address provided by the memory address comparing unit 15.

The texture data storing means 18 is a texture data memory that stores the texture data C (U, V) which has been read from the memory 17 by the memory accessing unit 17.

The texture data restructuring unit 19 is a texture data restructuring device that reads desired texture data C (U, V) from the texture data storing unit 18 in accordance with the compared result information stored in the compared result storing unit 16. That is, if the information from the compared result storing unit 16 represents that the present memory address of texture data associated with the present pixel is the same as the previous memory address of texture data associated with an adjacent pixel, the texture data corresponding to the previous memory address of texture data associated with an adjacent pixel is recursively used in the texture data restructuring unit 19. This operation is performed as follows.

Thus, in the texture reading apparatus 12, when the present memory address of texture data associated with a present pixel is the same as the previous memory address of texture data associated with an adjacent pixel, texture

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data is not read from the memory 14. Rather, texture data, corresponding to the previous memory address, associated with the adjacent pixel is re-used. However, when the present memory address of texture data associated with a present pixel is different from the previous memory address of texture data associated with an adjacent pixel, texture data associated with the present pixel is read from the memory 14, and the newly read texture data is used. Accordingly, in the present invention, the number of memory access operations is substantially reduced.

Next, with reference to Fig. 2, an example of the process accomplished by the structure shown in Fig. 1 is described. The memory address comparing unit 15 shown in Fig. 1 compares the present memory address of texture data associated with a present pixel and a memory address of texture data associated with an adjacent pixel determine whether or not to read texture data from the memory.

As shown in Fig. 2, assume that there are five pixels on a scan line and that memory addresses (U, V) (including the decimal part) for reading texture data from the memory 14 are as follows:

(1.4, 1.2), (1.9, 1.7), (2.4, 2.2), (2.9, 2.7), (3.4, 3.2)

The memory address values can be truncated into integers as follows:

(1, 1), (2, 2) (2, 2), (3, 3), (3, 3)

Thus, to obtain texture data for five pixels, the reading operation for the memory 14 should be performed five times.

When a memory address of texture data associated with each pixel and a memory address of texture data associated with a preceding adjacent pixel are compared, the memory address of texture data associated with the

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third pixel is the same as the memory address of texture data associated with the second pixel. In addition, the memory address of texture data associated with the fifth pixel is the same as the memory address of texture data associated with the fourth pixel. Thus, the memory address comparing unit 15 determines whether to re-use texture data of the second pixel for the third pixel, and texture data of the fourth pixel for the fifth pixel, thereby sending only the following three memory addresses to the memory accessing unit 17, shown in Fig. 1,

(1, 1), (2, 2), (3, 3)

In addition, the memory address comparing unit 15 sends information Info, which indicates either: texture data that is newly read from the memory 14 is to be used; or texture data that has been read from the memory is to be re-used for each pixel to the compared result storing unit 16.

As an example of the information Info to be sent, texture data which is newly read from the memory is denoted by '1', whilst texture data that has been read from the memory and re-used is denoted by '0'. The information Info is composed of data which is a bit in length for each data sample; for instance, Info1 as the compared result of the first pixel, Info2 as the compared result of the second pixel, Info3 as the compared result of the third pixel, Info4 as the compared result of the fourth pixel, and Info5 as the compared result of the fifth pixel. As an example, the information Info of '1, 1, 0, 1, 0' represents the pixels on the scan line shown in Fig. 2.

The compared result storing unit 16, shown in Fig. 1, is a FIFO, first in - first out, type of buffer that stores the information Info received from the memory address comparing unit 15. The compared result storing

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unit 16 successively reads the information Info corresponding to a request received from the texture data restructuring unit 19 shown in Fig. 1.

The memory accessing unit 17 shown in Fig. 1 accesses the memory 14, corresponding to the provided memory address of the memory address comparing unit 15, and reads texture data from the memory 14.

In the example of the five pixels on the scan line shown in Fig. 2, texture data is read from the memory 14 in accordance with three memory addresses (1, 1) (2, 2), (3, 3) received from the memory address comparing unit 15.

Assuming that texture data that has been read is denoted by C (U, V), three texture data C (1, 1), C (2, 2), and C (3, 3) are sent to the texture data storing unit 18 shown in Fig. 1.

The texture data storing unit 18 shown in Fig. 1 is a FIFO, first in - first out, type of buffer that stores texture data read from the memory 14 by the memory accessing unit 17. The texture data stored in the texture data storing unit 18 is successively read in accordance with a request received from the texture data restructuring unit 19.

The texture data restructuring unit 19 shown in Fig. 1 reads the desired texture data from the texture data storing unit 18 according to the information stored in the compared result storing unit 16.

In the example of the five pixels on the scan line shown in Fig. 2, the compared result storing unit 16 and the texture data storing unit 18 store the following data respectively: 1, 1, 0, 1, 0; and C (1, 1), C (2, 2),

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C (3, 3).

In regard to the texture data restructuring unit 19, the following describes a method for restructuring texture data for five pixels with the information stored in the compared result storing unit 16, and the texture data storing unit 18.

The information for the first pixel (Info1) is read from the compared result storing unit 16. Since this information is represented by "1", a first texture data C (1, 1) is read from the texture data storing unit 18, wherein the read texture data C (1, 1) is used.

The information for the second pixel (Info2) is read from the compared result storing unit 16. Since this information is also represented by "1", a new texture data C (2, 2) is read from the texture data storing units 18 wherein the read texture data C (2, 2) is used.

The information for the third pixel (Info3) is read from the compared result storing unit 16. Since this information is represented "0", a new texture data is not read from the texture data storing unit 18, rather that texture data C (2, 2), which was previously read, is re-used.

The information for the fourth pixel (Info4) is read from the compared result storing unit 16. Since this information is represented by "1", a new texture data C (3, 3) is read from the texture data storing units 18, wherein the read texture data C (3, 3) is used.

