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(71) **Demandeur/Applicant:**
IGNIS INNOVATION INC., CA

(72) **Inventeur/Inventor:**
CHAJI, GHOLAMREZA, CA

(74) **Agent:** MARKS & CLERK

(54) **Titre : DISPOSITIF DE RETROACTION OPTIQUE**
(54) **Title: OPTICAL FEEDBACK SYSTEM**

(57) **Abrégé/Abstract:**

What is disclosed are systems and methods of optical feedback for pixel identification, evaluation, and calibration for active matrix light emitting diode device (AMOLED) and other emissive displays. Optical feedback is utilized to calibrate pixel whose output luminance exceeds a threshold difference from a reference value, and may include the use of sparse pixel activation to ensure pixel identification and luminance measurement, as well as a coarse calibration procedure for programming the starting calibration data for a fine calibration stage.

ABSTRACT

What is disclosed are systems and methods of optical feedback for pixel identification, evaluation, and calibration for active matrix light emitting diode device (AMOLED) and other emissive displays. Optical feedback is utilized to calibrate pixel whose output luminance exceeds a threshold difference from a reference value, and may include the use of sparse pixel activation to ensure pixel identification and luminance measurement, as well as a coarse calibration procedure for programming the starting calibration data for a fine calibration stage.

IGNIS
Innovation Inc.

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OPTICAL FEEDBACK SYSTEM

REZA CHAJI

Revision: 1.0

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1. Introduction

The challenge with optical feedback system is the pixel level correction. Also, if the non-uniformity in the system is high each pixel will have significantly different point in the input-output response curve which will results in significantly different propagation error in the extracted input-output curve based on the measurement points.

This invention is to address the two issues.

