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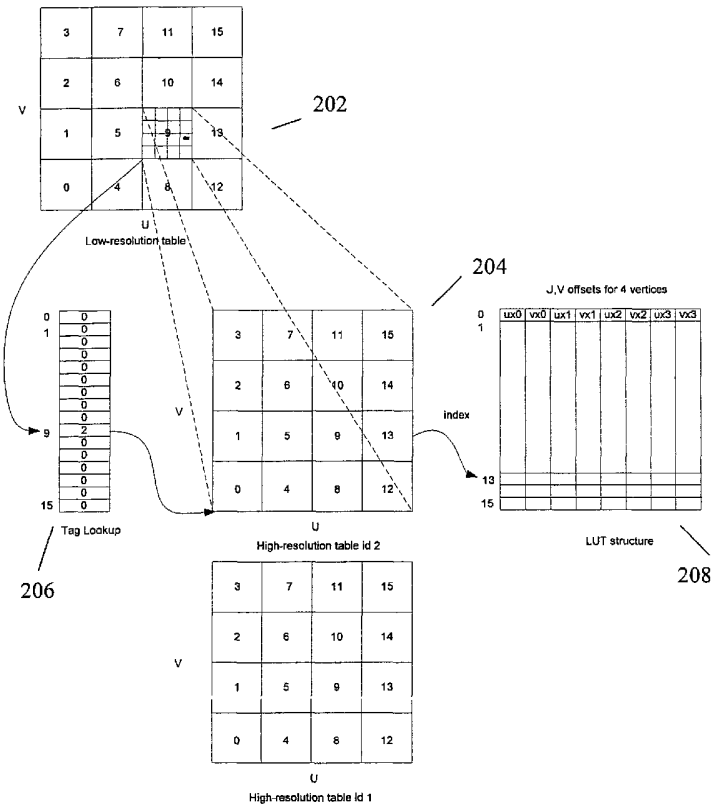

(57) Abstract: An apparatus and method for allowing color adjustments in display devices is disclosed. The apparatus comprises a multi-resolution structure (3) for providing color adjustments; and an interpolator (5) for interpolating at least one offset of the multi-resolution structure. An apparatus and method in accordance with the present invention uses a combination of color look-up tables (202, 204) with different levels of resolution, followed by interpolation to provide a display process which has high resolution but utilizes minimal memory. In so doing, memory is used for high-resolution areas only where needed. The multi-resolution structure is a very good approximation to the theoretical mapping table in the areas where it is needed. At the same time, since the high resolution areas are localized, a significant reduction in memory storage is possible.

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APPARATUS AND METHOD FOR MULTI-RESOLUTION COLOR MAPPING FOR DISPLAY DEVICES

FIELD OF THE INVENTION

The present invention relates generally to digital display devices and particularly to an apparatus and method for multi-resolution color mapping for display devices.

BACKGROUND OF THE INVENTION

Video displays normally have color adjustment controls for hue and saturation. The hue control adjusts the tint and the saturation control adjusts the color richness of the display. These controls are global in the sense that they affect all the display pixels.

For applications such as skin tone adjustment, global color controls cannot be applied. These applications require local modification of a small subset of colors in the color space without affecting the other colors.

Local color modifications in display devices can be implemented by a mapping table that specifies an output color for every input color. This would be feasible if the set of all possible colors was reasonably small. However, a standard 24-bit RGB display device would need to map approximately 16 million different colors. The map, also known as a look-up table (LUT), would require 48Mbytes of memory storage. Considering the cost of a 48Mbyte lookup table implemented either in hardware or in software, this solution is not practical. Using a luma-chroma color space such as YUV, YPrPb etc. is a better solution because the colors are then represented by a subset of the components. The standard 8-bit resolution for U and V would require 128Kbytes for the color map. This is still a very large memory for hardware implementations.

A more practical solution approximates the theoretical map by sampling the color space with a regular grid.