The information for the fifth pixel (Info5) is read from the compared result storing unit 16. Since this information is represented by "0", new texture data is not read from the texture data storing unit 18; rather the

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texture data C (3, 3), which was previously read, is re-used.

In such a manner, the following texture data for five pixels is restructured with the memory accessing operation occurring only three times.

C (1, 1), C (2, 2), C (2, 2), C (3, 3), C (3, 3)

According to the present invention, when the present memory address of texture data associated with a pixel is the same as the previous memory address of texture data associated with an adjacent pixel, texture data is not read from the memory. Instead, previously read texture data with the same memory address is re-used. Thus, even at low speed memory is used, a texture data reading apparatus that operates at high speed is provided because the number of operations involving memory access is reduced.

In addition, the present invention can be used where the texture data associated with a pixel to be read is interpolated using the four sets of texture data which is associated with adjacent pixels, as shown in Fig. 3, thereby generating high quality texture data.

As an example, the following describes the situation in which the texture data associated with a pixel to be read is interpolated with the four sets of texture data having the structure shown in Fig. 1.

When four adjacent points are interpolated, four sets of texture data are read from the four corresponding memory addresses that are adjacent to a memory address of texture data associated with each current pixel. Assuming that the decimal part of the given memory address is truncated as (UO, VO), texture data is read from four memory addresses (UO, VO), (UO+1, VO), (UO, VO+1), and

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(UO+1, VO+1).

In the example shown in Fig. 3, texture data should be read with the following 20 memory addresses:

First pixel - (1, 1), (2, 1), (1, 2), (2, 2)
Second pixel - (1, 1), (2, 1), (1, 2), (2, 2)
Third pixel - (2, 2), (3, 2), (2, 3), (3, 3)
Fourth pixel - (2, 2), (3, 2), (2, 3), (3, 3)
Fifth pixel - (3, 3), (4, 3), (3, 4), (4, 4)

The memory address comparing unit 15, shown in Fig. 1, receives the present memory address of texture data associated with the pixel to be read, and determines the four memory addresses which are adjacent to the present memory address. The memory address comparing unit 15 compares the four memory addresses which are adjacent to the present memory address and the four memory addresses which are adjacent to the previous memory address of texture data associated with an adjacent pixel. Following which, the memory address comparing unit 15 ignores those memory addresses that are the same, supplying only those memory addresses which are different to the memory accessing unit 17.

In the example shown in Fig. 3, the memory address comparing unit 15 sends the following 10 memory addresses to the memory accessing unit 17:

First pixel - (1, 1), (2, 1), (1, 2), (2, 2)
Third pixel - (3, 2), (2, 3), (3, 3)
Fifth pixel - (4, 3), (3, 4), (4, 4)

In addition, the memory address comparing unit 15 provides the compared result storing unit 16 with information 1 and information 2, as the information representing the compared result. The information 1 and

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the information 2 is necessary for the texture data restructuring unit 19, shown in Fig. 1, to restructure the texture data.

The information 1 as the first information is four-bit information which indicates that texture data newly read from the memory is to be used, or texture data that has been read is re-read for each pixel.

The information 2 as the second information is two-bit information which is the least significant bits of U and V of the memory address (U, V) of each pixel.

In the example shown in Fig. 3, the following information Info of each pixel is sent to the compared result storing unit 16. The relation between each information (information 1 and information 2) of the table and the four memory addresses is given in the order of (UO, VO), (UO+1, VO), (UO, VO+1), (UO+1, VO+1).

	Information 1	Information 2 (least significant bit of memory address)
1-st pixel	1111	(1, 1), (0, 1), (1, 0), (0, 0)
2-nd pixel	0000	(1, 1), (0, 1), (1, 0), (0, 0)
3-rd pixel	0111	(0, 0), (1, 0), (0, 1), (1, 1)
4-th pixel	0000	(0, 0), (1, 0), (0, 1), (1, 1)
5-th pixel	0111	(1, 1), (0, 1), (1, 0), (0, 0)

Hereinafter, for simplicity of explanation, (0, 0), (1, 0), (0, 1), and (1, 1) of the information 2 are denoted by A, B, C, and D, respectively. Thus, the above table is rewritten as follows:

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	Information 1	Information 2
1-st pixel	1111	DCBA
2-nd pixel	0000	DCBA
3-rd pixel	0111	ABCD
4-th pixel	0000	ABCD
5-th pixel	0111	DCBA

In the aforedescribed example, "1" denotes that newly read texture data is used for a pixel, whilst "0" denotes that texture data previously read is re-used.

According to the table, at the memory address (UO, VO) of the third pixel, the information 1 indicates that the memory is not accessed, rather texture data is re-used. The information 2 indicates that the texture data at the memory address (UO, VO) is the same as the memory address (UO+1, VO+1) of the second pixel (first pixel).

The memory accessing unit 17, shown in Fig. 1, reads texture data from the memory in accordance with the memory address (U, V), which is received from the memory address comparing unit 15, and sends the texture data C (U, V), which corresponds to the provided memory address, to the texture data storing unit 18 shown in Fig. 1.

In the example shown in Fig. 3, the memory accessing unit 17 reads texture data C (U, V) from the memory 14, which corresponds to the following memory addresses received from the memory address comparing unit 15, and sends the texture data C to the texture data storing unit 18.

Memory Address -
First pixel: (1, 1), (2, 1), (1, 2), (2, 2)
Second pixel: (3, 2), (2, 3), (3, 3)
Fifth pixel: (4, 3), (3, 4), (4, 4)

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Texture Data -
C (1, 1), C (2, 1), C (1, 2), C (2, 2)
C (3, 2), C (2, 3), C (3, 3)
C (4, 3), C (3, 4), C (4, 4)

The texture data storing unit 18, shown in Fig. 1, is a FIFO type buffer that stores the texture data C (U, V) received from the memory accessing unit 17.

