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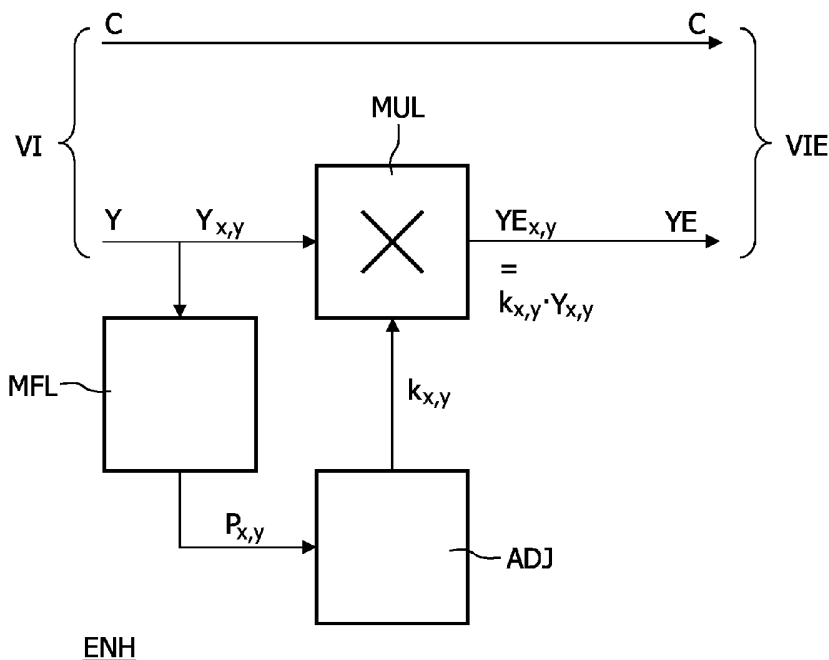
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(54) Title: IMAGE PROCESSOR COMPRISING A CONTRAST ENHANCER



(57) Abstract: An image processor comprises a contrast enhancer that multiplies a brightness- determining component (Y<sub>x,y</sub>) of an image element by a scale factor (k<sub>x,y</sub>). The scale factor (k<sub>x,y</sub>) is a function of an extreme value (P<sub>x,y</sub>) in a signal that is representative of the brightness- determining component (Y<sub>x,y</sub>) and respective brightness-determining components (Y) of neighboring image elements. In a preferred embodiment, a morphological filter (MFL) establishes aforementioned signal and provides the extreme value (P<sub>x,y</sub>) thereof.

WO 2006/123290 A2



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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

Image processor comprising a contrast enhancer.

## FIELD OF THE INVENTION

An aspect of the invention relates to an image processor that comprises a contrast enhancer. The image processor may be, for example, a video display driver that causes a display device to display a video input signal, which the display driver receives.

5 Other aspects of the invention relate to a corresponding method of image processing, a computer program product for an image processor, and an image display system comprising an image processor.

## DESCRIPTION OF PRIOR ART

10 US patent application published under number 2002/0039152 describes a contrast enhancement apparatus of a video signal. The contrast enhancement apparatus comprises a logarithmic conversion unit that converts an input video signal into a logarithm-converted signal. A low pass filter passes a low-frequency component of the logarithm-converted signal. A high pass filter passes a high frequency component of the logarithm-converted signal. A first multiplier multiplies the low frequency component by a low-  
15 frequency mapping coefficient. A second multiplier multiplies the high frequency component by an output signal from an edge detection unit. An adder adds output signals from the first multiplier and the second multiplier. An exponential conversion unit converts an output signal from the adder.

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## SUMMARY OF THE INVENTION

According to an aspect of the invention, an image processor comprises a contrast enhancer that multiplies a brightness-determining component of an image element by a scale factor. The scale factor is a function of an extreme value in a signal that is  
25 representative of the brightness-determining component and respective brightness-determining components of neighboring image elements. In a preferred embodiment, a morphological filter establishes the aforementioned signal and provides the extreme value thereof.

The invention takes the following aspects into consideration. A person may  
30 prefer one image display system over another image display system while both image display systems display a same image. Various display parameters account for such a preference. Contrast is an important display parameter in this respect. Contrast enhancement generally

contributes to a more pleasant viewing experience. A person will generally prefer an image display system that displays an image with an enhanced contrast over an image display system that faithfully reproduces the image.

Contrast enhancement may be carried out in the following manner. A high  
5 frequency portion of an image signal is amplified with respect to a low-frequency portion of the image signal. The more the high frequency portion is amplified, the stronger the contrast enhancement is. The aforementioned prior art is an example of such an approach.

Amplification of a high frequency portion of an image signal may introduce  
10 certain artifacts such as, for example, ringing and overshoot. Such artifacts may degrade image quality and may even become annoying. This is particularly true if the high frequency portion is amplified to relatively large extent. Consequently, the high frequency portion of the image signal should be amplified to relatively modest extent only. This limits the extent to which contrast can be enhanced.

In accordance with the aforementioned aspect of the invention, a contrast  
15 enhancer multiplies a brightness-determining component of an image element by a scale factor. The scale factor is a function of an extreme value in a signal that is representative of the brightness-determining component and respective brightness-determining components of neighboring image elements.

In contradistinction with the prior art, the invention does not require a high  
20 frequency portion of an image signal to be amplified with respect to a low-frequency portion. Consequently, artifacts, which are inherent to such a frequency-selective amplification, can be avoided. Instead, the invention provides a combined brightness and contrast enhancement, which may vary from one image portion to another depending on local brightness conditions. The invention allows amplifying local peaks in image brightness towards a maximum  
25 brightness that a given display device can produce. For those reasons, the invention allows improved contrast enhancement and, therefore, a more pleasant viewing experience.

Another advantage of the invention relates to the following aspects. Relatively  
30 simple hardware or software, or both, can establish the scale factor by which the brightness-determining component is multiplied. For example, a relatively simple morphological filter, which scans an image of interest, may provide respective extreme values for respective image elements. A relatively simple function may define a relationship between the extreme value for each respective image element and the scaling factor by which the brightness-determining component of that image element is multiplied.. For those reasons, the invention allows cost-efficient implementations.

