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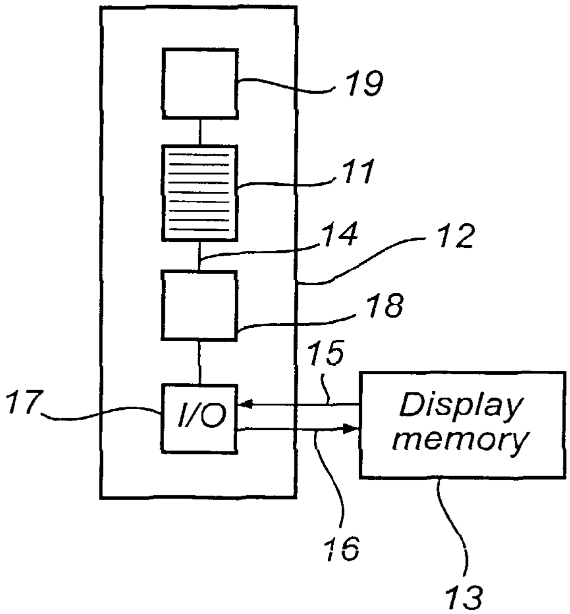
(54) **Title:** PIXEL FAULT MASKING




**(57) Abstract:** A method for masking faulty sub-pixels in a display having a plurality of pixels formed of a number of sub-pixels, wherein at least one pixel in said display is faulty and comprises at least one sub-pixel having a defect. The method comprises obtaining (S2) a set (15) of sub-pixel values (2, 3, 4) for generating desired perceptive characteristics for said pixel and determining (S3) a modified set (16) of sub-pixel values (2', 3', 4') for generating modified perceptive characteristics for said pixel. This modified set of sub-pixel values is based on information (14)regarding the sub-pixel defect so as to be implementable in the display, and has values chosen to reduce an error perceived by a user. The modified values are then implemented (S4) in the display. The display is preferably of the kind where each pixel comprises a set of primary sub-pixels each emitting a primary color and at least one additional, redundant sub-pixel for emitting an additional color, such as a RGBW display.

WO 03/100756 A2

# Pixel fault masking

The present invention relates to pixel fault masking in a display having a plurality of pixels formed of a number of sub-pixels. Aspects of the invention include a method, a control unit, and a display device.

In conventional display systems, a number of sub-pixels, normally three for the red green and blue (RGB) primaries, make up a pixel. Mixing appropriate levels of each of the primaries makes up the desired color and intensity of a pixel. Recently, displays are emerging that make use of an additional, redundant sub-pixel in addition to the primary colors, such as a white sub-pixel (RGBW). The redundant sub-pixel can be used for enhancing the luminance of the display, preferably without altering the chrominance at all. An example of this is described in WO 0137249, hereby incorporated by reference.

When manufacturing displays such as liquid crystal displays, an important factor for determining the unit cost is the yield, i.e., the number of defect displays produced for every functioning display. A display is defect if it contains faulty pixels, i.e., pixels that for some reason will not function appropriately, typically resulting from a defect sub-pixel.

Normally, a certain number of faulty pixels can be accepted for a specific class of displays, and displays having a number of faulty pixels exceeding this number are scrapped. However, even a single faulty sub-pixel can be a source of irritation, especially once it is spotted.

To eliminate the occurrence of faulty pixels is very expensive, if at all possible. Further, the difficulty of producing a perfect display is related to the number of pixels and the size of the display, and the problem with faulty pixels is therefore likely to increase as resolution and panel size increase.

Therefore, it would be desirable to mask the effect of faulty pixels, hence reducing the risk of spotting them. This would also permit increasing the number of accepted faulty pixels per display, and thereby reduce the number of scrapped displays. This increases the yield, and is beneficial in many aspects: more displays can be sold, less waste material is generated in the process, and the production cost per display is reduced.

In camera systems, fault masking already exists, and has been implemented in commercially available chips. According to this technique, the surrounding of a defect sub-pixel is used to compute its expected value, thus masking the fault. This technique is, however, not applicable to displays.

Another approach is error diffusion, i.e., distributing the error in approximating a certain value over a set of neighbouring pixels. This is by itself not a suitable technique for fault masking, since the error to be distributed typically is too large, e.g., a sub-pixel stuck at level zero. In fact, the visibility of the fault appears increase due to the sharpening effect that occurs in the diffusion. Thus, so far, there is no available technique for masking of defect sub-pixels.

An object of the present invention is to provide adequate masking of faulty pixels in a display.

Another object is to provide a satisfying quality of the displayed image characteristics as perceived by a user.

According to a first aspect of the present invention, these objects are achieved with a method according to the preamble of claim 1, further comprising obtaining, for each faulty pixel, information of said defect sub-pixel, obtaining a set of sub-pixel values for generating desired perceptive characteristics for said pixel, determining a modified set of sub-pixel values for generating modified perceptive characteristics for said pixel, said modified set of sub-pixel values being based on said information so as to be implementable in the display, said modified set (16) of sub-pixel values being such as to reduce an error perceived by a user resulting from a difference between said desired perceptive characteristics and said modified perceptive characteristics, and implementing said modified set of sub-pixel values in the display.

