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(54) Method and apparatus for color space conversion.

(57) A method and appаratus for performing color space conversion between digitized YCbCr components and digitized RGB components uses a color lookup table unit (1,1A) which is provided with transformation component values based on a selected one of two sets of conversions. A plurality of adder units are coupled to the lookup table unit (1,1A) so as to receive the outputs thereof and generate individual color components of converted space by adding the transformation component values corresponding to each of the individual color components of converted space relative to the color components of original space.

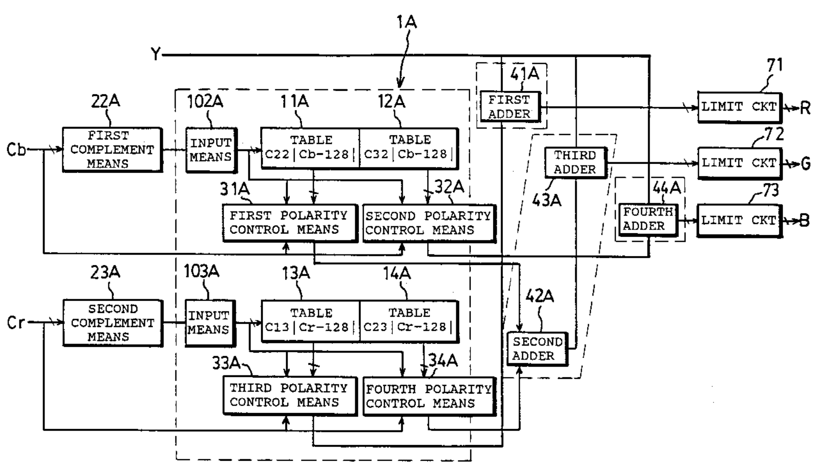

FIG.4

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This invention relates to a method and apparatus for performing color space conversion, more particularly to a method and apparatus for performing color space conversion between digitized YCbCr color components and digitized RGB color components.

Nowadays, due to the growing popularity of multimedia applications, the development of advanced data processing techniques for digital audio data and digital video data has become more and more important. It is noted that, due to the limited bandwidth of the transmission networks and the limited storage spaces of the existing computer systems, digital video data have to be compressed before transmission or storage. Thereafter, the compressed data are decompressed so as to obtain the original digital video data from the storage or transmission media.

Presently, digitized YCbCr components, wherein the Y component represents luminance or picture brightness, the Cb component (B-Y) represents the scaled difference between the blue value (B) and the luminance (Y), and the Cr component (R-Y) represents the scaled difference between the red value (R) and the luminance (Y), are used in known compression algorithms since the digitized YCbCr components occupy less bandwidth when compared to digitized RGB (Red-Green-Blue) components which are obtained by passing analog RGB signals through an analog-to-digital converting means. However, the existing imaging and displaying apparatuses generally use analog RGB signals to represent image. Therefore, the analog RGB signals must initially pass through an analog-to-digital converting means and are then converted into digitized YCbCr components before compression. The digitized YCbCr components are converted into the digitized RGB components after decompression. If necessary, the digitized RGB components are converted into analog RGB signals.

Although there are many conventional techniques for color space conversion, the architecture of the conventional techniques permits conversion in only one mode, that is, either converting YCbCr components to RGB components or converting RGB components to YCbCr components. Additionally, the conventional techniques are expensive due to the large memory requirements thereof. Furthermore, the conventional techniques that use multipliers are relatively expensive and have a relatively slow operating speed.

Therefore, the main object of the present invention is to provide a method and apparatus for performing color space conversion between digitized YCbCr color components and digitised RGB color components, which method and apparatus are inexpensive and are highly efficient.

Accordingly, an apparatus of the present invention is capable of performing color space conversion between digitized YCbCr color components and digitized RGB color components. When converting the digitized YCbCr color components to the digitized RGB color components, digitized transformation component values corresponding to a Y-in-R component, a Cb-in-R component, a Cr-in-R component, a Y-in-G component, a Cb-in-G component, a Cr-in-G component, a Y-in-B component, a Cb-in-B component and a Cr-in-B component, are placed into a programmable color lookup table means based on a set of conversions from individual digitized Y, Cb and Cr components. The color lookup table means has a plurality of address inputs and includes first to ninth segments. The transformation component values corresponding to the Y-in-R component, the Y-in-G component, the Y-in-B component, the Cb-in-R component, the Cb-in-G component, the Cb-in-B component, the Cr-in-R component, the Cr-in-G component and the Cr-in-B component occupy the first to ninth segments, respectively. The digitized Y, Cb and Cr components are inputted to the address inputs of the color lookup table means to effect reference to the corresponding Y-in-R transformation component value, the corresponding Cb-in-R transformation component value, the corresponding Cr-in-R transformation component value, the corresponding Y-in-G transformation component value, the corresponding Cb-in-G transformation component value, the corresponding Cr-in-G transformation component value, the corresponding Y-in-B transformation component value, the corresponding Cb-in-B transformation component value and the corresponding Cr-in-B transformation component value. The corresponding Y-in-R transformation component value, the corresponding Cb-in-R transformation component value and the corresponding Cr-in-R transformation component value are added to obtain the digitized R component. The corresponding Y-in-G transformation component value, the corresponding Cb-in-G transformation component value and the corresponding Cr-in-G transformation component value are added to obtain the digitized G component. Finally, the corresponding Y-in-B transformation component value, the corresponding Cb-in-B transformation component value and the corresponding Cr-in-B transformation component value are added to obtain the digitized B component.