When four adjacent points are interpolated, texture data corresponding to four memory addresses of texture data associated with each pixel is stored. Corresponding to the least significant bits of the texture address (U, V), C (0, 0), C (1, 0), C (0, 1), and C (1, 1) are stored in A, B, C, and D that are four FIFO type texture data storing units 18, respectively.

In the example shown in Fig. 3, the following texture data C (U, V) is stored in A, B, C, and D.

A: C (2, 2), C (4, 4)
B: C (1, 2), C (3, 2), C (3, 4)
C: C (2, 1), C (2, 3), C (4, 3)
D: C (1, 1), C (3, 3)

The texture data restructuring unit 19, shown in Fig. 1, reads the texture data stored in the texture data storing unit 18, which corresponds to information stored in the compared result storing unit 16.

In the method for restructuring texture data, it is determined whether new texture data is read from the texture data storing unit 18, or texture data is re-used in accordance with the information 1 of the compared result storing unit 16. In addition, it is determined from A, B, C, or D of the FIFO type texture data storing units 18, which texture data is read in accordance with the information 2 of the compared result storing unit 16.

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In the example shown in Fig. 3, information and texture data (U, V) are read from the compared result storing unit 16 and the texture data storing unit 18, respectively, in sequence. Thus, four texture data per pixel (a total of 20 texture data) are restructured.

First pixel -

From compared result storing unit: Information 1 (1111) and information 2 (DCBA)

From Texture data storing unit:

New texture data C (1, 1) is read from D.

New texture data C (2, 1) is read from C.

New texture data C (1, 2) is read from B.

New texture data C (2, 2) is read from A.

Second pixel -

From compared result storing unit: Information 1 (0000) and information 2 (DCBA)

From texture data storing unit:

Texture data C (1, 1) read from D is re-used.

Texture data C (2, 1) read from C is re-used.

Texture data C (1, 2) read from B is re-used.

Texture data C (2, 2) read from A is re-used.

Third pixel -

From compared result storing unit: Information 1 (0111) and information 2 (ABCD)

From texture data storing unit:

Texture data C (2, 2) read from A is re-used.

New texture data C (3, 2) is read from B.

New texture data C (2, 3) is read from C.

New texture data C (3, 3) is read from D.

Fourth pixel -

From compared result storing unit: Information 1 (0000) and information 2 (ABCD)

From texture data storing unit:

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Texture data C (2, 2) read from A is re-used.
Texture data C (3, 2) read from B is re-used.
Texture data C (2, 3) read from C is re-used.
Texture data C (3, 3) read from D is re-used.

Fifth pixel -
From compared result storing unit: Information 1 (0111) and information 2 (DCBA)
From texture data storing unit:
Texture data C (3, 3) read from D is re-used.
New texture data C (4, 3) is read from C.
New texture data C (3, 4) is read from B.
New texture data C (4, 4) is read from A.

As described above, 20 texture data can be restructured using 10 memory access operations. Even if four adjacent points are interpolated, the number of memory access operations can be reduced. Thus, a texture data reading apparatus that operates at high speed can be obtained.

Fig. 4 is a block diagram showing the structure of a rendering apparatus 40 having the above described texture data reading apparatus. The rendering apparatus 24 is composed of an XY processing unit 31 that processes XY coordinates (X, Y), a color processing unit 32 that processes color values (R, G, B), a texture processing unit 33 that processes texture coordinates (S, T, Q), and a blending unit 34 that calculates output data from the color processing unit 32 and the texture processing unit 33 to generate a new color. The rendering apparatus 24 is connected to a texture memory 25 that stores texture data, and a frame buffer 26 that stores drawing data.

The XY processing unit 31 generates XY coordinates (x, y) in a triangle polygon with the XY coordinates (X, Y) of three vertexes of the triangle

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received from the input terminal 21. The color processing unit 32 linearly interpolates the color values (R, G, B) of the three vertexes of the triangle polygon received from the input terminal 22, obtains a color value Cf of each pixel in the triangle, and outputs the color value Cf to the blending unit 34.

As shown in Fig. 1, the texture processing unit 33 is composed of a texture address generating unit 35 and a texture data reading apparatus 36. The texture address generating unit 35 generates a texture address (U, V) in a triangle polygon from the texture coordinates (S, T, Q) of the three vertexes of the triangle received from the input terminal 23, and sends the texture address (U, V) to the texture data reading apparatus 36. Thus, the texture data reading apparatus 36 reads texture data Ct from the texture memory 25 and sends the texture data Ct to the blending unit 34.

The blending unit 34 performs an adding operation or subtracting operation, for the output data Cf of the color processing unit 32 and the output data Ct of the texture processing unit 33, and generates a new color C.

The new color C generated by the above described processing units is written to the frame buffer 26 corresponding to the XY coordinates (x, y) generated by the XY processing unit 31. Thus, a rendering apparatus is obtained.

The rendering apparatus 24 can read texture data at high speed with a low speed memory rather than a large scale circuit such as a texture cache. Thus, texture data can be mapped at high sped with a small scale circuit.

In addition, according to the present invention,

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texture data can be independently read for each scan line. Fig. 5 is a block diagram showing the structure of a rendering apparatus which contains a plurality of rendering apparatuses 24 shown in Fig. 4.

The XY coordinates (X, Y) of three vertexes of a triangle, having the color values (R, G, B) of the three vertexes of the triangle, and texture coordinates (S, T, Q) of the three vertexes of the triangle are supplied to a high speed rendering apparatus 42 from an input terminal 41. The high speed rendering apparatus 42 has a plurality of rendering apparatuses 24 so as to process different scan lines in parallel. The input signals are supplied to the rendering apparatuses 241 to 24n. Each of the rendering apparatuses 241 to 24n perform the above described process. The texture memories 251 to 25n generate new colors C1 to Cn and write the colors to a frame buffer 26 which correspond to XY coordinates (x1, y1) to (xn, yn). Thus, a high speed rendering apparatus that processes signals several times faster than the rendering apparatus 24 can be accomplished.