These and other aspects of the invention will be described in greater detail hereinafter with reference to drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5 FIG. 1 is a block diagram that illustrates a video display system.

FIG. 2 is a functional diagram that illustrates a video enhancement module, which forms part of the video display system illustrated in FIG.1.

FIG. 3 is a functional diagram that illustrates a morphological filter, which forms part of the video enhancement module of FIG.2.

10 FIG. 4A is a matrix that illustrates a luminance shift operation, which the morphological filter of FIG.3 carries out.

FIG. 4B is a matrix that illustrates a luminance shift operation of a simplified morphologic filter.

15 FIG. 5 is a conceptual diagram that illustrates an analogy between the simplified morphological filter of Fig.4B and a pick-up needle in a groove of a gramophone.

FIG. 6 is a functional diagram that illustrates a scaling adjuster, which forms part of the video enhancement module of FIG.2.

#### DETAILED DESCRIPTION

20 FIG. 1 illustrates a video display set VDS. The video display set VDS comprises a video display driver VDD, a display device DPL, and a remote control device RCD. The video display driver VDD comprises an input circuit INP, a video enhancement module ENH, an output circuit OUT, and a controller CTRL. The video display driver VDD receives various input video signals VA, VB, VC from various video sources, which are not  
25 shown. The display device DPL may be, for example, a flat panel display of the liquid crystal type.

The video display driver VDD basically operates as follows. Let it be assumed that a user selects a particular video source on his or her remote control device RCD. The remote control device RCD sends a command to the controller CTRL that indicates the  
30 particular video source to be selected. In response, the controller CTRL causes the input circuit INP to select that particular video source. The input circuit INP applies an internal video signal VI to the video enhancement module ENH. The internal video signal VI corresponds with the input video signal from the video source that the user has selected.

The video enhancement module ENH processes the internal video signal VI so as to enhance various display characteristics, such as, for example, brightness and contrast. The user may adjust one or more display characteristics by means of his or her remote control device RCD. The video enhancement module ENH applies an enhanced internal video signal  
5 VIE to the output circuit OUT. The output circuit OUT provides a display driver signal DDS in response to the enhanced internal video signal VIE. To that end, the output circuit OUT may carry out various signal processing operations, such as, for example, amplification, level shifting, bias voltage generation, and synchronization. The display device DPL, which receives the display driver signal DDS, displays the input video signal that the user has  
10 selected.

FIG. 2 illustrates the video enhancement module ENH. The video enhancement module ENH comprises a multiplier MUL, a morphological filter MFL, and a scaling adjuster ADJ. Any of these functional entities may be implemented by means of software or hardware, or a combination of software and hardware. A suitably programmed processor may carry out  
15 operations that will be described hereinafter with reference to the video enhancement module ENH, which FIG. 2 illustrates.

FIG. 2 illustrates an example in which the internal video signal VI comprises a luminance component Y and a chrominance component C. The example is further based on the assumption that the internal video signal VI is a digital signal. Accordingly, a binary  
20 number defines the luminance component  $Y_{x,y}$  of a pixel of an image. The same applies to a chrominance component C. In FIG. 2, a reference sign that relates to a pixel may comprise an index. The index indicates the location of the pixel in the image in terms of x,y-coordinates. The same applies to the other figures.

The video enhancement module ENH processes the luminance component Y of  
25 an image on a pixel-by-pixel basis. The chrominance component C is not processed. The video enhancement module ENH globally processes the luminance component  $Y_{x,y}$  of a pixel in the following manner. The morphological filter MFL establishes a peak value  $P_{x,y}$  on the basis of the luminance component  $Y_{x,y}$  of the pixel that is processed and respective luminance components Y of neighboring pixels. The scaling adjuster ADJ establishes a scale factor  $k_{x,y}$   
30 for the luminance component  $Y_{x,y}$  of the pixel that is processed on the basis of the peak value  $P_{x,y}$ , which the morphological filter MFL provides. The multiplier MUL multiplies the luminance component  $Y_{x,y}$  of the pixel with the scale factor  $k_{x,y}$  so as to obtain an enhanced luminance component  $YE_{x,y}$  for the pixel.

FIG. 3 illustrates operations that the morphological filter MFL carries out for a particular pixel so as to obtain the peak value  $P_{x,y}$ . The morphological filter MFL carries out a luminance shift operation LSH and a peak detection operation PDT.

The luminance shift operation LSH subtracts an offset value OV from the luminance component Y of each neighboring pixel. A luminance shift function defines the offset value OV for a particular pixel as function of the location of the pixel with respect to the pixel for which the scale factor  $k_{x,y}$  needs to be established. The offset value OV may be zero (0) for the pixel for which the scale factor  $k_{x,y}$  needs to be established.

The luminance shift operation LSH provides level-shifted luminance components  $Y_s$ . Each level-shifted luminance component  $Y_s$  is associated with a particular neighboring pixel. The level-shifted luminance component  $Y_s$  has a value that is equal to the value of the luminance component Y of the neighboring pixel concerned minus the offset value OV that applies to that pixel according to the luminance shift function.

FIG. 4A illustrates the luminance shift operation LSH. FIG. 4A comprises a matrix, which has numbered columns in an x-direction and which has numbered rows in a y-direction. Each cell of the matrix represents a particular pixel. A cell has a column number and a row number, which corresponds with the x-coordinate and the y-coordinate, respectively, of the pixel that the cell represents.

FIG. 4A illustrates an example in which the scale factor  $k_{x,y}$  for the pixel with coordinates  $x,y=100,100$  needs to be established. The cell that represents that pixel is shaded. Each cell comprises a number. The number in a cell represents the offset value OV, which the luminance shift operation LSH subtracts from the luminance value Y of the pixel that the cell represents. The luminance shift function, which defines the respective offset values, can be expressed as:

$$H[\Delta x, \Delta y] = |\Delta x| + |\Delta y|$$

wherein  $H[\Delta x, \Delta y]$  denotes the luminance shift function,  $\Delta x$  the location relative to the pixel for which the scale factor  $k_{x,y}$  needs to be established in the x-direction, and  $\Delta y$  the location relative to the pixel for which the scale factor  $k_{x,y}$  needs to be established in the y-direction. For example, the offset value OV for the pixel with x,y-coordinates 98,97 is equal to 5 because the pixel is located two units away in the x-direction and three units away in the y-direction from the pixel for which the scale factor  $k_{x,y}$  needs to be established.