2. Optical Feedback System

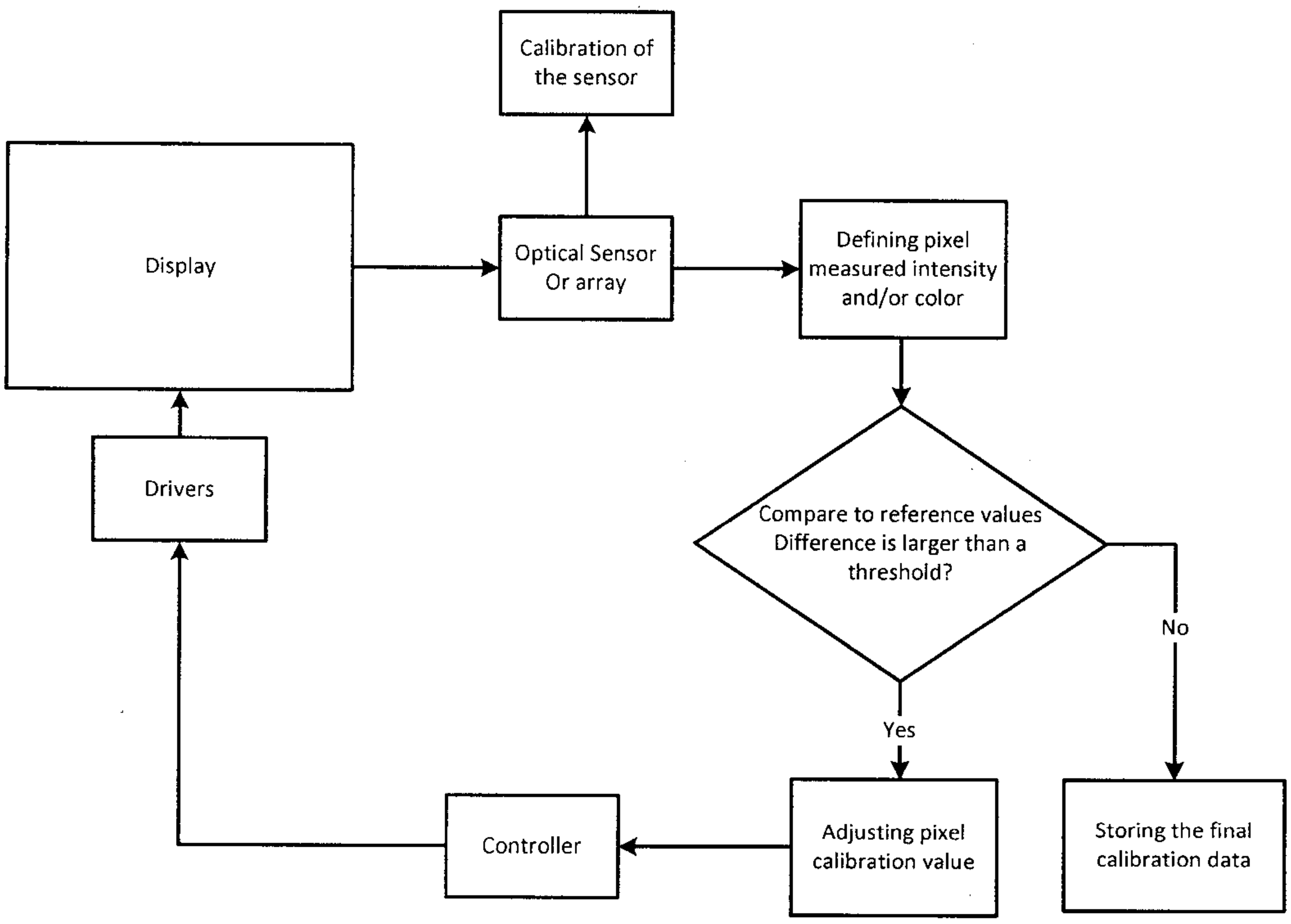

Figure 1: system block diagram.

Figure 1 shows an example of optical system block diagram. Here, after the sensor (or array of sensors) is calibrated, the image is taken from the display. A processing block identifies the pixels in the display and extracts the value of each pixel from the image. Then the value of each pixel (or sub-pixel) is compared with a reference value. If the difference is less than a threshold, the data for that pixel is stored. If not, a processing block adjusts the calibration value for each pixel based on the measured data. Then a controller that control the entire process and the display, program the display with new calibrated data. And the process continues till the number of pixels that their values are different from the reference value is smaller than a predefined threshold.

In another case, a block diagram can be added to the system for identifying the defective pixels for eliminating them from the calibration process. This block can be added at the beginning outside the calibration loop or inside the calibration loop. If it is outside calibration loop, few measurements are done to identify the pixels that do not response to change to the data. If the defective pixel block is inside the calibration loop, the defective pixel list gets updated as the system identify the pixels that do not response to change in the calibration values.