In accordance with the foregoing description of the present invention, when a memory address of texture data associated with a pixel is the same as a memory address of texture data associated with an adjacent pixel, texture data is not read from the memory. When the memory address of texture data associated with the pixel is different from the memory address of texture data associated with an adjacent pixel, texture data that was previously read is re-used, thereby reducing the number of memory access operations. Thus, a small scale, high speed texture mapping operation can be accomplished without need to use a large scale circuit, such as a cache unit.

Hence, the present invention satisfies a long existing need for enhanced image data processing which can

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more efficiently map, read and render texture data.

It will be apparent from the foregoing that, while particular forms of the invention have been illustrated and described, various modifications can be made without departing from the spirit and scope of the invention. Accordingly, it is not intended that the invention be limited, except as by the appended claims.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

For the purposes of this specification it will be clearly understood that the word "comprising" means "including but not limited to", and that the word "comprises" has a corresponding meaning.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A texture data reading apparatus for reading texture data to be mapped from a memory, including:

texture data reading means for comparing the memory address of texture data associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

means for accessing the memory address of texture data associated with the current pixel;

means for reading new texture data only when the memory address of texture data associated with the current pixel is different from the memory address of texture data associated with an adjacent pixel; and

means for reusing stored texture data rather than reading new texture data from the memory when the memory address of texture data associated with the current pixel is the same as the memory address of texture data associated with an adjacent pixel, thereby enhancing efficiency.

2. A texture data reading apparatus for reading texture data to be mapped from a memory, including:

memory address comparing means for comparing the memory address of texture data associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

compared result storing means for storing information, in response to a compared result of said memory address comparing means, that indicates that texture data newly read from the memory is to be used, or texture data previously read from the memory is to be reused;

memory accessing means for accessing the memory corresponding to the compared result of said memory address comparing means, and for reading texture data from the memory;

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texture data storing means for storing the texture data that has been read from the memory by said memory accessing means; and

texture data restructuring means for reading desired texture data from said texture data storing means corresponding to the information stored in said compared result storing means,

whereby when the memory address of texture data associated with a pixel is the same as the memory address of texture data associated with an adjacent pixel, texture data is not read from the memory, instead texture data with the same address is reused, thereby increasing efficiency.

3. The texture data reading apparatus as claimed in claim 2, wherein said texture data reading apparatus:

inputs the memory address of texture data associated with each pixel in a triangle;

compares the memory address of texture data associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

accesses the memory address of texture data associated with the current pixel;

reads new texture data only when the memory address of texture data associated with the current pixel is different to the memory address of texture data associated with an adjacent pixel; and

reuses stored texture data, rather than reading new texture data from the memory when the memory address of texture data associated with the current pixel is the same as the memory address of texture data associated with an adjacent pixel.

4. A rendering apparatus, including:

a plurality of memories; and

a plurality of texture data reading units for reading texture data from said memories, said texture data

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reading units being connected to said memories in parallel, texture data of a plurality of pixels being read from said memories,

each of said texture data reading units:

compares the memory address of texture data associated with a current pixel and the memory address of texture data associated with an adjacent pixel;

accesses the memory with the memory address of texture data associated with the current pixel;

reads new texture data only when the memory address of texture data associated with the current pixel is different from the memory address of texture data associated with adjacent pixel; and

reuses stored texture data, rather than reading new texture data from the memory, when the memory address of texture data associated with the current pixel is the same as the memory address of texture data associated with an adjacent pixel, thereby increasing efficiency.

5. A method for reading texture data to be mapped from a memory, including the steps of:

comparing the present memory address of texture data associated with a current pixel to be read, with a previous memory address of texture data associated with adjacent pixel; and

restructuring texture data, in response to a result of said comparing step, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data, read in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address.

6. The method as claimed in claim 5, wherein said step of comparing generates information indicting whether

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or not the texture data is to be read and selects the memory address to read the texture data from said memory in response to the compared result.

7. The method as claimed in claim 6, further including the steps of:

storing the information;

accessing texture data in accordance with the selected memory address; and

storing the texture data read by said accessing step;

whereby said restructuring step restructures texture data by reading new texture data or by reusing texture data which has been previously read, in accordance with said compared result.

8. The method as set forth in claim 5, further including:

interpolating data for four adjacent pixels to increase image resolution.

9. The method as claimed in any one of claims 5-7, further including:

interpolating data for four adjacent pixels to increase image resolution.

10. An apparatus for reading texture data to be mapped from a memory, including:

a first memory for storing texture data;

a comparator for comparing the present memory address of texture data associated with a current pixel with a previous memory address of texture data associated with an adjacent pixel, thereby providing a compared result; and

a restructuring device for restructuring texture data, in response to said compared result, by reading

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texture data from said memory, in accordance with the present memory address, whenever the present memory address is different from the previous sequential memory address, or by reusing texture data, read in accordance with the previous memory address, whenever the present memory address is same as the previous memory address.

11. The apparatus as claimed in claim 10, wherein said comparator generates information indicating whether or not the texture data is to be read, and selects the memory address to read the texture data from said first memory in response to said compared result.

12. The apparatus as claimed in claim 11, further including:

a second memory for storing said information;

an accessing device for accessing texture data from said first memory in accordance with the selected memory address; and

a third memory for storing the texture data read by said accessing device;

wherein said restructuring device restructures texture data by reading texture data from said third memory or by reusing texture data which was previously read from said third memory, in accordance with the information from said second memory.