Figure 1 is an example of a 4x4 sampling grid 10. The output values at the grid 10 intersections are stored in a table. A specific color will map to a unique coordinate within the grid. In general, the coordinate will not coincide with a grid vertex. An output value related to the coordinate is then calculated as an interpolation of the nearest output

values, i.e. the values stored at the nearest grid vertices.

Sampling a space with a finer grid allows better control over the map because of the higher resolution, but at the cost of higher memory usage. A coarser grid saves memory at the expense of color resolution.

What is needed, therefore is a solution that approximates the theoretical mapping table as closely as possible without requiring an impractical amount of memory. Real-life applications such as skin tone adjustment concentrate on a small region of the full color space. Therefore high-resolution mapping is only required in a small subset of the color space. The present invention addresses such a need.

SUMMARY OF THE INVENTION

An apparatus and method for allowing color adjustments in display devices is disclosed The apparatus comprises a multi-resolution structure for providing color adjustments; and an interpolator for interpolating at least one offset of the multi-resolution structure.

An apparatus and method in accordance with the present invention uses a combination of color look-up tables with different levels of resolution, followed by interpolation to provide a display process which has high resolution but utilizes minimal memory.

In so doing, memory is used for high-resolution areas only where needed. The multi-resolution structure is a very good approximation to the theoretical mapping table in the areas where it is needed. At the same time, since the high resolution areas are localized, a significant reduction in memory storage is possible.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an example of a 4x4 sampling grid 10.

Figure 2 illustrates a multi-resolution UV color structure in accordance with the present invention.

Figure 3 illustrates a multi-resolution mapping system using a 2-levek, 8-bit UV color space.

Figure 4 is a flow chart which illustrates multi-resolution chroma mapping in an

8-bit UV space using two resolution levels.

Figure 5 is an example of a sample hardware implementation of bilinear interpolator for a two-dimensional look-up table.

DETAILED DESCRIPTION

The present invention relates generally to digital display devices and particularly to an apparatus and method for multi-resolution color mapping for display devices. The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the preferred embodiment and the generic principles and features described herein will be readily apparent to those skilled in the art. Thus, the present invention is not intended to be limited to the embodiment shown but is to be accorded the widest scope consistent with the principles and features described herein.

Definitions

Digital Display Device : An electronic image display device that uses digitized (sampled and quantized) image data. The input data itself may be analog in nature, and digitized within the device for final display on a digital display such as an LCD, OLED or plasma panel. Alternatively, the input data itself may be digital in nature and finally displayed on an analog display such as a CRT.

Pixel : The smallest discrete region on a digital display device that can be addressed for display.

Luma : The component of the input image data value that is correlated to the perceived intensity of the displayed data value.

Chroma : The component of the input image data value that is correlated to the perceived color of the displayed data value. In YUV color space, the chroma component is defined by the U and V data values.

An apparatus and method in accordance with the present invention uses a combination of color look-up tables with different levels of resolution, followed by interpolation to provide a display process which has high resolution but utilizes minimal memory.

In so doing, memory is used for high-resolution areas only where needed. The multi-resolution structure is a very good approximation to the theoretical mapping table in the areas where it is needed. At the same time, since the high resolution areas are localized, a significant reduction in memory storage is possible.

An apparatus utilized in accordance with the present invention may be a hardware implementation, a combination of hardware and software, or a software implementation. An example of a hardware solution would be an FPGA or ASIC design. An example of a hardware and software implementation would include a DSP implementation and embedded firmware implementation.

Please refer to the following for a more detailed description of the features of the present invention.

Apparatus

Figure 2 illustrates a multi-resolution UV color table 100 in accordance with the present invention. As is seen in this embodiment, a plurality of squares on the grid 200 are of one resolution, as illustrated by squares A, B, C and D, and at least one of the other squares is of another resolution as illustrated by Figure 4. The apparatus for this invention is a set of data structures that can be implemented in hardware as memory and registers or in software as arrays. The primary data structure is used for storing the color LUT at different resolutions. The secondary data structures are used for indexing the final LUT to be applied.