A level-shifted luminance component  $Y_s$  may generically be expressed as:

$$Y_{S_{x-\Delta x, y-\Delta y}} = Y_{x-\Delta x, y-\Delta y} - H[\Delta x, \Delta y]$$

wherein  $x$  and  $y$  denote the location of the pixel for which the scale factor  $k_{x,y}$  needs to be established in the  $x$ -direction and the  $y$ -direction, respectively.

The morphological filter MFL may define a limited set of  $\Delta x, \Delta y$  pairs that are taken into account. The limited set of  $\Delta x, \Delta y$  pairs corresponds with a filter window, which has a certain shape. For example, the filter window may have a rectangular shape, be 7 units wide in the  $x$ -direction and 7 units wide in the  $y$ -direction, and centered on the pixel for which the scale factor  $k_{x,y}$  needs to be established. In this case,  $\Delta x$  is an integer comprised between -3 and +3. The same applies to  $\Delta y$ . FIG. 4A illustrates this case if it is assumed that the morphological filter MFL takes into account only the pixels that are illustrated, with row and column numbers comprised between 97 and 103.

FIG. 4B illustrates a luminance shift operation of a simplified morphological filter. The simplified morphological filter has a filter window FW that takes into account only the three right most adjacent pixels and the three left most adjacent pixels in the  $x$ -direction with respect to the pixel for which the scale factor  $k_{x,y}$  needs to be established. FIG. 4B illustrates an example in which the scale factor  $k_{x,y}$  for the pixel with coordinates  $x,y=100,100$  needs to be established, like FIG. 4A.

The peak detection operation PDT detects the level-shifted luminance component  $Y_s$  that has the highest value. The highest value constitutes the peak value  $P_{x,y}$ , which the morphological filter MFL applies to the scaling adjuster ADJ.

FIG. 5 illustrates that the operations, which the morphological filter MFL carries out, are analogous to a pick-up needle that reads a groove of an old-fashioned gramophone record. FIG. 5 illustrates a series of bars that represent respective luminance components of the pixels with  $y$ -coordinate 100 and  $x$ -coordinates 97-103. These luminance components form the groove of the old-fashioned gramophone record. FIG. 5 further illustrates a shaded object in the form of needle. The shaded object represents the simplified morphological filter that carries out the luminance shift operation, which FIG. 4B illustrates. The simplified morphological filter forms the pick up needle. The luminance shift function defines the shape of the pick up needle, which is relatively blunt. The pick up needle is 7 pixels wide.

FIG. 5 illustrates an instant when the pick up needle points to the luminance component  $Y_{x,y}$  with  $x$ -coordinate 100. This corresponds with the simplified morphological filter providing the peak value  $P_{100,100}$ , which will determine the scale factor  $k_{x,y}$  for the

aforementioned luminance component  $Y_{x,y}$ . FIG. 4B equally illustrates this case. The pick up needle has a certain height  $H$  with respect to a reference level, which may be zero (0). This height corresponds with the peak value  $P_{100,100}$ .

5 FIG. 5 illustrates that the luminance component  $Y_{99,100}$  with x-coordinate 99 determines the height  $H$  of the pick up needle and, therefore, the peak value  $P_{100,100}$ . The pick up needle rests, as were, on this luminance component. This is because the luminance component  $Y_{99,100}$  with x-coordinate 99 provides the highest level-shifted luminance component when the respective offset values 0, 1, 2, 3 are subtracted from the respective luminance components in accordance with the luminance shift function.

10 It should be noted that the luminance shift operation LSH and the peak detection operation PDT, which the morphological filter MFL carries out, have been described hereinbefore in a rather illustrative fashion. A practical implementation may carry out these operations in a different fashion. That is, a practical implementation need not necessarily carry out the respective operations in succession, one after the other.

15 A software-based implementation of the morphological filter MFL may operate as follows. Reference is made to FIG. 4A. A processor reads the luminance component  $Y$  of the pixel with coordinates  $x,y=97,100$  from a data memory. It is recalled that the luminance component  $Y$  is a digital value. Subsequently, the processor subtracts 3 from the luminance component  $Y$ . Accordingly, the processor calculates a level-shifted luminance component for the pixel concerned and stores this value in the data memory.

20 In a new cycle, the processor reads the luminance component  $Y$  of the pixel with coordinates  $x,y=98,100$  from the data memory. Subsequently, the processor subtracts 2 from the luminance component  $Y$ . Accordingly, the processor calculates a level-shifted luminance component for the pixel concerned. The processor compares this level-shifted component value with the previously calculated level-shifted luminance component, which has been stored in the data memory. The processor retains the higher of the two level-shifted luminance components concerned and stores that level-shifted luminance component in the data memory. The processor continues to carry out similar cycles for each pixel, which the cells in FIG. 4A represent. At the end, the data memory will comprise the level-shifted

30 luminance component that has the highest value.

The morphological filter MFL may equally be implemented like a digital filter that has an infinite impulse response (IIR). Such an implementation has a feedback path that comprises a memory. A current calculation cycle uses results from a previous calculation cycle.

FIG. 6 illustrates operations that the scaling adjuster ADJ carries out so as to establish the scale factor  $k_{x,y}$  on the basis of the peak value  $P_{x,y}$ . The scaling adjuster ADJ carries out an inversion operation INV, a temporal low-pass operation TLP, and a clipping operation CLP.

5 The inversion operation INV divides a maximum luminance value  $Y_{\max}$  by the peak value  $P_{x,y}$ , which the morphological filter MFL has established. The maximum luminance value  $Y_{\max}$  may be, for example, 255 in case 8-bit binary words represent the luminance components. The inversion operation INV provides a gross scale factor  $kg_{x,y}$ , which is the result of the aforementioned division.