13. A rendering apparatus for generating drawing image data, including:

a coordinate processing unit for receiving vertex data of a polygon including coordinates of the vertices, and for generating coordinate data representing coordinates in the polygon from the coordinates of the vertices of the polygon;

a color value processing unit for receiving vertex data of the polygon including color values of the

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vertices and for generating color values in the polygon from the color values of the vertices of the polygon;

a texture memory for storing texture memory;

a texture address generating unit for receiving vertex data of the polygon including texture coordinates of the vertices and for generating texture addresses in the polygon from the texture coordinates of the vertices of the polygon, said texture addresses referring to texture data in said texture memory;

a texture data rendering unit for reading texture data from said texture memory in accordance with each texture address; and

a blending unit for blending the color values and texture data and generating new color data;

a comparator for comparing the present memory address of texture data associated with a current pixel and a previous memory address of texture data associated with an adjacent pixel to thereby provide a compared result, wherein the present memory address and the previous memory address being provided by said texture address generating unit; and

a restructuring device for restructuring texture data, in response to said compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data read, in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address,

whereby said coordinate data and said new color data are transmitted for drawing an image.

14. The apparatus as claimed in claim 13, wherein said comparator generates information indicating whether or not the texture data is to be read, and selects a memory address to read the texture data from said texture

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memory in response to said compared result.

15. The apparatus as claimed in claim 14, further including:

an information memory for storing said information;

an accessing device for accessing texture data from said texture memory in accordance with the selected memory address; and

a temporary texture memory for storing the texture data read by said accessing device;

wherein said restructuring device restructures texture data by reading texture data from said temporary texture memory or by reusing texture data which has been previously read from said temporary texture memory, in accordance with the information from said information memory.

16. A rendering apparatus for generating drawing image data, including:

a plurality of rendering units disposed in parallel for receiving vertices data of a polygon and for generating data for drawing an image each rendering unit including a texture memory and a reading unit for reading texture data from said texture memory; and wherein

each reading unit includes:

a comparator for comparing the present memory address of texture data associated with a current pixel with a previous memory address of texture data associated and an adjacent pixel, the present memory address and the previous memory address being provided from a texture address generating unit, to thereby provide a compared result; and

a restructuring device for restructuring texture data, in response to said compared result, by reading texture data from the memory, in accordance with the

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present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data, read in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address.

17. The apparatus as claimed in claim 16, further including:

an information memory for storing said information;

an accessing device for accessing texture data from said texture memory in accordance with the selected memory address; and

a temporary texture memory for storing the texture data read by said accessing device;

wherein said restructuring device restructures texture data by reading texture data from said temporary texture memory or by reusing texture data which has been previously read from said temporary texture memory, in accordance with the information from said information memory.

18. The apparatus as claimed in any one of claims 13-17, further including means for interpolating data for four pixels adjacent to the current pixel to enhance image resolution.

19. A rendering method for generating drawing image data, including the steps of:

receiving vertex data of a polygon including coordinates of the vertices;

generating coordinate data representing coordinates in the polygon from the coordinates of the vertices of the polygon;

receiving vertex data of the polygon including color values of the vertices;

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generating color values in the polygon from the color values of the vertices of the polygon;

receiving vertex data of the polygon including texture coordinates of the vertices;

generating texture addresses in the polygon from the texture coordinates of the vertices of the polygon, said texture addresses referring to texture data in a texture memory;

reading texture data from said texture memory in accordance with each texture address; and

comparing the present memory address of texture data associated with a current pixel and a previous memory address of texture data associated with an adjacent pixel, to thereby provide a compared result;

restructuring texture data, in response to said compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data read, in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address; and

blending the color values and texture data and generating new color data.

20. The method as claimed in claim 19, wherein said step of comparing generates information determinative of whether or not the texture data is to be read, and selects a memory address to read the texture data from said texture memory in response to said compared result.

21. The method as claimed in claim 20, and further including:

storing said information in an information memory;

accessing texture data from said texture memory

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in accordance with the selected memory address; and

a temporary texture memory for storing in the texture data read by said accessing device;

whereby said step of restructuring restructures texture data by reading texture data from said temporary texture memory, or by reusing texture data which has been previously read from said temporary texture memory, in accordance with the information from said information memory.

22. The method claimed in any one of claims 19-21, further including:

interpolating data for four adjacent pixels to increase image resolution.

23. A method for reading texture data, including the steps of:

comparing a present memory address of texture data associated with a current data point with a previous memory address of texture data associated with an adjacent data point, to thereby produce a compared result; and

restructuring the texture data, in response to the compared result, by reading texture data from the memory, in accordance with the present memory address, whenever the present memory address is different from the previous memory address, or by reusing texture data read, in accordance with the previous memory address, whenever the present memory address is the same as the previous memory address.

24. A texture data reading apparatus, substantially as herein described with reference to the accompanying diagrams.

25. A rendering apparatus, substantially as herein described with reference to the accompanying diagrams.

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26. A method for reading texture data, substantially as herein described with reference to the accompanying diagrams.

27. An apparatus for reading texture data to be mapped from a memory, substantially as herein described with reference to the accompanying diagrams.

28. A rendering method, substantially as herein described with reference to the accompanying diagrams.

Dated this 30th day of May 2001
SONY CORPORATION
By their Patent Attorneys
GRIFFITH HACK
Fellows Institute of Patent and
Trade Mark Attorneys of Australia