By taking the sub-pixel defect into consideration, the set of sub-pixel values is thus recalculated into a modified set, in order to minimize the error perceived by the user. Typical perceived characteristics include luminance (brightness) and chrominance (color).

It is important to realize that this does not necessarily mean that the error in terms of absolute sub-pixel values is minimized. Minimizing the error in terms of absolute sub-pixel values would minimize the chrominance error, without taking luminance into consideration. In order to obtain a smaller perceived error, an adjustment might therefore be made to better maintain desired luminance.

A requirement for effective fault masking is that the intended sub-pixel values can be adjusted both up and down to result in the actual sub-pixel values. In a case where all sub-pixels are used in normal operation, some remaining capacity of these sub-pixels is preferably reserved, in order to enable optimal fault masking according to the invention.

By this method, sub-pixel defects become practically invisible to the human visual system, and will hence no longer be a source of irritation. By allowing more defects in a display, the yield can be improved drastically, with the advantages mentioned above.

Considering that the number of faulty pixels is low compared to the total number of pixels, the method will be low-cost, even in a case when the implemented method is computationally complex. If the fault masking is kept relatively simple, then the overhead, compared to normal pixel processing, is extremely low.

The information about faulty pixels can be obtained from a predefined list storing location and details of each faulty pixel. It may also be advantageous, as an alternative or in combination with the list, to automatically detect sub-pixel defects. This eliminates the need for storing information about defects at the time of production, and also makes the fault masking adaptive to the occurrence of new faults. This in turn makes it possible to enhance the useful lifetime of displays for which defects appear over time (e.g., PLED, but also LCD).

The set of sub-pixel values can be obtained from a display memory, and the modified set of sub-pixel values can be returned to the memory. This offers an efficient way to interface with a conventional display driver.

The determination can include solving an approximation problem of constrained least square (CLS) type.

The display is preferably of the kind where each pixel comprises a set of primary sub-pixels each emitting a primary color and at least one additional, redundant sub-pixel for emitting an additional color. The primary colors are chosen so as to enable generation of any given color by combining them in adequate ratios. The most conventional combination of primaries is of course red, green and blue (RGB). The additional color can be chosen so as to include contributions from each of the primary colors. The example mentioned above was white (RGBW), but also other colors, such as cyan, magenta, or yellow can be useful. With more than three sub-pixels, it is also possible with an altogether different set of colors, making division into primaries and non-primaries superfluous.

The redundant sub-pixel can be shared by several pixels, for example by two pixels. This reduces the total number of additional sub-pixels, making the display less expensive.

The set of sub-pixel values and the modified set of sub-pixel values can each comprise values for sub-pixels adjacent to said defect sub-pixel. The sets are preferably related to the sub-pixels of a specific pixel, but may well be related to other neighborhoods of sub-pixels, if this is found advantageous.

The original set of sub-pixel preferably comprises values for the primary color sub-pixels of a pixel. By only comprising these values, in a redundant sub-pixel type display, a certain "headroom" is guaranteed by the additional intensity that can be provided by activating the additional, redundant color sub-pixel. The modified set of sub-pixel values then also comprises values for any such redundant sub-pixel of the pixel.

Note that there is a trade-off between maximum luminance (no headroom reserved) and maximum fault masking performance (headroom available). This trade off can be very useful used in situation where produced displays are graded according to the number of faults and to their application (monitor, TV, video, still images, *etc.*) and market (professional or consumer). In expensive, essentially fault free displays, no headroom needs to be reserved, while in less expensive, faulty displays, headroom should be reserved in order to allow for the fault masking according to the present invention.

Grading of displays according to the number of defects/headroom in the described way can also work for non-redundant displays (e.g., conventional RGB).

The method can further comprise compensating faulty pixels by error diffusion. While inefficient for large errors such as sub-pixel stuck at zero, error diffusion may be advantageous for small errors remaining after fault masking according to the above method. This may be particularly advantageous in a case of limited headroom as described above.

The method according to the invention is preferably implemented in a display in which sub-pixels can be addressed accurately (matrix displays). Examples of such displays are active matrix LCD and PLEDs.

According to a second aspect of the present invention, the above objects are achieved with a control unit for a display having a plurality of pixels formed of a number of sub-pixels, the control unit comprising means for obtaining, for each faulty pixel, information of said defect sub-pixel, means for obtaining a set of sub-pixel values for generating desired perceptive characteristics for the faulty pixel, means for determining a modified set of sub-pixel values for generating actual perceptive characteristics for said faulty pixel, said modified set of sub-pixel values being based on information regarding said sub-pixel defect so as to be implementable in the display, said modified set of sub-pixel values being such as

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