(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 424 672 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.06.2004 Bulletin 2004/23

(51) Int Cl.7: G09G 3/20

(21) Application number: 02447233.4

(22) Date of filing: 29.11.2002

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: BARCO N.V.
8500 Kortrijk (BE)

(72) Inventors:
- Matthijs, Paul
  9810 Eke (BE)
- Kimpe, Tom
  9000 Gent (BE)

(74) Representative: Bird, William Edward et al
Bird Goen & Co.,
Klein Dalenstraat 42A
3020 Winksele (BE)

(54) Method and device for correction of matrix display pixel non-uniformities

(57) The present invention relates to a system and method for correction of the non-uniformity of pixel light-output behaviour present in matrix addressed electronic display devices.

The present invention provides a method for correction of nonuniformities of display elements (pixels or sub-pixels) in a matrix display, the display being driveable between a maximum and a minimum brightness. The method comprises: storing characterisation data characterising the light-output response, i.e. luminance and/or colour response, of individual display elements of the matrix display, the characterisation data representing light-outputs of an individual display element as a function of its drive signals, and the characterisation data being classified into a pre-set number of categories, the pre-set number being less than the number of display elements in the display and greater than one, the characterisation data of at least two display elements being assigned to one of the categories, and the light-outputs/drive signals relationships represented by at least two characterisation data in two different categories crossing over within the maximum and minimum brightness of the display. The method furthermore comprises pre-correcting, in accordance with the characterisation data in the relevant categories, drive signals of individual display elements so as to obtain a pre-determined spatial light-output of display elements, to thereby display an image.

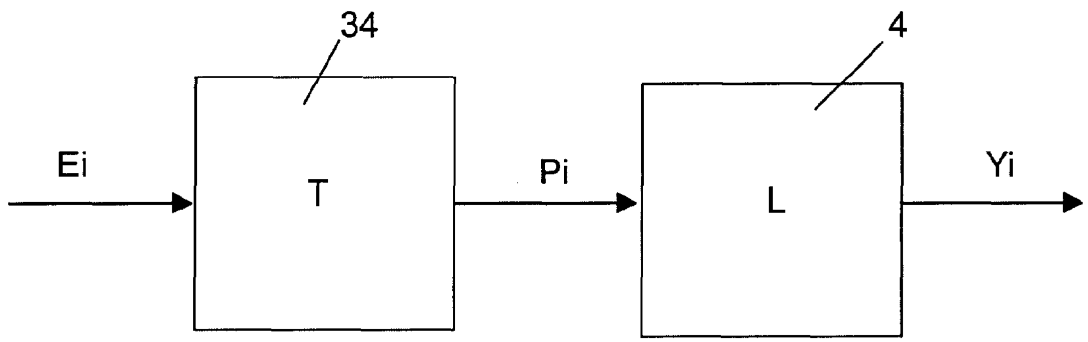

Fig. 8

Description

Technical field of the invention

[0001] The present invention relates to a system and method for correction, for example real-time correction, of the non-uniformity of pixel light-output behaviour present in matrix addressed electronic display devices such as plasma displays, liquid crystal displays, light emitting diode (LED) and organic light emitting diode (OLED) displays used in projection or direct viewing concepts.

[0002] It applies to emissive, transmissive, reflective and trans-reflective display technologies fulfilling the feature that each pixel is individually addressable.

Background of the invention

[0003] At present, most matrix based display technologies are in its technological infancy compared to long established electronic image forming technologies such as Cathode Ray Tubes. As a result, many domains of image quality deficiency still exist and cause problems for the acceptance of these technologies in certain applications.

[0004] Matrix based or matrix addressed displays are composed of individual image forming elements, called pixels (Picture Elements), that can be driven (or addressed) individually by proper driving electronics. The driving signals can switch a pixel to a first state, the on-state (luminance emitted, transmitted or reflected), to a second state, the off-state (no luminance emitted, transmitted or reflected), see for example EP-0117335 which describes an LCD. For some displays, one stable intermediate state between the first and the second state is used - see EP-0462619 which also describes an LCD. For still other displays, one or more intermediate states between the first and the second state (modulation of the amount of luminance emitted, transmitted or reflected) are used - see EP-0117335. A modification of these designs attempts to improve uniformity by using pixels made up of individually driven sub-pixel areas and to have most of the sub-pixels driven either in the on- or off-state - see EP-0478043 which also describes an LCD. One sub-pixel is driven to provide intermediate states. Due to the fact that this sub-pixel only provides modulation of the grey-scale values determined by selection of the binary driven sub-pixels the luminosity variation over the display is reduced.