3. Pixel Identification

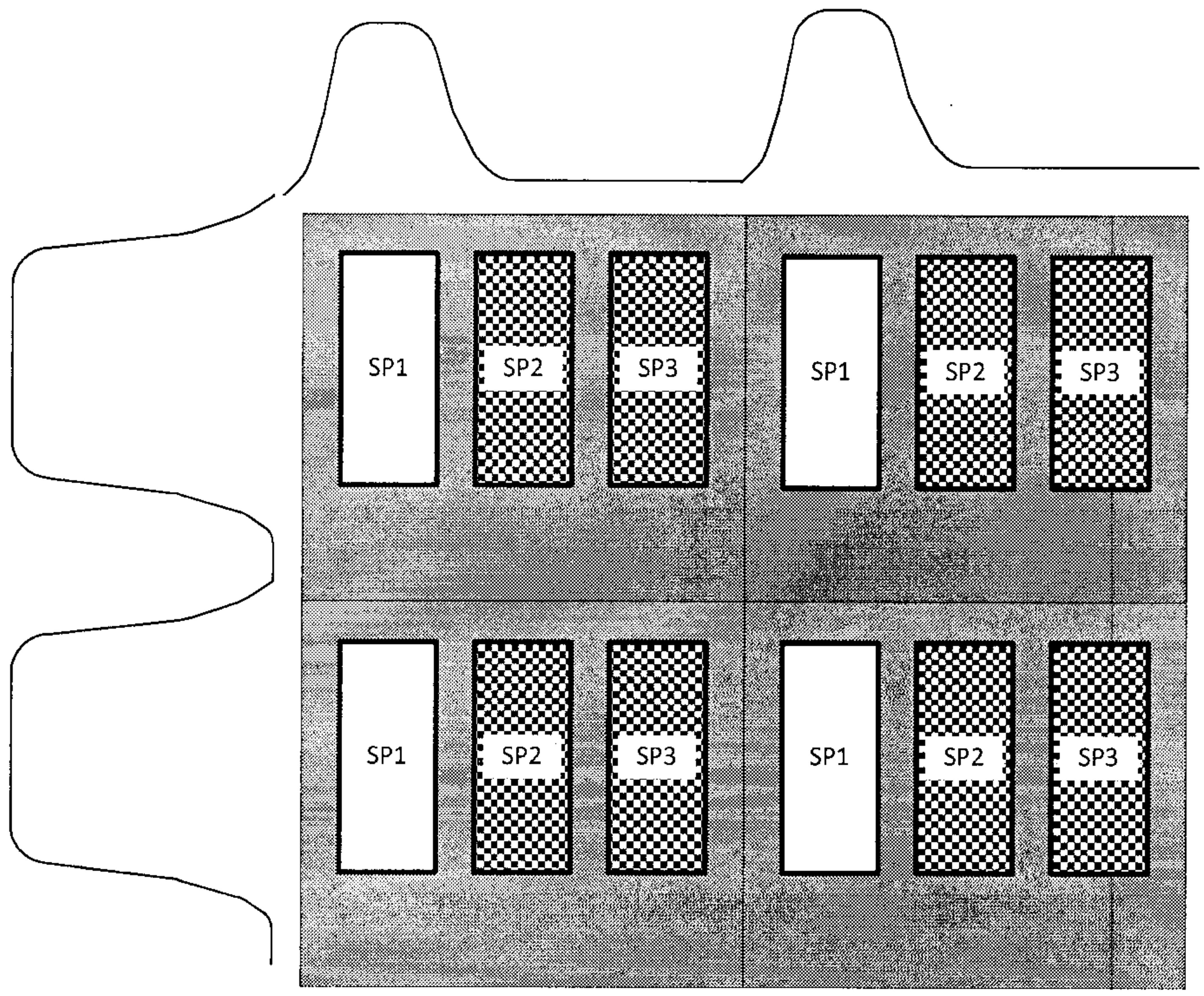

Figure 2: Using black space between sub-pixels to identify each sub-pixel.

To extract the value of each display pixel, one can use the profile in the image. The image will have black areas between each pixel (sub-pixel) and the different between the black area and the pixel can be used to identify the pixel area. The main challenge with this is the edges are blue and the pixels are too close for high resolution displays.