When converting the digitized RGB color components to the digitized YCbCr color components, digitized transformation component values corresponding to an R-in-Y component, a G-in-Y component, a B-in-Y component, an R-in-Cb component, a G-in-Cb component, a B-in-Cb component, an R-in-Cr component, a G-in-Cr component and a B-in-Cr component, are placed into the programmable color lookup table means based on a set of conversions from individual digitized R, G and B components. The transformation component values corresponding to the R-in-Y component, the R-in-Cb component, the R-in-

Cr component, the G-in-Y component, the G-in-Cb component, the G-in-Cr component, the B-in-Y component, the B-in-Cb component and the B-in-Cr component occupy the first to ninth segments of the color lookup table means, respectively. The digitized R, G and B components are inputted to the address inputs of the color lookup table means to effect reference to the corresponding R-in-Y transformation component value, the corresponding G-in-Y transformation component value, the corresponding B-in-Y transformation component value, the corresponding R-in-Cb transformation component value, the corresponding G-in-Cb transformation component value, the corresponding B-in-Cb transformation component value, the corresponding R-in-Cr transformation component value, the corresponding G-in-Cr transformation component value and the corresponding B-in-Cr transformation component value. The corresponding R-in-Y transformation component value, the corresponding G-in-Y transformation component value and the corresponding B-in-Y transformation component value are added to obtain the digitized Y component. The corresponding R-in-Cb transformation component value, the corresponding G-in-Cb transformation component value and the corresponding B-in-Cb transformation component value are added to obtain the digitized Cb component. The corresponding R-in-Cr transformation component value, the corresponding G-in-Cr transformation component value and the corresponding B-in-Cr transformation component value are added to obtain the digitized Cr component.

In another aspect of the present invention, a method for converting digitized YCbCr color components to digitized RGB color components includes the steps of: providing a color lookup table means which has a plurality of address inputs and which includes a first segment provided with a digitized transformation component value corresponding to a Cb-in-G component, a second segment provided with a digitized transformation component value corresponding to a Cb-in-B component, a third segment provided with a digitized transformation component value corresponding to a Cr-in-R component, and a fourth segment provided with a digitized transformation component value corresponding to a Cr-in-G component; inputting the digitized Y, Cb and Cr components to the address inputs of the color lookup table means to effect reference to the corresponding Cb-in-G transformation component value, the corresponding Cb-in-B transformation component value, the corresponding Cr-in-R transformation component value and the corresponding Cr-in-G transformation component value; adding the Y component and the corresponding Cr-in-R transformation component value to obtain the digitized R component; adding the Y component, the corresponding Cb-in-G transformation component value and the corresponding Cr-in-G transformation component value to obtain the digitized G component; and adding the Y component and the corresponding Cb-in-B transformation component value to obtain the digitized B component.

Other features and advantages of the present invention will become apparent in the following detailed description of the preferred embodiments, with reference to the accompanying drawings, of which:

Figs. 1A, 1B and 1C are schematic block diagrams showing an apparatus for performing color space conversion between digitized YCbCr color components and digitized RGB color components in accordance with a first embodiment of the present invention;

Fig. 2 is a schematic block diagram showing a first complement means and an address decoder of the apparatus of Fig. 1;

Fig. 3 is a schematic block diagram illustrating one of the polarity control means shown in Fig. 1;

Fig. 4 is a schematic block diagram of an apparatus for converting digitized YCbCr components to digitized RGB components in accordance with a second embodiment of the present invention;

Fig. 5 is a schematic block diagram showing how a programmable color lookup table means of the apparatus shown in Fig. 1 is programmed;

Fig. 6 is a table illustrating an address decoding method employed in the present invention; and

Fig. 7 illustrates the operation of a programming control circuit upon input of differing combinations of selecting signals, which programming control circuit is used to program the programmable color lookup table means of the apparatus shown in Fig. 1.