10 The temporal low-pass operation TLP makes a weighted combination of the gross scale factor  $kg_{x,y}$  and respective corresponding gross scale factors of previous images. In FIG. 6, reference signs  $kg_{x,y}@F_{n-1}$ , ...,  $kg_{x,y}@F_{n-k}$  illustrate corresponding gross scale factors of previous images. It is recalled that the gross scale factor  $kg_{x,y}$  relates to a pixel that has a particular location in terms of  $x,y$ -coordinates. The temporal low-pass operation TLP thus  
 15 makes a weighted combination of respective gross scale factors that relate to pixels that belong to different images but that have the same location. As a result, the temporal low-pass operation TLP damps a variation of gross scale factors, which relate to a pixel of a given location, from one image to another. Such a damping is inherent to a low pass filter function, which the temporal low-pass operation TLP carries out for respective gross scale factors in  
 20 the time domain. The temporal low-pass operation TLP provides a filtered scale factor  $kf_{x,y}$ , which corresponds with the aforementioned weighted combination.

The clipping operation CLP clips the filtered scale factor  $kf_{x,y}$  so that the scale factor  $k_{x,y}$  is within a desired range between a maximum scale value  $k_{\max}$  and a minimum scale value  $k_{\min}$ . The scale factor  $k_{x,y}$  is equal to the filtered scale factor  $kf_{x,y}$  if the filtered scale  
 25 factor  $kf_{x,y}$  is within the desired range. The scale factor  $k_{x,y}$  is equal to the maximum scale value  $k_{\max}$  if the filtered scale factor  $kf_{x,y}$  exceeds the maximum scale value  $k_{\max}$ . Conversely, the scale factor  $k_{x,y}$  is equal to the minimum scale value  $k_{\min}$  if the filtered scale factor  $kf_{x,y}$  is below the minimum scale value  $k_{\min}$ .

As mentioned hereinbefore, the multiplier MUL multiplies the scale factor  $k_{x,y}$   
 30 with the luminance component  $Y_{x,y}$  of the pixel for which the scale factor  $k_{x,y}$  was established. The video enhancement module ENH, which FIG. 2 illustrates, may amplify each pixel of an image in this fashion. This will generally cause the image, which the display device DPL displays, to be relatively bright and to have relatively rich contrast. The video enhancement module ENH may optionally comprise an overall brightness corrector in order to prevent that

the image becomes too bright. In any case, the video enhancement module ENH allows the video display systems to display images that an average person will generally consider more pleasant compared with conventional video display systems. The user may adjust display characteristics.

5

## CONCLUDING REMARKS

The detailed description hereinbefore with reference to the drawings illustrates the following characteristics, which are cited in various independent claims. A brightness-determining component (luminance component  $Y_{x,y}$ ) of an image element is multiplied by a scale factor ( $k_{x,y}$ ). The scale factor ( $k_{x,y}$ ) is a function of an extreme value ( $P_{x,y}$ ) in a signal (a collection of level-shifted luminance components  $Y$ s) that is representative of the brightness-determining component ( $Y_{x,y}$ ) and respective brightness-determining components (respective luminance components  $Y$ ) of neighboring image elements.

The detailed description hereinbefore further illustrates various optional characteristics, which are cited in the dependent claims. These characteristics may be applied to advantage in combination with the aforementioned characteristics. Various optional characteristics are highlighted in the following paragraphs. Each paragraph corresponds with a particular dependent claim.

A morphological filter (MFL) provides the extreme value ( $P_{x,y}$ ) on the basis of the brightness-determining component ( $Y_{x,y}$ ), which is multiplied by the scale factor ( $k_{x,y}$ ), and respective brightness-determining components ( $Y$ ) of neighboring image elements. This characteristic allows low-cost implementations.

The respective magnitudes of the respective brightness-determining components ( $Y$ ) of the neighboring image elements are shifted in accordance with a level shift function so as to obtain a set of level-shifted brightness-determining components ( $Y$ s). The highest magnitude among the set of level-shifted brightness-determining components ( $Y$ s) constitutes the extreme value ( $P_{x,y}$ ). These characteristics contribute to an improved contrast enhancement and, therefore, to a more pleasant viewing experience.

The level shift function is a linear function of a distance between a neighboring image element and the image element of which the brightness-determining component ( $Y_{x,y}$ ) is multiplied by the scale factor ( $k_{x,y}$ ). This allows cost-efficient implementations.

The scale factor ( $k_{x,y}$ ) varies inversely with the extreme value ( $P_{x,y}$ ) within at least a range of scale factors.

The scale factor ( $k_{x,y}$ ) is equal to a maximum magnitude for brightness-determining components ( $Y_{\max}$ ) divided by the extreme value ( $P_{x,y}$ ), within at least a range of scale factors values.

5 The scale factor ( $k_{x,y}$ ) is established on the basis of respective extreme values for corresponding image elements in a series of images.

The scale factor ( $k_{x,y}$ ) is kept within a desired range of scale factors between a minimum scale value ( $k_{\min}$ ) and a maximum scale value ( $k_{\max}$ ).

The brightness-determining component ( $Y_{x,y}$ ), which is multiplied by the scale factor ( $k_{x,y}$ ), is a luminance component.

10 The characteristics in each of the six preceding paragraphs, contribute to an improved contrast enhancement and, therefore, to a more pleasant viewing experience.

The aforementioned characteristics can be implemented in numerous different manners. In order to illustrate this, some alternatives are briefly indicated.

15 The aforementioned characteristics may be applied to advantage in any type of product or method that relates to image processing. A video display driver is merely an example. The aforementioned characteristics may equally be applied in, for example, a digital photo camera, a photo-editing software program, a personal computer, a set-top box, a television set, a personal digital assistant, a mobile phone, and so on.

20 Moreover, image data, which is processed in accordance with the invention, need not have a specific format. Any image data comprises at least one brightness-determining component in one form or the other. A format that comprises a luminance component and a chrominance component is merely an example. Image data may also be, for example, in the so-called RGB format, which comprises a red component, a green component, and a blue component. A pixel has a brightness that depends on each of these respective  
25 components.