[0005] A known image quality deficiency existing with these matrix based technologies is the unequal light-output response of the pixels that make up the matrix addressed display consisting of a multitude of such pixels. More specifically, identical electric drive signals to various pixels may lead to different light-output of these pixels. Current state of the art displays have pixel arrays ranging from a few hundred to millions of pixels. The observed light-output differences between (even neighbouring) pixels is as high as 30% (as obtained from the formula (minimum luminance - maximum luminance) / minimum luminance).

[0006] These differences in behaviour are caused by various production processes involved in the manufacturing of the displays, and/or by the physical construction of these displays, each of them being different depending on the type of technology of the electronic display under consideration. As an example, for liquid crystal displays (LCDs), the application of rubbing for the alignment of the liquid crystal (LC) molecules, and the colour filters used, are large contributors to the different luminance behaviour of various pixels. The problem of lack of uniformity of OLED displays is discussed in US-20020047568. Such lack of uniformity may arise from differences in the thin film transistors used to switch the pixel elements.

[0007] This phenomenon of non-uniform light-output response of a plurality of pixels is disturbing in applications where image fidelity is required to be high, such as for example in medical applications, where luminance differences of about 1% are supposed to have a meaning. The unequal light-output response of the pixels superimposes an additional, disturbing and unwanted random image on the required or desired image, thus reducing the SNR of the resulting image.

[0008] EP-0755042 describes a method and device for providing uniform luminosity of a field emission display (FED). Non-uniformities of luminance characteristics in a FED are compensated pixel by pixel. This is done by storing a matrix of calibration values, one value for each pixel. These calibration values are determined by a previously measured emission efficiency of the corresponding pixels. These calibration values are used for correcting the level of the signal that drives the corresponding pixel. 16 different calibration values are proposed.

[0009] It is a disadvantage of the method described in EP-0755042 that a linear approach is applied, i.e. that a same calibration value is used to correct a drive signal of a given pixel, independent of whether a high or a low luminance has to be provided. However, pixel luminance for different drive signals of a pixel depends on physical features of the pixel, and those physical features may not be the same for high or low luminance levels. Therefore, pixel non-uniformity is different at high or low levels of luminance, and if corrected by applying to a pixel drive signal a same calibration value independent of the drive value corresponds to a high or to a low luminance level, non-uniformities in the luminance are still observed.

Summary of the invention

[0010] It is an object of the present invention to provide a system and a method for correction of non-uniformities in light-output, i.e. in luminosity and/or colour, of display elements of a matrix display.

[0011] It is a further object of the present invention to overcome the disadvantages of the prior art solution mentioned above.

[0012] The above objectives are accomplished by a method and device according to the present invention.

[0013] The present invention provides a method for correction of non-uniformities of display elements in a matrix display. Display elements may be pixels or subpixels. The method comprises: storing characterisation data characterising the non-linear light-output response, i.e. luminance and/or colour response, of individual display elements of the matrix display, the characterisation data representing light-outputs of an individual display element as a function of its drive signals, and the characterisation data being classified into a pre-set number of categories, the pre-set number being less than the number of display elements in the display and greater than one, and the characterisation data of at least two display elements being assigned to one of the categories; and pre-correcting, in accordance with the characterisation data in the relevant categories, drive signals of individual display elements so as to obtain a pre-determined spatial light-output of display elements, to thereby display an image. Obtaining a pre-determined spatial light-output may comprise compensating for unequal light output between different display elements, so that, when all display elements are driven with a same level of a drive signal, then all light-outputs are the same, and the displayed image looks uniform over the display. Alternatively, obtaining a pre-determined spatial light-output may comprise obtaining a second pre-determined non-uniform light-output behaviour of display elements, which second light-output behaviour is different from a first pre-determined non-uniform light-output behaviour generated by the non-uniformities of the display elements in the matrix display. This may be used to pre-correct for non-uniformities of post-processing systems that are added to the display, such as, but not limited to, optical systems such as lenses in case of projectors, tiled displays, screen magnification lenses, etc.

[0014] The non-linear light-output response of a display element may comprise its luminance response and/or its colour response.

[0015] The matrix display may be driveable between a maximum and a minimum brightness. According to the present invention, the light-outputs/drive signals relationships represented by at least two characterisation data in two different categories may be crossing over within the maximum and minimum brightness of the display, i.e. at certain drive levels the light-output response of a first pixel is higher than the light-output response of a second pixel, while at other drive levels the light-output response of the second pixel is higher than the light-output response of the first pixel. This situation cannot be dealt with by the prior art solution of EP-0755042.

[0016] A method according to the present invention may further comprise generating the characterisation data from images captured from individual display elements. Generating the characterisation data may comprise building a display element profile map representing characterisation data for each display element of the matrix display. Building a display element profile map may comprise storing the display element characterisation data in a storage device such as a memory.