The data input is a chroma value that is specified with two components – these may be defined as the UV components of a YUV representation for this description, but in general are any orthogonal representation of chroma. These components are digital values that are specified with a fixed precision, e.g. 8bits or 10bits.

For the description that follows, we assume the following :

1. 8bit UV color space
2. Two levels of resolution
3. One low-resolution table that divides the two-dimensional UV color space into 16 squares (4 sub-divisions on each axis).
4. Multiple high-resolution tables further divide each low-resolution square into 16 sub-squares.

5. Each LUT entry is a data word containing the U and V color offsets for all 4 square vertices.

Assuming that the U,V offset is represented with No bits, one vertex chroma offset requires 2No bits for storage. Storing all 4 vertex offsets for a square will require 4x2No = 8No bits. One low-resolution table is required. If we specify Nh high-resolution tables, the multi-resolution table structure will then require a (Nh+1) x 8No memory structure for a hardware implementation.

The savings in memory for the same effective resolution is readily seen – dividing the UV color space into a 16x16 grid requires 16x16x8No = 2048No bits. A multi-resolution hybrid table with a 4x4 low-resolution table and four 4x4 high-resolution tables requires (4+1)x8No = 40No bits.

Figure 3 illustrates a multi-resolution mapping system 200 using a 2-level, 8-bit UV color space. As is seen, there is a low resolution table 202 and two high resolution tables 204. For a two-level resolution implementation, one secondary data structure 206, which is a one-dimensional tag table with 16 entries. The index to this table identifies a unique square in the low resolution table. A non-zero tag entry at this index specifies a unique high-resolution 204 table to be overlaid on this square in the low-resolution table. If it is zero, the low-resolution table 202 square is used for the color offset lookup and interpolation. If non-zero, the corresponding high-resolution table 204 is used for color offset lookup and interpolation. For the above example, an additional 16x3 = 48 bits of register storage would be required.

The low-resolution and high-resolution UV grids are conceptual representations only. The only data structures required are the chroma offset LUTs 208 and Tag Lookup table 206.

The location of an input pixel chroma value in UV space is shown as a black dot in square 9 in the low-resolution table. There are two high-resolution tables available with id 1 and 2 respectively. The high-resolution table with id 2 has been overlaid on square 9 of the low-resolution table, by specifying its id in the Tag Lookup table.

Method

Figure 4 is a flow chart which illustrates multi-resolution chroma mapping in an

8-bit UV space using two resolution levels. The following description of the method applies to the above example with two-level resolution with a grid division of 4 – however it can be easily extended to higher level resolution hierarchies and grid division factors.

Consider an input pixel that needs to be processed by the multi-resolution color map process. The chroma value is defined by the U and V components, which are 8 bit values.

1. Indexing : The 2 MSbs of U and V are concatenated to create a 4bit index which uniquely identifies the high-resolution square in which this pixel chroma value lies (step 402).

2. Tag lookup : The index is used to read a tag from the Tag Lookup table. The tag value determines whether a high-resolution table has been overlaid on this particular coarse-resolution square, and if so, which table. If the tag is zero, the low-resolution table should be used. If the tag is non-zero, the value identifies which high-resolution table has been overlaid (step 404)..

3. Low-resolution table interpolation: If the tag is zero, the remaining LSbs of U and V define the location of the input chroma value with respect to the four vertices of the surrounding low resolution square. The actual chroma offset to be applied is then determined by interpolation of the programmed chroma offsets stored at the four vertices using the U and V LSbs as the interpolation weights. The interpolated chroma offset is added to the input value to generate the output chroma value (steps 408 and 412).

4. High resolution table indexing : If the tag is non-zero, it uniquely identifies which fine-resolution table must be overlaid. The next 2 MSbs of U and V now are concatenated to form a 4bit index which uniquely identifies the square in the high resolution table which encloses the input chroma value (steps 414 and 416).