An image processor that handles image data in the RGB format may comprise, for example, three contrast enhancers similar to the contrast enhancer that FIG. 2 illustrates: a contrast enhancer for the red component, another contrast enhancer for the green component, and yet another contrast enhancer for the blue component. The image data may also have a  
30 format of the non-photometric type. Such a format includes a depth component, which allows 3-D video. The principles that underlie the contrast enhancement in accordance with the invention may equally be used for depth enhancement in 3-D video. For example, the operations that have been described in the detailed description hereinbefore may be applied to depth components instead of luminance components.

Furthermore, the invention may be used for enhancing an analog image signal. Such an implementation may be based on the contrast enhancer that FIG. 2 illustrates. The multiplier MUL may be replaced by a gain controllable amplifier. The scaling adjuster ADJ may be replaced by a gain control circuit. The morphological filter MFL can be implemented  
5 by means of analog circuits.

There are various different manners to establish a signal that is representative of a set of brightness-determining components and to derive an extreme value from that signal. Although a preferred manner comprises the use of a morphological filter, this is not the only possible manner. In principle, any type of circuit or method that takes into account local  
10 brightness conditions can be used. A level shift function is preferable but not indispensable. A filter window is not required, in particular if the level shift function subtracts a relatively large offset value from a neighboring brightness-determining component that is relatively distant from the brightness-determining component that is to be scaled. Moreover, the level shift function and the filter window, if any, may vary from one application to another, for example,  
15 in order to meet a given set of requirements.

There are numerous functions that may suitably define the scale factor on the basis of the extreme value. An inversely proportional function is merely an example. An inverse square root function may equally define the scale factor on the basis of the extreme value. Such a function provides a smoother adjustment of the scale factor, which may be  
20 preferable in a particular application.

In general, there are numerous manners to implement contrast enhancement in accordance with the invention. The detailed description merely illustrates an example. It is possible to leave out one or more operations, which have been described. Conversely, it is possible to add further operations or to replace a particular operation, which has been  
25 described, by another operation. For example, referring to the scaling adjuster ADJ, which FIG. 6 illustrates, is possible to omit the temporal low-pass operation TLP. This simplifies the video enhancement module.

The term "image" should be understood in a broad sense. This term includes a frame, a field, and any other entity that may wholly or partially constitute an image or picture.  
30

There are numerous ways of implementing functions by means of items of hardware or software, or both. In this respect, the drawings are very diagrammatic, each representing only one possible embodiment of the invention. Thus, although a drawing shows different functions as different blocks, this by no means excludes that a single item of

hardware or software carries out several functions. Nor does it exclude that an assembly of items of hardware or software or both carry out a function.

The remarks made herein before demonstrate that the detailed description with reference to the drawings, illustrate rather than limit the invention. There are numerous  
5 alternatives, which fall within the scope of the appended claims. Any reference sign in a claim should not be construed as limiting the claim. The word “comprising” does not exclude the presence of other elements or steps than those listed in a claim. The word “a” or “an” preceding an element or step does not exclude the presence of a plurality of such elements or steps.

Claims.

1. An image processor comprising a contrast enhancer arranged to multiply a brightness-determining component ( $Y_{x,y}$ ) of an image element by a scale factor ( $k_{x,y}$ ) that is a function of an extreme value ( $P_{x,y}$ ) in a signal ( $Ys$ ) that is representative of the brightness-determining component ( $Y_{x,y}$ ) and respective brightness-determining components  
5 ( $Y$ ) of neighboring image elements.
2. An image processor according to claim 1 comprising:
- a morphological filter (MFL) arranged to provide the extreme value ( $P_{x,y}$ ) on the basis of the brightness-determining component ( $Y_{x,y}$ ), which is multiplied by the  
10 scale factor ( $k_{x,y}$ ), and respective brightness-determining components ( $Y$ ) of neighboring image elements.
3. An image processor according to claim 2, the morphological filter (MFL) comprising:
- a lever shifter (LSH) arranged to shift the respective magnitudes of the  
15 respective brightness-determining components ( $Y$ ) of the neighboring image elements in accordance with a level shift function so as to obtain a set of level-shifted brightness-determining components ( $Ys$ ); and
  - a peak detector arranged to establish the highest magnitude among the  
20 set of level-shifted brightness-determining components ( $Ys$ ), the highest magnitude constituting the extreme value ( $P_{x,y}$ ).
4. An image processor according to claim 3, the level shift function being a linear function of a distance between a neighboring image element and the image element of  
25 which the brightness-determining component ( $Y_{x,y}$ ) is multiplied by the scale factor ( $k_{x,y}$ ).
5. An image processor according to claim 2 comprising a scaling adjuster (ADJ) arranged to vary the scale factor ( $k_{x,y}$ ) inversely with the extreme value ( $P_{x,y}$ ) within at least a range of scale factors.  
30
6. An image processor according to claim 5, the scaling adjuster (ADJ) being arranged so that the scale factor ( $k_{x,y}$ ) is equal to a maximum magnitude ( $Y_{max}$ ) for

brightness-determining components divided by the extreme value ( $P_{x,y}$ ), within at least a range of scale factors.

7. An image processor according to claim 2 comprising a scaling adjuster (ADJ) arranged to establish the scale factor ( $k_{x,y}$ ) on the basis of respective extreme values for corresponding image elements in a series of images.

8. An image processor according to claim 2 comprising a scaling adjuster (ADJ) arranged to keep the scale factor ( $k_{x,y}$ ) within a desired range of extreme values between a minimum scale value ( $k_{\min}$ ) and a maximum scale value ( $k_{\max}$ ).

9. An image processor according to claim 1, the contrast enhancer being arranged so that the brightness-determining component ( $Y_{x,y}$ ) that is multiplied by the scale factor ( $k_{x,y}$ ) is a luminance component.