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Fig. 1

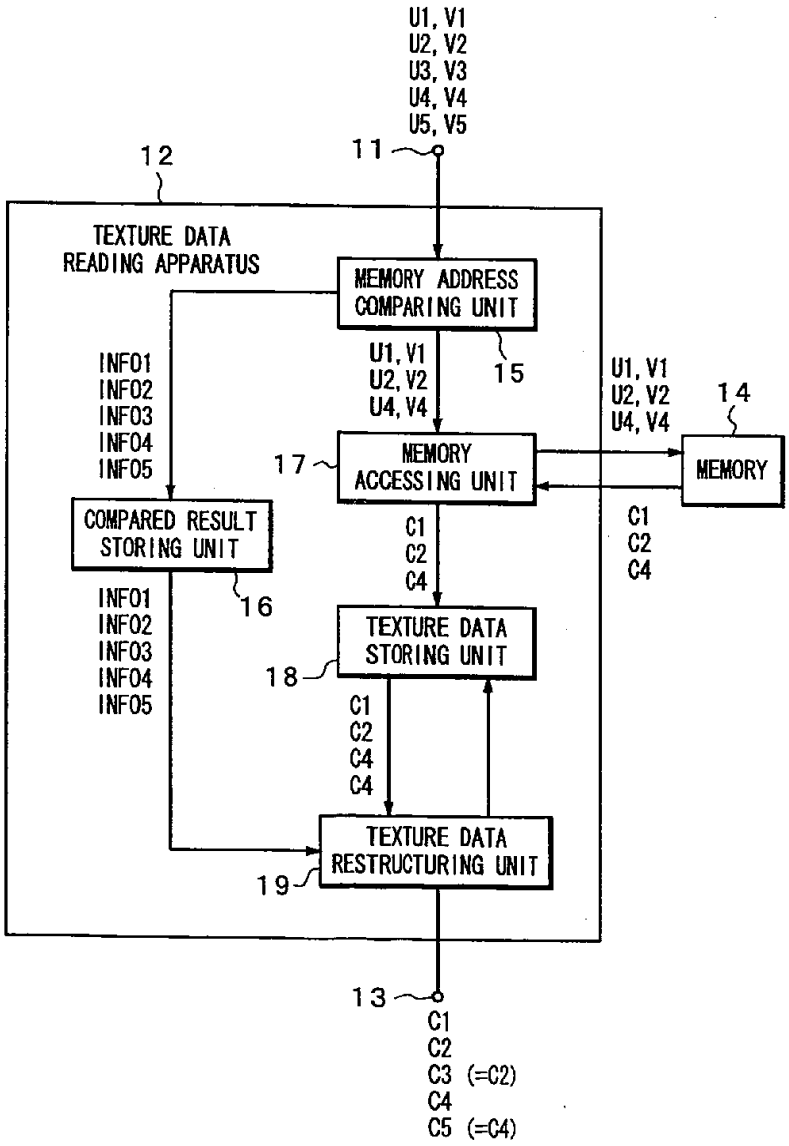

U1, V1
U2, V2
U3, V3
U4, V4
U5, V5
11
12
TEXTURE DATA
READING APPARATUS
MEMORY ADDRESS
COMPARING UNIT
15
U1, V1
U2, V2
U4, V4
INFO1
INFO2
INFO3
INFO4
INFO5
17
MEMORY
ACCESSING UNIT
U1, V1
U2, V2
U4, V4
14
MEMORY
C1
C2
C4
COMPARED RESULT
STORING UNIT
16
INFO1
INFO2
INFO3
INFO4
INFO5
C1
C2
C4
TEXTURE DATA
STORING UNIT
18
C1
C2
C4
C4
TEXTURE DATA
RESTRUCTURING UNIT
19
13
C1
C2
C3 (=C2)
C4
C5 (=C4)

Fig. 2A

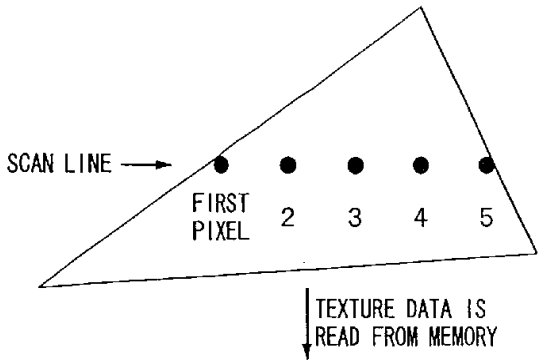

SCAN LINE
FIRST PIXEL
2
3
4
5
TEXTURE DATA IS READ FROM MEMORY

Fig. 2B

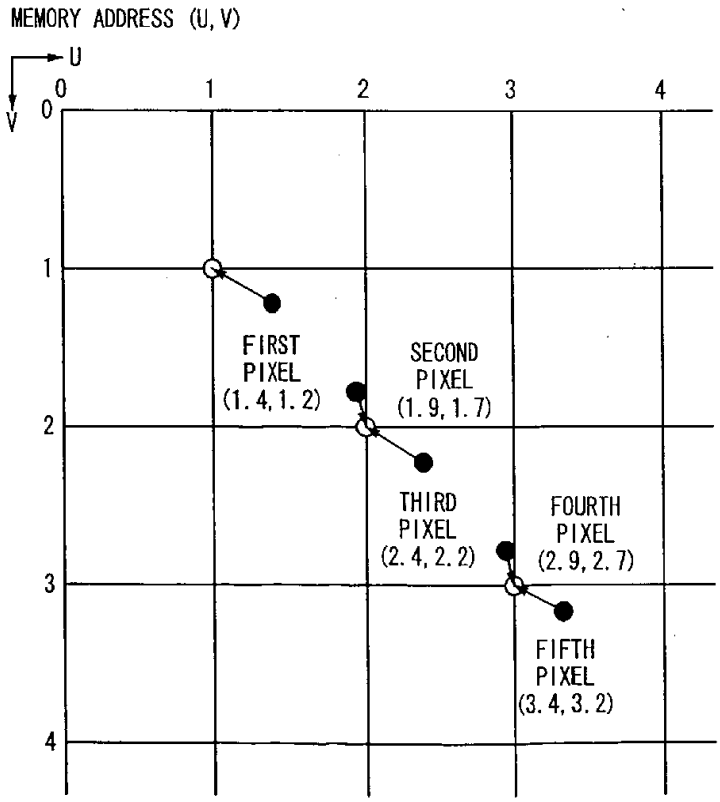

MEMORY ADDRESS (U, V)
U
V
0
1
2
3
4
FIRST PIXEL (1.4, 1.2)
SECOND PIXEL (1.9, 1.7)
THIRD PIXEL (2.4, 2.2)
FOURTH PIXEL (2.9, 2.7)
FIFTH PIXEL (3.4, 3.2)