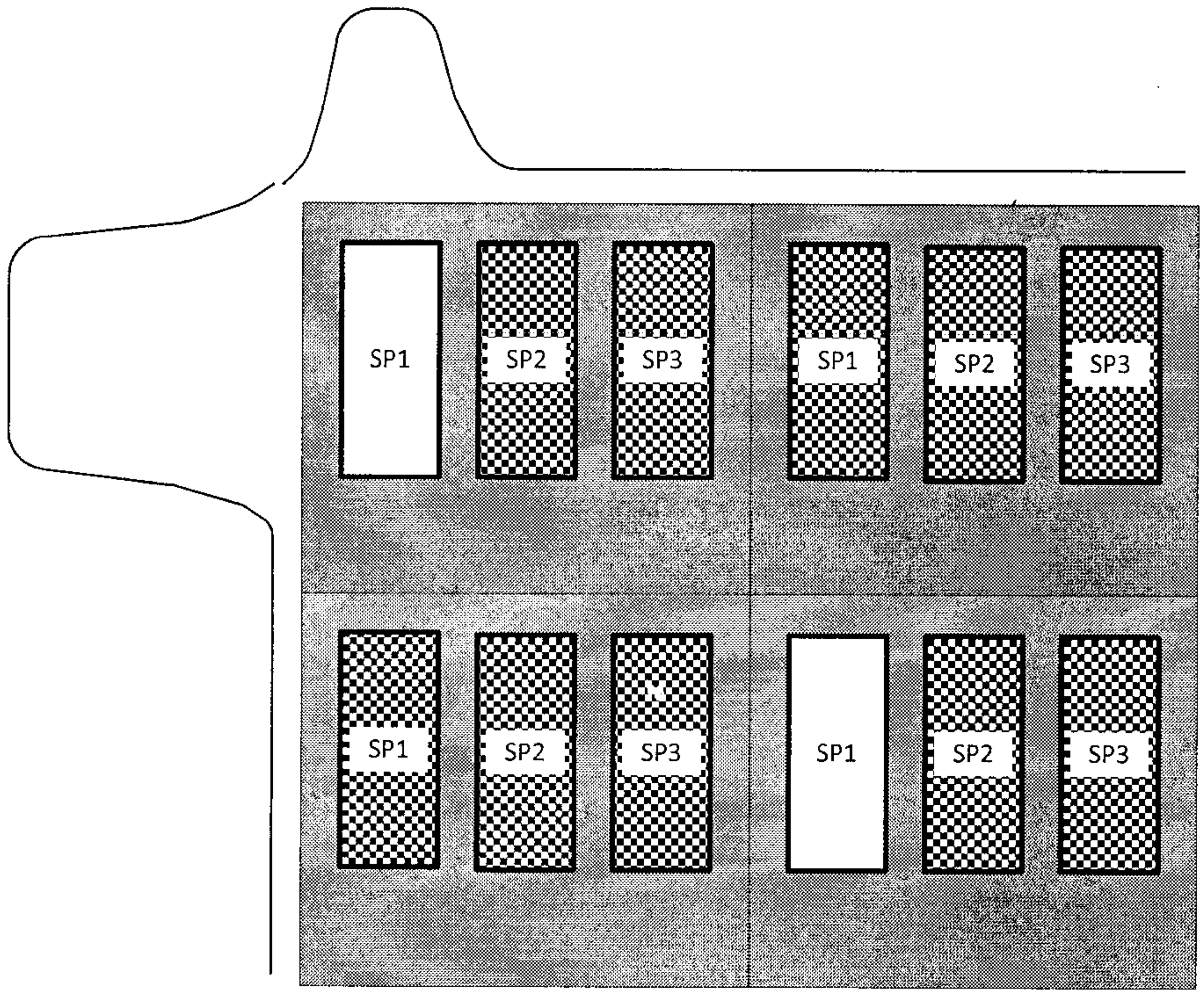

Figure 3: turning off few pixels between the active pixels in the feedback system for easy detection of each pixel (or sub-pixel).

Figure 3 shows another example of extending the black area by turning on only few pixels for each calibration loop. This will make identifying the pixels (sub-pixel) much easier. However, the calibration time will increase since one need to repeat the calibration loop for different pixels at different time.

Figure 4 uses multiple channels for measuring each sub-pixel in different channel. This will increase the black area between the sub-pixels while enables measuring multiple sub-pixels in parallel.