In the present invention, each of the digitized Y, Cb and Cr components and each of the digitized R, G and B components is an 8-bit component. Direct conversion of digitized RGB components to digitized YCbCr components is achieved in the following manner:

$$\begin{vmatrix} Y \\ Cb \\ Cr \end{vmatrix} = \begin{vmatrix} 0.229 & 0.587 & 0.114 \\ -0.173 & -0.338 & 0.511 \\ 0.511 & -0.428 & -0.083 \end{vmatrix} \begin{vmatrix} R-128 \\ G-128 \\ B-128 \end{vmatrix} + \begin{vmatrix} 128 \\ 128 \\ 128 \end{vmatrix} \quad (a)$$

Direct conversion of digitized YCbCr components to RGB components is achieved in the following manner:

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 1 & -0.001 & 1.370 \\ 1 & -0.336 & -0.698 \\ 1 & 1.733 & 0.001 \end{vmatrix} \begin{vmatrix} Y-128 \\ Cb-128 \\ Cr-128 \end{vmatrix} + \begin{vmatrix} 128 \\ 128 \\ 128 \end{vmatrix} \quad (b)$$

The above conversions (a) and (b) can be represented by the following equation:

$$POn=\sum_{m=1}^{3} Cnm(PIm-128)+128, \ n=1,2,3 \quad (c)$$

In the equation (c), PIm is defined as a color component of an original space, POn is defined as a color component of a converted space, and Cnm is defined as a transformation coefficient corresponding to an nth color component of the converted space relative to an mth color component of the original space, and the product of Cnm and PIm-128 is defined as a transformation component value corresponding to a PIm-in-POn component. Therefore, in the present embodiment, when PO1, PO2 and PO3 represent Y, Cb and Cr components respectively, PI1, PI2 and PI3 represent R, G and B components respectively. Similarly, when PO1, PO2 and PO3 represent R, G and B components respectively, PI1, PI2 and PI3 represent Y, Cb and Cr components respectively.

Referring to Figs. 1A, 1B, 1C, 2 and 3, an apparatus for performing color space conversion between digitized YCbCr color components and digitized RGB color components in accordance with a first embodiment of the present invention includes a programmable color lookup table means 1, first to third complement means 21 to 23, first to ninth polarity control means 31 to 39, first to third adder means and first to third compensation and limit circuits 51 to 53.

In the present embodiment, the programmable color lookup table means 1 is a RAM device. The lookup table means 1 has a plurality of address inputs and includes first to ninth segments 11 to 19, and input means 101, 102 and 103. The input means 101, 102 and 103 receive digitized PI1, PI2 and PI3 for addressing the address inputs of the lookup table means 1. In the present embodiment, each of the input means 101,102,103 is an address decoder. When converting the RGB components to the YCbCr components, the digitized transformation component values corresponding to an R-in-Y component, an R-in-Cb component, an R-in-Cr component, a G-in-Y component, a G-in-Cb component, a G-in-Cr component, a B-in-Y component, a B-in-Cb component and a B-in-Cr component are programmed into the first to ninth segments 11 to 19, respectively, based on the conversion (a). As best shown in Figs. 5 and 7, the programming of the lookup table means 1 is accomplished by a programming control circuit 8 and a demultiplexer 9. The demultiplexer 9 is connected to the first, second and third complement means 21 to 23. The programming control circuit 8 has a WRITE signal line and a DATA bus that are connected to the first to ninth segments 11 to 19 of the lookup table means 1. The control circuit 8 further has a SELECTOR signal line and a ADDRESS signal line that are connected to the demultiplexer 9. The control circuit provides a 2-bit selecting signal to the demultiplexer 9 via the SELECTOR signal line. When the selecting signal is 01, the first to third segments 11 to 13 are selected to be programmed. When the selecting signal is 10, the fourth to sixth segments 14 to 16 are selected to be programmed. When the selecting signal is 11, the seventh to ninth segments 17 to 19 are selected to be programmed. When the selecting signal is 00, programming of the lookup table means 1 is prohibited. Since the segments 11 to 19 of the lookup table means 1 corresponding to the same component of the original space are written thereinto simultaneously, programming of the entire lookup table means 1 requires only 3*128=384 write cycles. When converting the YCbCr components to the RGB components, the digitized transformation component values corresponding to a Y-in-R component, a Y-in-G component, a Y-in-B component, a Cb-in-R component, a Cb-in-G component, a Cb-in-B component, a Cr-in-R component, a Cr-in-G component and a Cr-in-B component are programmed into the first to ninth segments 11 to 19, respectively, based on the conversion (b) by a similar programming procedure as described above.