5. High resolution table interpolation : Now the remaining 4LSbs of U and V define the location of the input chroma value with respect to the surrounding fine resolution square vertices. The actual chroma offset to be applied is then determined by interpolation of the programmed chroma offsets stored at the four vertices, using the U and V LSbs as interpolation weights. The interpolated chroma offset is added to the input value to generate the output chroma value (steps 418 and 412). Figure 5 is an

example of a sample hardware implementation of bilinear interpolator for the two-dimensional look-up table.

The above process can be easily extended to higher levels of resolution hierarchy. For a three-level structure, we will need two tag tables in addition to the color LUTs. The MSbs are used to progressively index into the tag tables until either the tag entry is zero, or the highest resolution level has been reached. Then the remaining LSbs are used to interpolate the chroma offset from the surrounding 4 vertices. This offset is then added back to the original to generate the output chroma value.

The final table indexing process is very efficient as it only requires concatenation of chroma data MSbs followed by table lookups.

For hardware implementations, the storage of all 4 vertex offsets in one memory word, combined with the storage of the tag entries in a separate data structure, allows single cycle access to memory for the interpolation, irrespective of the resolution level. This also allows the color LUTs at all resolution levels to be stored in a single physical memory.

For a specific application, such as skin tone adjustment, the high resolution tables are overlaid only in the low resolution squares that contain skin tone chroma values. This user-definable localization of high resolution areas in the map provides a very good approximation to the theoretical full resolution color map in the area of interest, while keeping the overall memory requirements manageable.

The purpose of storing offsets instead of an absolute chroma component is to reduce the amount of memory storage required. This is possible because the amount of offset applied is relatively small in comparison to the chroma dynamic range and can therefore be represented with less bits.

Although the present invention has been described in accordance with the embodiments shown, one of ordinary skill in the art will readily recognize that there could be variations to the embodiments and those variations would be within the spirit and scope of the present invention. Accordingly, many modifications may be made by one of ordinary skill in the art without departing from the spirit and scope of the appended claims.

CLAIMS

What is claimed is:

1. A method for allowing non-global color adjustments comprising the step of providing a plurality of multi-resolutional look-up tables which are used for mapping chroma values.

2. A system for allowing non-global color adjustments comprising the step of providing a plurality of multi-resolutional look-up tables which are used for mapping chroma values.

3. An apparatus for allowing color adjustments in display devices, comprising:

a multi-resolution structure which includes color values; and

an interpolator for interpolating the color values based upon the multi-resolution claim.

4. The apparatus of claim 3 wherein the color adjustment for a specific color is derived from predefined color adjustments for a subset of the colors.

5. The apparatus of claim 3 wherein multi-resolution structure specifies between higher resolution and lower resolution look-up tables within the chroma space.

6. The apparatus of claim 3 wherein a multi-resolution color LUT is constructed by overlaying separate LUTs.

7. The apparatus of claim 6 wherein a single physical memory area is utilized for the separate LUTs.

8. The apparatus of claim 3 that uses successive most significant bits of the input pixel data to index a final LUT to be applied.

9. The apparatus of claim 3 wherein separate look-up tables are utilized to specify the higher resolution tables overlaid on the lower resolution tables.

10. The apparatus of claim 3 wherein at least one tag bit is utilized for each primary look-up table entry to indicate if a secondary look-up table needs to be accessed.

11. The apparatus of claim 10 wherein the at least one tag bit is stored in at least one separate register or memory.

12. The apparatus of claim 10 wherein the at least one tag bit is stored in the same memory as the look-up table data.

13. The apparatus of claim 13 wherein the multi-resolution structure can be utilized with RGB, YUV, YCrCB, YPrPb or any other color domain.

14. The apparatus of claim 3 wherein the multi-resolution structure can be utilized with analog or digital displays.

15. A method for color mapping for a display device comprising the steps of:

(a) providing color values within a multi-resolution structure; and

(b) interpolating the color values based upon the multi-resolution structure.

16. The method of claim 15 wherein the interpolator pre-defined adjustments for stored colors.

17. The method of claim 15 wherein the multi-resolution structure specifies between higher resolution and lower resolution within the chroma space.