Fig. 3A

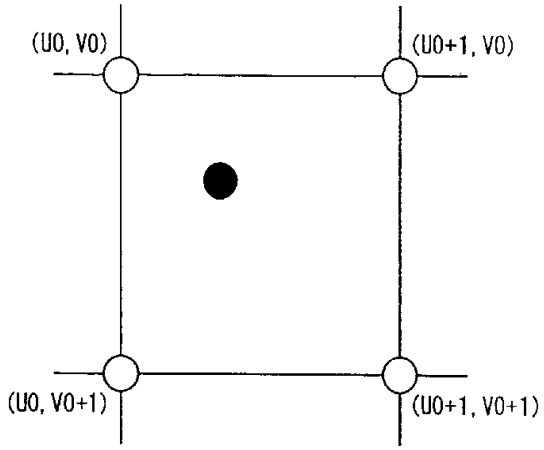

(U0, V0)
(U0+1, V0)
(U0, V0+1)
(U0+1, V0+1)

Fig. 3B

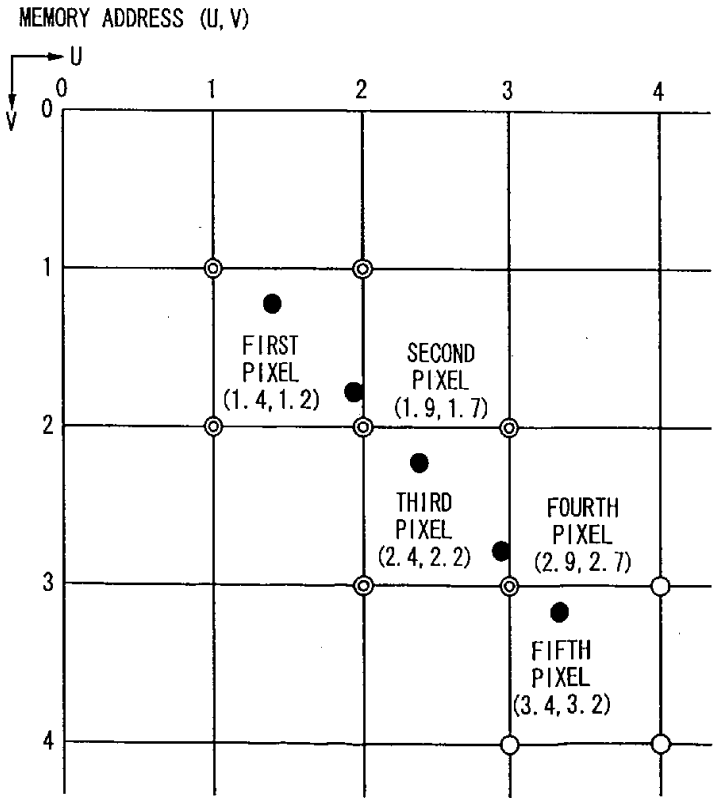

MEMORY ADDRESS (U, V)
U
V
0
1
2
3
4
FIRST PIXEL (1.4, 1.2)
SECOND PIXEL (1.9, 1.7)
THIRD PIXEL (2.4, 2.2)
FOURTH PIXEL (2.9, 2.7)
FIFTH PIXEL (3.4, 3.2)

Fig. 4

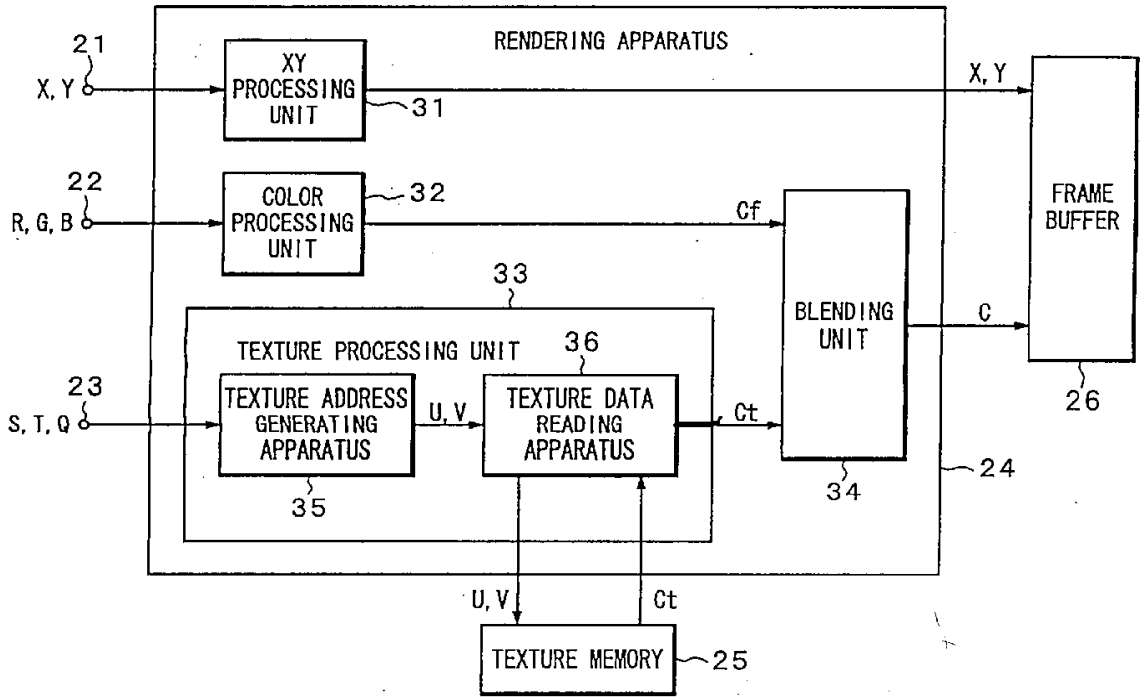

RENDERING APPARATUS
21
X, Y
XY PROCESSING UNIT
31
X, Y
22
R, G, B
COLOR PROCESSING UNIT
32
Cf
FRAME BUFFER
33
TEXTURE PROCESSING UNIT
36
BLENDING UNIT
C
23
S, T, Q
TEXTURE ADDRESS GENERATING APPARATUS
U, V
TEXTURE DATA READING APPARATUS
Ct
35
34
26
24
U, V
Ct
TEXTURE MEMORY
25