[0017] The pre-correcting may either be carried out in real-time or off-line.

[0018] The present invention also provides a system for characterising the light-output response, i.e. luminance and/or colour response, of each individual display element of a matrix display, and uses this characterisation to pre-correct the driving signals to that display in order to obtain that pre-determined drive signals to pre-determined display elements generate a pre-determined spatial light-output.

[0019] A system for correction of non-uniformities of light-output, i.e. luminance and/or colour, of display elements in a matrix display is provided. The method comprises a characterising device for generating characterisation data for every individual display element of the matrix display by establishing a non-linear relationship between light-outputs of each display element and the corresponding drive signals, a classifying device for classifying the characterisation data into a pre-set number of categories, the pre-set number of categories being larger than one and smaller than the total number of display elements in the display and the characterisation data of at least two display elements being assigned to one of the categories; and a correction device for pre-correcting, in accordance with the characterisation data in the relevant categories, driving signals to the display elements to obtain that pre-determined drive signals to pre-determined display elements generate a pre-determined spatial light-output of said display elements to thereby display an image. The pre-correction may be such that equivalent drive signals to different display elements generate equivalent luminance behaviour of said display elements. Alternatively, the pre-correction may be so as to obtain a pre-determined non-uniform light-output behaviour of display elements which is different from the first non-uniform light-output behaviour generated by the display elements in the matrix display.

[0020] This may be used to pre-correct for non-uniformities of post-processing systems that are added to the display, such as, but not limited to, optical systems such as lenses in case of projectors, tiled displays, screen magnification lenses, etc.

[0021] The characterising device can take various forms. The purpose of the characterising device is to define the light-output response for each individual display element of the matrix addressed display. The light-output response is a relationship, e.g. under the form of a curve, between a display element's drive signal, and that display element's light-output behaviour. Said light-output behaviour can be caused by any optical process affecting visual light, be it for example, but not limited thereto, reflection, emission, transmission or a combination of said processes, or an electrical process indirectly defining the optical response of the system.

[0022] The characterising device may comprise an image capturing device for generating an image of the display elements of the matrix display. The image capturing device may comprise for example a scanner, a camera, a CCD or photodiode, with adequate spatial resolution compared to the spatial resolution of the matrix display that needs to be characterised, in order to identify the individual display elements. Image processing hardware also needs to have enough luminance sensitivity and resolution in order to give a precise quantisation of the light-output emitted by the display elements. The image capturing device allows to capture images from the individual display elements of the display, and this for a variety of test images. The test images are chosen in a particular way to allow extraction of the light-output response data of display elements later in the process.

[0023] The characterising device may comprise a display element location identifying device for identifying the actual location of individual display elements of the matrix display.

[0024] The characterising device described above delivers various electronic images of arrays of display elements. Algorithms isolate the image of each individual display element and quantitatively assign a light-output value to these pixels.

[0025] If images of various test images are combined, and light-output values of individual display elements are listed in this way, a non-linear light-output response curve of each individual display element can be obtained. As explained before, the light-output response curve will fix the relationship between the light-output of one individual display element as a function of its drive signal. The drive signal can be expressed using any physical quantity giving a relationship with the intensity of the drive applied to the display element. This is technology dependent: it is voltage in case of LCD, and current in case of LED displays. As a generic representation of said physical quantity digital driving level (DDL) may be used, which is proportional to current or voltage drive and is defined by a digital to analog conversion process.

[0026] The actual light-output response curve allows to calculate a drive curve required to obtain a linear light-output response (or any other desired response) of the display element under consideration. The obtained drive curve that will yield a linear and equal response of an individual display element is called the display element characterisation data (PCD) of that display element.

[0027] The PCD of each individual display element may contain a lot of information that, given its format and quantity of data, is not practically applicable for adaptation of the drive signals. A set of algorithms is used to condense or compress the characterisation data so as to be able to store it and use it in real time correction of the drive applied to the display elements.

[0028] From the light-output response curves, said algorithms extract key parameters that define the response of the display elements such as offset, gain, maximum. Another approach is to extract a limited set of (light-output; DDL) points of the light-output response curve that allow a reconstruction of the original light-output response curve. Yet another algorithm will classify the measured light-output response of a display element to a limited set of allowed "typical" display element light-output responses by approximating the actual response with the best matching "typical" response. All algorithms (or a combination of these algorithms) mentioned have in common that the vast amount of display element characterisation data is compressed and prepared to a useable format, called the display element profile map (PPM) which is compatible to real time hardware compensation schemes.

[0029] The PPM is describing the relation between the input and output of the transfer function of the correction device or transformation system. The input to this correction device are the uncorrected drive signals defining the light-output of the display elements. The output are the corrected drive signals to the display elements. The transformation circuit is implemented in hardware and designed such that transformation (e.g. correction) of the drive signals can happen in real time, this is at the pixel frequency of the system under consideration.