It should be recognized that the conversion from digitized YCbCr components to digitized RGB components is similar to the conversion from digitized RGB components to digitized YCbCr components. Therefore, the following description of the first embodiment of the present invention is based on the conversion from digitized RGB components to digitized YCbCr components only.

The first complement means 21 is connected to the input means 101 and receives the digitized R color component. The first complement means 21 generates 2's complement of the seven lower bits (PIm6 to

Plm0) of the R color component when the most significant bit (Plm7) of the R color component is equal to 0.

The second complement means 22 is connected to the input means 102 and receives the digitized G color component. The second complement means 22 generates 2's complement of the seven lower bits of the G color component when the most significant bit of the G color component is equal to 0.

The third complement means 23 is connected to the input means 103 and receives the digitized B color component. The third complement means 23 generates 2's complement of the seven lower bits of the B color component when the most significant bit of the B color component is equal to 0.

The first polarity control means 31 includes a complement means 310 connected to an output of the first segment 11 of the lookup table means 1, an output shading circuit 311 connected to the complement means 310 and a detector 312. The complement means 310 generates 2's complement of the output of the first segment 11 of the lookup table means 1 when the most significant bit (Plm7) of the digitized R color component is equal to 0. The detector 312 detects whether the value of the digitized R component is 128 by means of an address signal (Am0) from the input means 101 and the most significant bit (Plm7) of the R component. The detector 312 generates a disabling signal when the value of the R component is 128. The shading circuit 311 outputs a value of 0 upon reception of the disabling signal from the detector 312. Otherwise, the shading circuit 311 outputs the output of the complement means 310.

The structure of the second polarity control means 32 is similar to that of the first polarity control means 31. The complement means (not shown) of the control means 32 is connected to an output of the second segment 12 of the lookup table means 1. The output shading circuit (not shown) of the control means 32 is connected to the complement means. The complement means generates 2's complement of the output of the second segment 12 of the lookup table means 1 when the most significant bit of the digitized R color component is equal to 0. The detector (not shown) of the control means 32 detects whether the value of the digitized R component is 128 by means of the address signal from the input means 101 and the most significant bit of the R component. The detector of the control means 32 generates a disabling signal when the value of the R component is 128. The shading circuit of the control means 32 outputs a value of 0 upon reception of the disabling signal from the detector. Otherwise, the shading circuit outputs the output of the complement means.

The structure of the third polarity control means 33 is similar to that of the first polarity control means 31. The complement means (not shown) of the control means 33 is connected to an output of the third segment 13 of the lookup table means 1. The output shading circuit (not shown) is connected to the complement means. The complement means generates 2's complement of the output of the third segment 13 of the lookup table means 1 when the most significant bit of the digitized R color component is equal to 0. The detector (not shown) of the control means 33 detects whether the value of the digitized R component is 128 by means of the address signal from the input means 101 and the most significant bit of the R component. The detector generates a disabling signal when the value of the R component is 128. The shading circuit outputs a value of 0 upon reception of the disabling signal from the detector. Otherwise, the shading circuit outputs the output of the complement means.

The structure of the fourth polarity control means 34 is similar to that of the first polarity control means 31. The complement means (not shown) of the control means 34 is connected to an output of the fourth segment 14 of the lookup table means 1. The output shading circuit (not shown) of the control means 34 is connected to the complement means. The complement means generates 2's complement of the output of the fourth segment 14 of the lookup table means 1 when the most significant bit of the digitized G color component is equal to 0. The detector (not shown) of the control means 34 detects whether the value of the digitized G component is 128 by means of an address signal from the input means 102 and the most significant bit of the G component. The detector generates a disabling signal when the value of the G component is 128. The shading circuit outputs a value of 0 upon reception of the disabling signal from the detector. Otherwise, the shading circuit outputs the output of the complement means.

The structure of the fifth polarity control means 35 is similar to that of the first polarity control means 31. The complement means (not shown) of the control means 35 is connected to an output of the fifth segment 15 of the lookup table means 1. The output shading circuit (not shown) of the control means 35 is connected to the complement means. The complement means generates 2's complement of the output of the fifth segment 15 of the lookup table means 1 when the most significant bit of the digitized G color component is equal to 0. The detector (not shown) of the control means 35 detects whether the value of the digitized G component is 128 by means of the address signal from the input means 102 and the most significant bit of the G component. The detector generates a disabling signal when the value of the G component is 128. The shading circuit outputs a value of 0 upon reception of the disabling signal from the control means 35. Otherwise, the shading circuit outputs the output of the complement means.

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