18. The method of claim 15 wherein the high resolution and low resolution are provided via look-up tables (LUTs).

19. The method of claim 15 wherein a multi-resolution color LUT is constructed by overlaying separate LUTs.

20. The method of claim 15 wherein a single physical memory area is utilized for the separate LUTs.

21. The method of claim 15 that uses successive most significant bits of the input pixel data to index a final LUT to be applied.

22. The method of claim 15 wherein separate look-up tables are utilized to specify the higher resolution tables overlaid on the lower resolution tables.

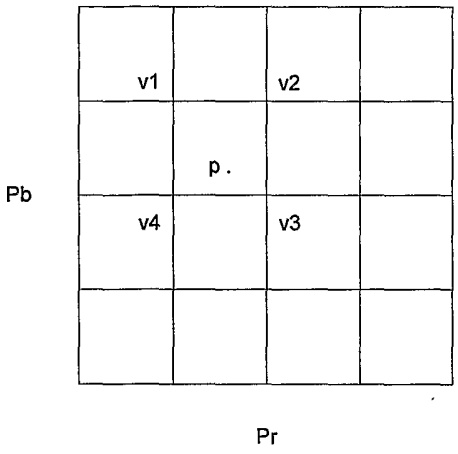
23. The method of claim 15 wherein at least one tag bit is utilized for each primary look-up table entry to indicate if a secondary look-up table needs to be accessed.

24. The method of claim 23 wherein the at least one tag bit is stored in at least one separate register or memory.

25. The method of claim 23 wherein the at least one tag bit is stored in the same memory as the look-up table data.

26. The method of claim 15 wherein the multi-resolution structure can be utilized with RGB, YUV, YCrCB, YPrPb or any other color domain.

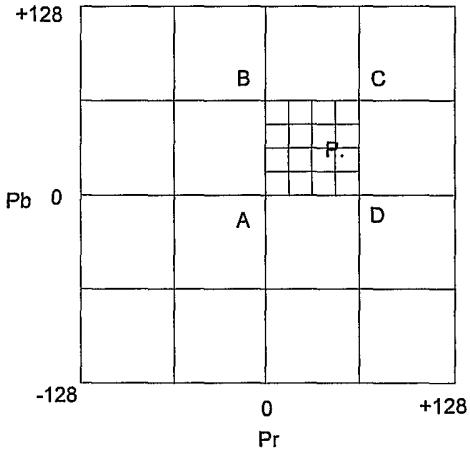
27. The method of claim 15 wherein the multi-resolution structure can be utilized with analog or digital displays.