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10. A method of image processing comprising:  
- an image enhancement step in which a brightness-determining component ( $Y_{x,y}$ ) of an image element is multiplied by a scale factor ( $k_{x,y}$ ) that is a function of an extreme value ( $P_{x,y}$ ) in a signal that is representative of the brightness-determining component ( $Y_{x,y}$ ) and respective brightness-determining components ( $Y$ ) of neighboring image elements.

20

11. A computer program product that comprises a set of instructions, which when loaded into an instruction executing arrangement, causes the instruction executing arrangement to carry out the method according to claim 10.

25

12. An image display system (VDS) comprising an image processor (VDD) according to claim 1 for providing an enhanced image signal (DSS) in response to an input image signal (VA, VB, VC), and a display device (DPL) for displaying the enhanced image signal.

30

1/5

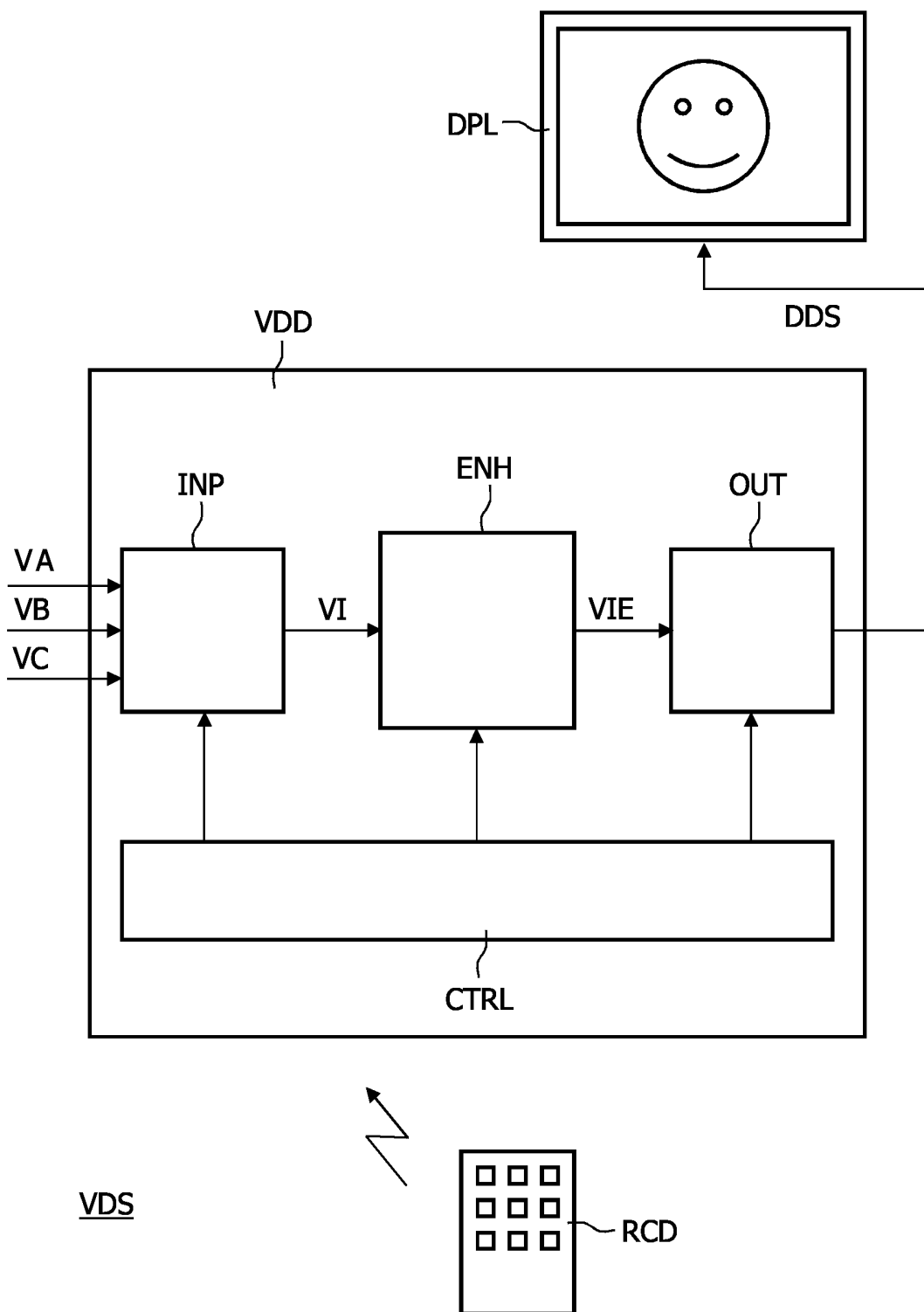


FIG. 1

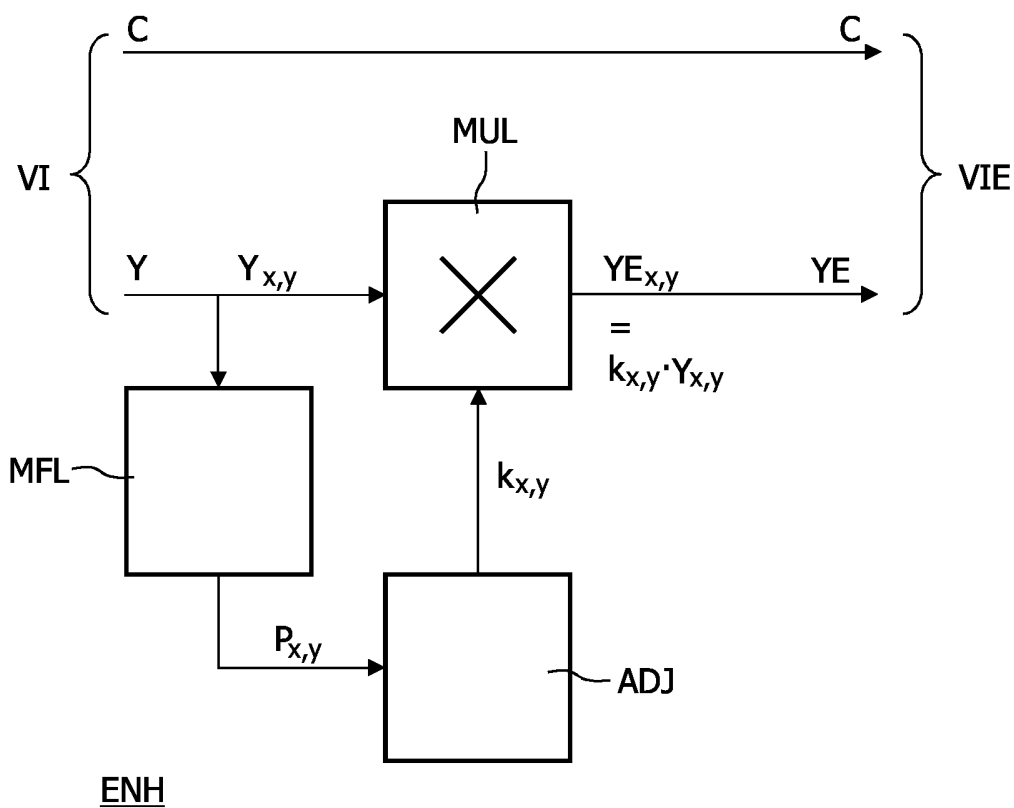


FIG. 2

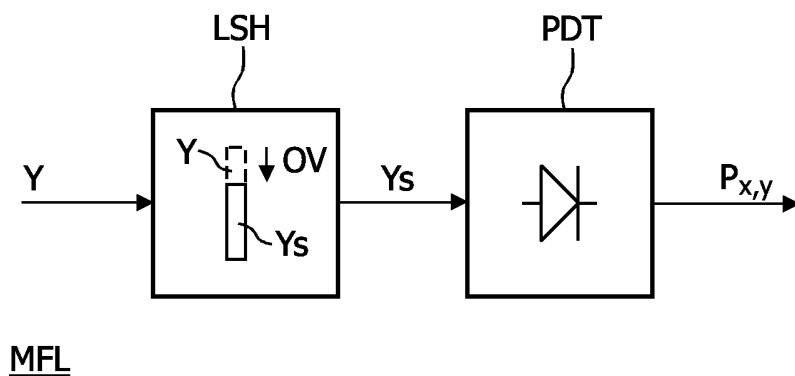


FIG. 3

3/5

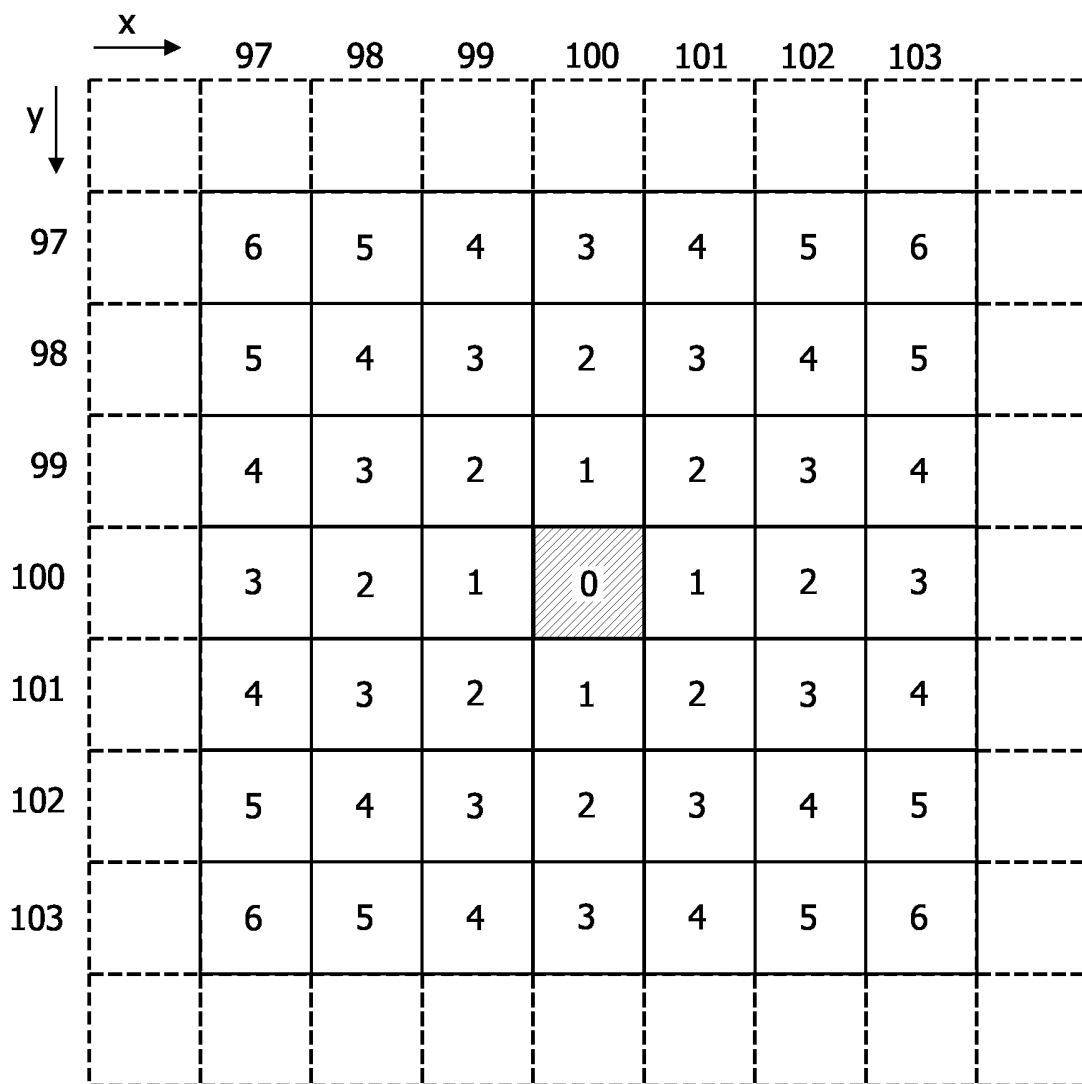


FIG. 4A

4/5

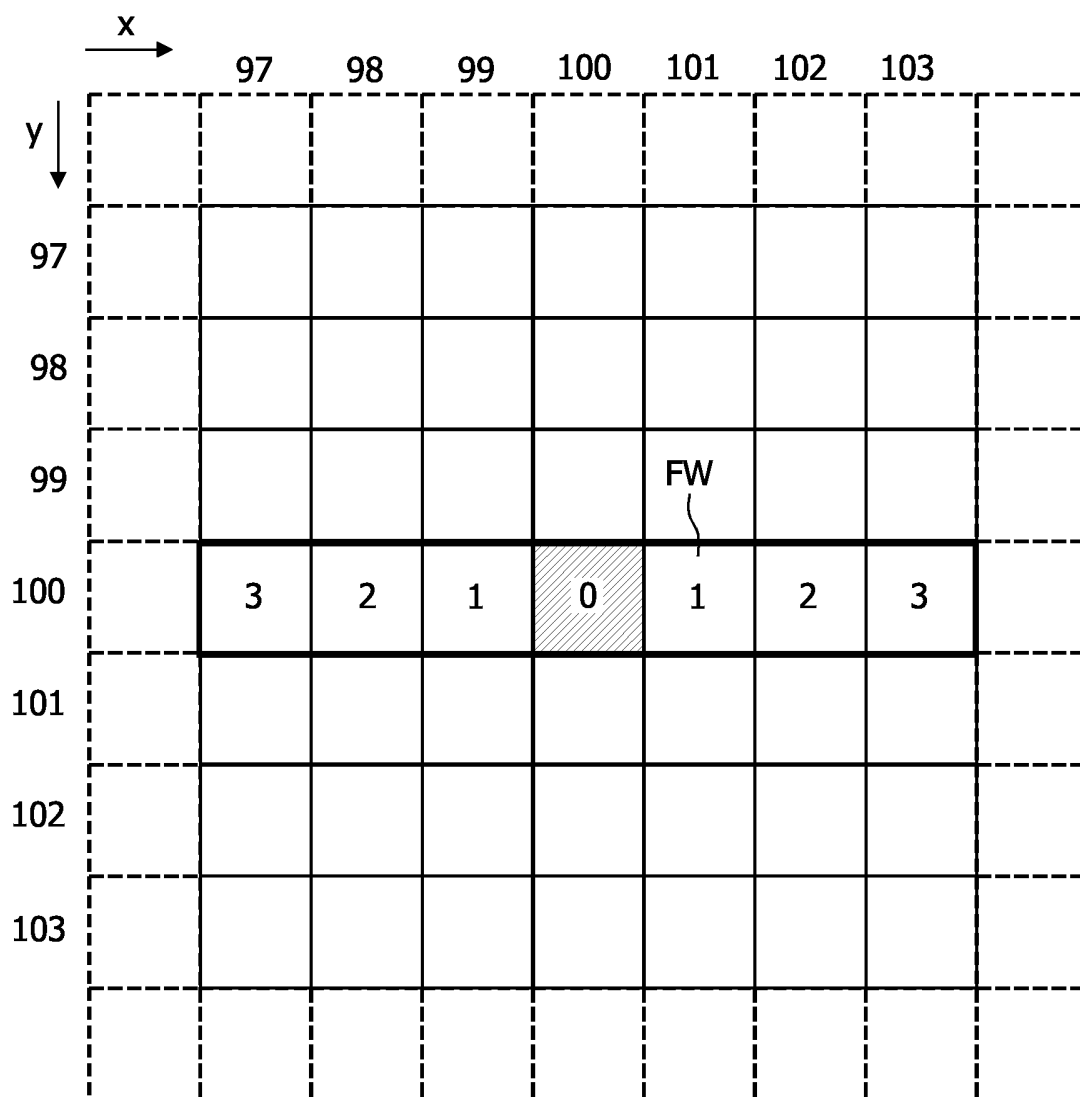


FIG. 4B

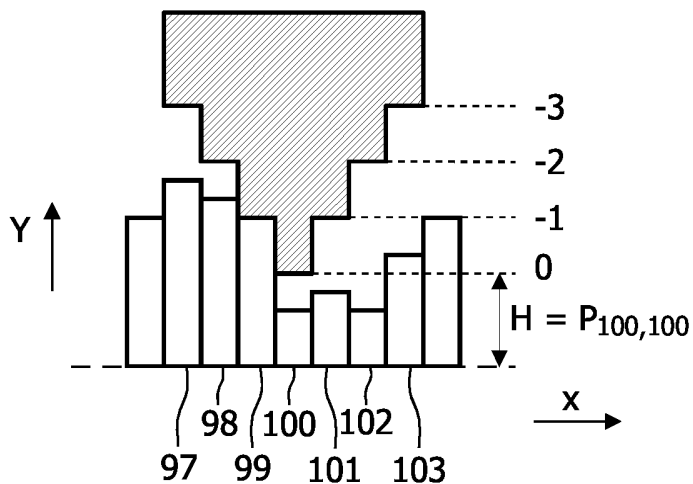
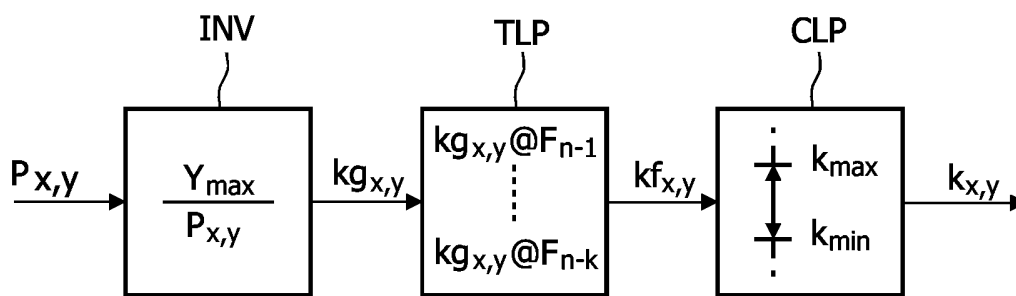


FIG. 5



ADJ

FIG. 6