[0030] For a good understanding, it is remarked that only the transformation of the display element drive signals described in the previous paragraph needs to happen in real time. All other processes described (image capturing, defining the PCD and PPM) can happen "off-line" in a non real time fashion using infactory methods.

[0031] The characterising device may comprise a light-output value assigning device for assigning one light-output value to each display element of the matrix display.

[0032] The present invention furthermore provides a matrix display device for displaying an image. The device comprises: a plurality of display elements, a memory for storing characterisation data for every individual display element of the matrix display, the characterisation data representing a relationship between light-outputs of a display element and its corresponding drive signals, the characterisation data being divided into a pre-set number of categories, the number of categories being less than the number of display elements in the matrix display and greater than one and the characterisation data of at least two display elements being assigned to one of the categories; and a correction device for pre-correcting, in accordance with the characterisation data of the relevant categories, driving signals to the display elements so as to obtain a pre-determined spatial light-output of the display elements. The correction device may be such that at least one drive signal to at least two different display elements generates equivalent luminance behaviour of said two different display elements to thereby display an image. Alternatively, if the non-uniformities of the display elements in the matrix display generate a first non-uniform light-output behaviour of the display elements, the pre-correction may be so as to obtain a second pre-determined non-uniform light-output behaviour of display elements different from the first pre-determined non-uniform light-output behaviour.

[0033] The present invention also provides a control unit for use with a system for correction of non-uniformities of light-output of display elements of a matrix display for displaying an image, the matrix display device comprising a plurality of display elements. The control unit comprises a memory for storing characterisation data for every individual display element of the matrix display, the characterisation data representing a non-linear relationship between light-outputs of a display element and its corresponding drive signals, the characterisation data being divided into a pre-set number of categories, the number of categories being less than the number of display elements in the matrix display and greater than one and the characterisation data of at least two display elements being assigned to one of the categories. The control unit also comprises means for pre-correcting, in accordance with the characterisation data of the relevant categories, driving signals to the display elements so as to obtain a pre-determined spatial light-output of the display elements. The pre-determined spatial light-output may be such that at least one drive signal to at least two different display elements generates equivalent light-output behaviour of said two different display elements. Alternatively, if the non-uniformities of the display elements in the matrix display generate a first non-uniform light-output behaviour of the display elements, the pre-determined spatial light-output may be such that a second pre-determined non-uniform light-output behaviour of display elements different from the first pre-determined non-uniform light-output behaviour is obtained.

[0034] The present invention furthermore provides a computer program product for executing any of the methods of the present invention when executed on a computing device associated with a system for correction of non-uniformities of luminance of display elements in a matrix display. The present invention also provides a machine readable data storage device storing the computer program product of the present invention. The present invention also provides transmission of the computer program product of the present invention over a local or wide area telecommunications network.

[0035] These and other characteristics, features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. This description is given for the sake of example only, without limiting the scope of the invention. The reference figures quoted below refer to the attached drawings.

Brief description of the drawings

[0036]

Fig. 1 illustrates a matrix display having greyscale pixels with equal luminance.

Fig. 2 illustrates a matrix display having greyscale pixels with unequal luminance

Fig. 3 illustrates a greyscale LCD based matrix display having unequal luminance in subpixels.

Fig. 4 illustrates a first embodiment of an image capturing device, the image capturing device comprising a flatbed scanner.

Fig. 5 illustrates a second embodiment of an image capturing device, the image capturing device comprising a CCD camera and a movement device.

Fig. 6 schematically illustrates an embodiment of an algorithm to identify matrix display pixel locations.

Fig. 7 shows an example of a luminance response curve of an individual pixel, the curve being constructed using eleven characterisation points.

Fig. 8 is a block-schematic diagram of signal transformation according to the present invention.

Fig. 9 illustrates the signal transformation of the diagram of Fig. 8.

Fig. 10 is a graph showing different examples of pixel response curves.

Fig. 11 illustrates an embodiment of a correction circuit.

[0037] In the different figures, the same reference figures refer to the same or analogous elements.

Description of illustrative embodiments

[0038] The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. Where the term "comprising" is used in the present description and claims, it does not exclude other elements or steps.

[0039] In the present description, the terms "horizontal" and "vertical" are used to provide a co-ordinate system and for ease of explanation only. They do not need to, but may, refer to an actual physical direction of the device.

[0040] A matrix addressed display comprises individual display elements. In the present description, the term "display elements" is to be understood to comprise any form of element which emits light or through which light is passed or from which light is reflected. A display element may therefore be an individually adressable el-

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase®
Smarter legal research.