10

Prior Art

Figure 1



100

Figure 2

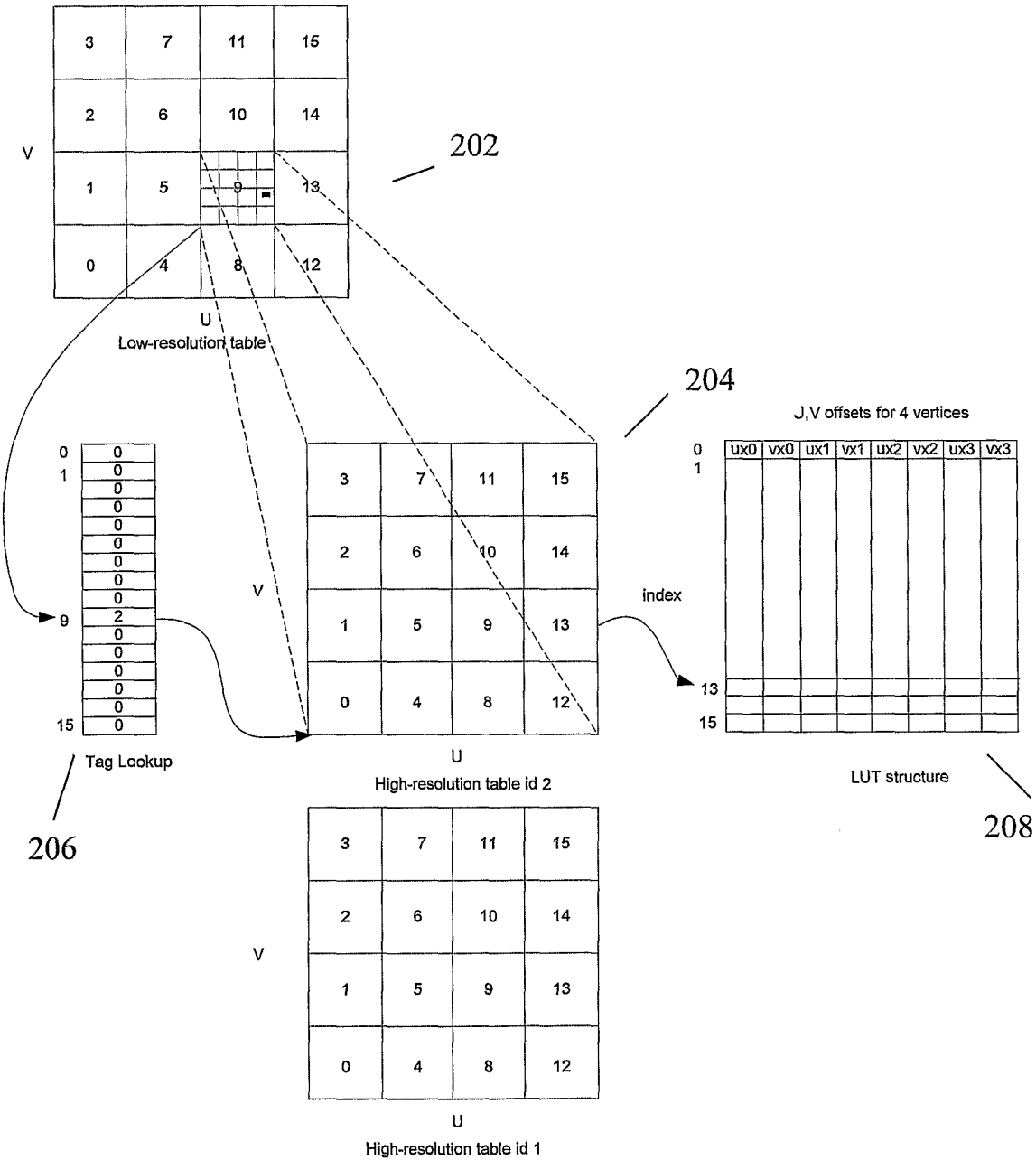

3 7 11 15
2 6 10 14
1 5 9 13
0 4 8 12
V
U
Low-resolution table
202
204
J,V offsets for 4 vertices
ux0 vx0 ux1 vx1 ux2 vx2 ux3 vx3
index
Tag Lookup
206
High-resolution table id 2
High-resolution table id 1
LUT structure
208