Fig. 5

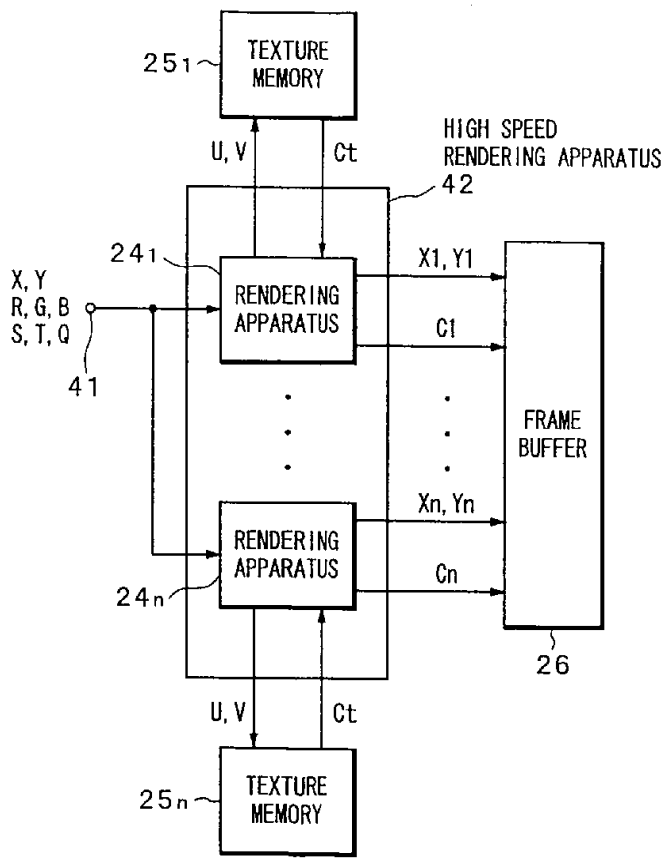

TEXTURE MEMORY
251
U, V
Ct
HIGH SPEED RENDERING APPARATUS
42
241
X, Y
R, G, B
S, T, Q
41
RENDERING APPARATUS
X1, Y1
C1
FRAME BUFFER
Xn, Yn
Cn
24n
26
U, V
Ct
25n
TEXTURE MEMORY

Fig. 6

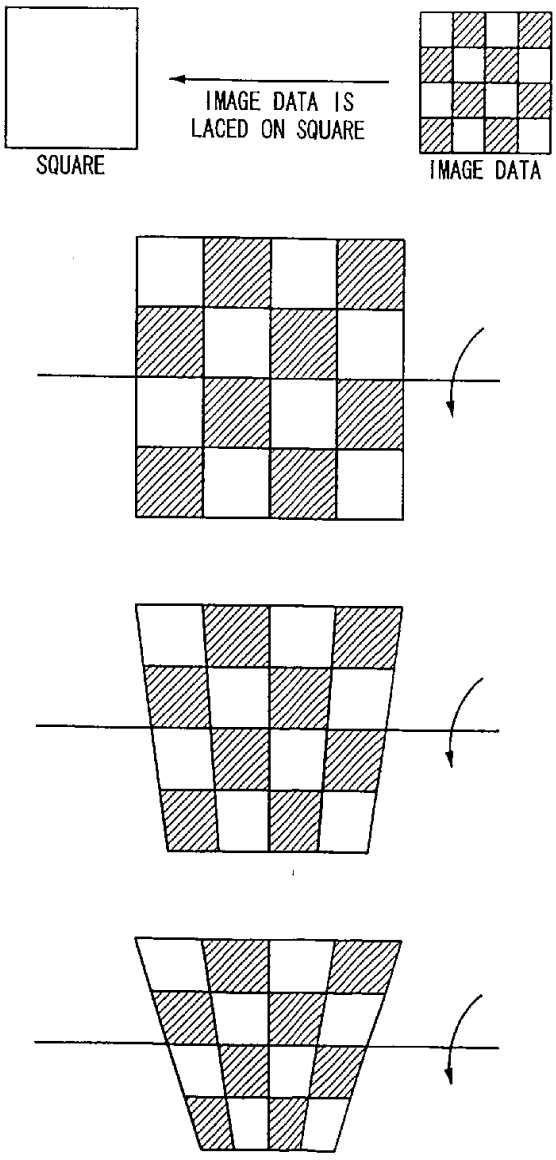


Fig. 7A

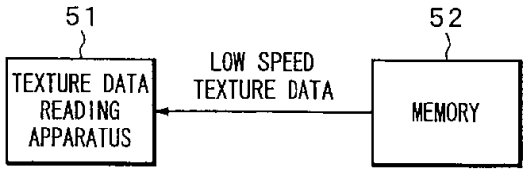
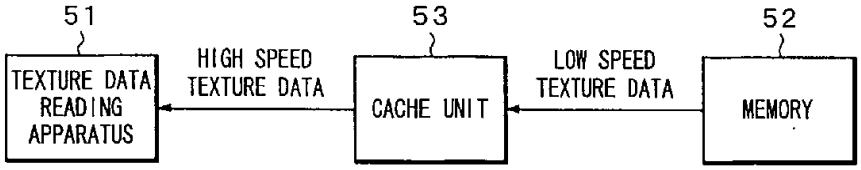

51
52
TEXTURE DATA READING APPARATUS
LOW SPEED TEXTURE DATA
MEMORY

Fig. 7B


51
53
52
TEXTURE DATA READING APPARATUS
HIGH SPEED TEXTURE DATA
CACHE UNIT
LOW SPEED TEXTURE DATA
MEMORY