Figure 3

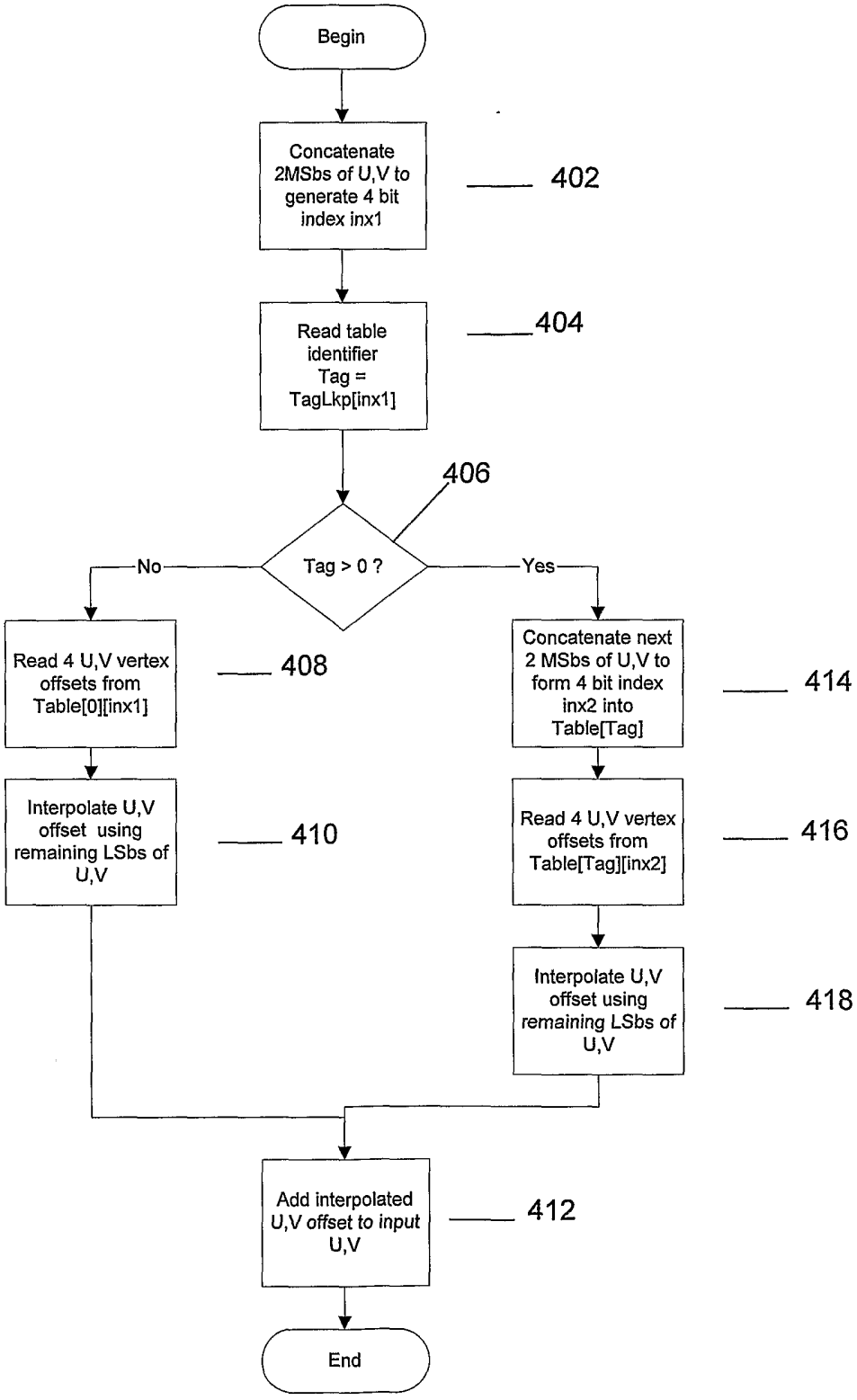
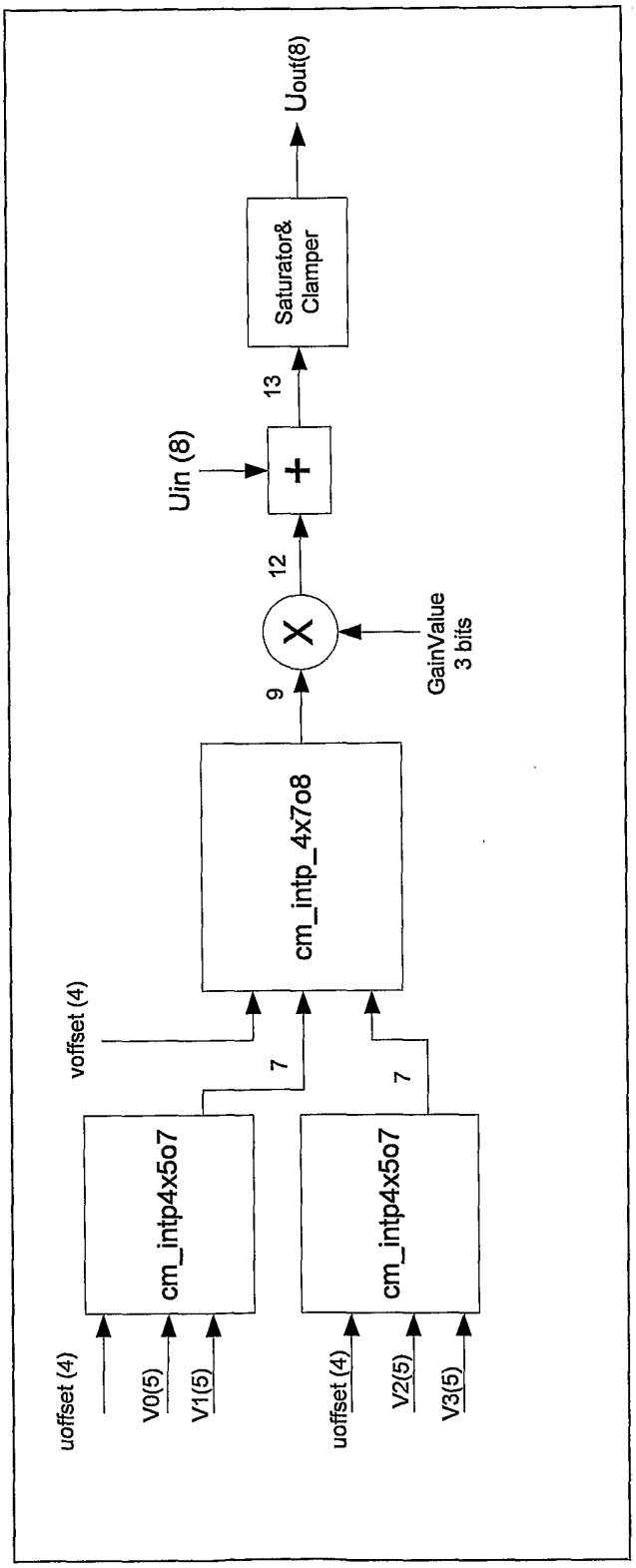

Begin
Concatenate 2MSbs of U,V to generate 4 bit index inx1
402
Read table identifier Tag = TagLkp[inx1]
404
406
Tag > 0 ?
No
Yes
Read 4 U,V vertex offsets from Table[0][inx1]
408
Interpolate U,V offset using remaining LSbs of U,V
410
Concatenate next 2 MSbs of U,V to form 4 bit index inx2 into Table[Tag]
414
Read 4 U,V vertex offsets from Table[Tag][inx2]
416
Interpolate U,V offset using remaining LSbs of U,V
418
Add interpolated U,V offset to input U,V
412
End

Figure 4


Uout(8)
Saturator&
Clamper
13
Uin (8)
+
12
X
GainValue
3 bits
9
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voffset (4)
7
7
cm_intp4x5o7
cm_intp4x5o7
uoffset (4)
V0(5)
V1(5)
uoffset (4)
V2(5)
V3(5)

FIGURE 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/14984

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G09G 5/02, 5/00; G06K 9/00, 9/36; G03F 3/08; H04N 1/46

US CL :Please See Extra Sheet.

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)

U.S. : 345/589, 590, 591, 600, 602, 601, 604, 605, 610; 382/162, 64, 165, 167; 358/518, 519, 520, 523, 524, 525

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

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

West 2.1

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,268,939 B1 (KLASSEN et al.) 31 July 2001, see col. 9, line 55 to col. 10, line 19, col. 11, line 23 to col. 12, line 53, col. 13, lines 21-38, and col. 16, lines 20-55.	1-3, 5, 8, 13-18, 20-21, 26-27

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 08 JULY 2003	Date of mailing of the international search report 14 AUG 2003
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer WESNER SAJOUS Telephone No. (703) 308-585

Form PCT/ISA/210 (second sheet) (July 1998)★

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

345/589, 590, 591, 600, 602, 601, 604, 605, 610; 382/162, 64, 165, 167; 358/518, 519, 520, 523, 524, 525