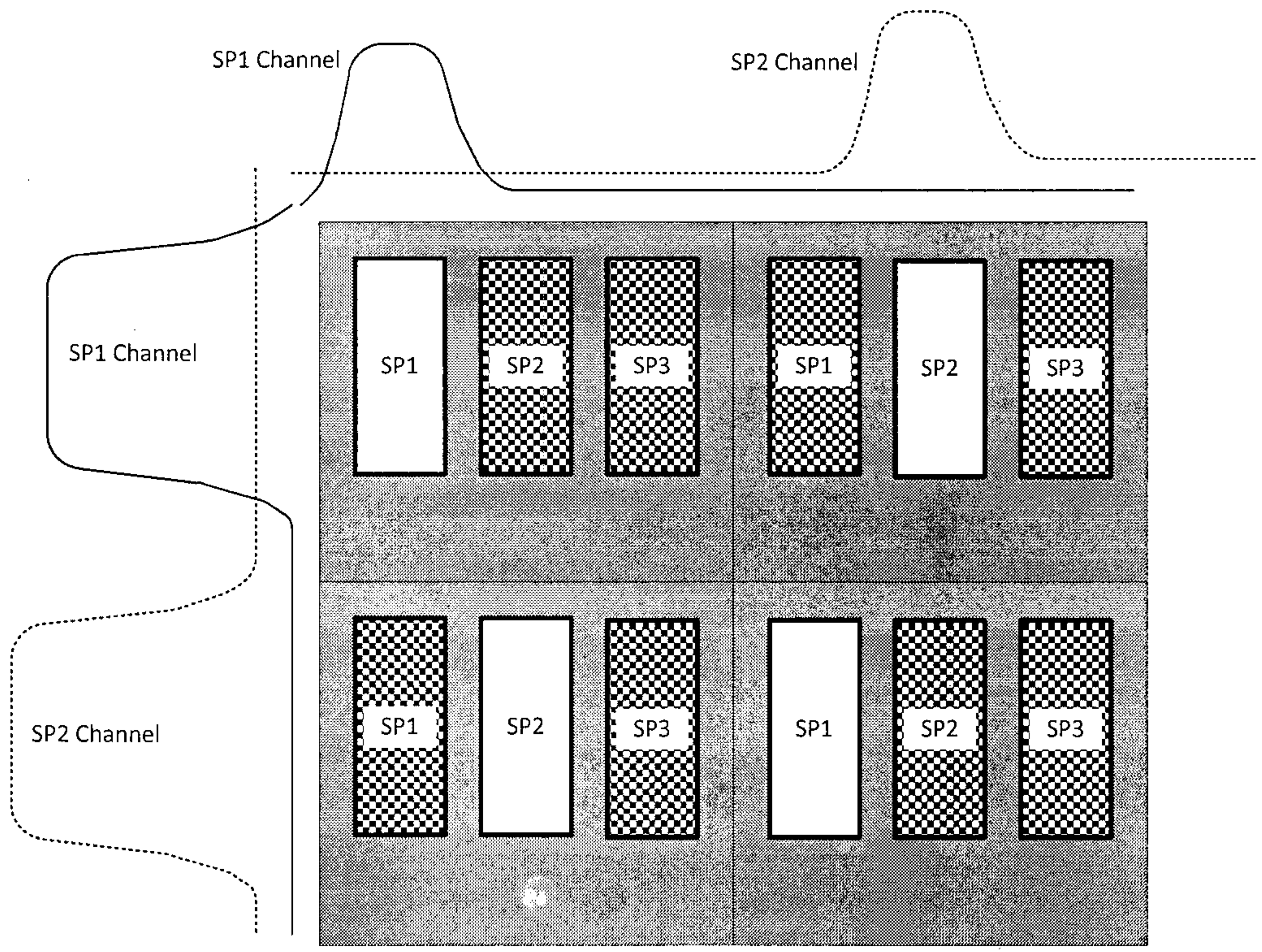

Figure 4: Using alternating sub-pixels and different optical feedback channel for increasing the optical feedback speed while enabling the pixel detection in each channel.

4. Data Calibration process

Figure 5 shows a method of calibrating the data for each pixel. Here, the dead pixels are identified first. Then at least one pixel is programmed with a value that higher than black level. The picture is taken from the display (the sensor and/or imager need to be calibrated before). The picture is fixed for the anomalies such as the sensor calibration curve. After that one or combination of the methods mentioned above (or different methods) is used to identify the pixels (sub-pixels). From the picture and the pixel profile, the value of each pixel is extracted. The values are compared with a reference value. If the number of the pixels that their values are not close the reference value is more than a threshold, each pixel programming value is calibrated based on the pixel value and previous pixel programming value. And the feedback loop continues till most of the pixels (excluding defective pixels) have values close to the reference value.

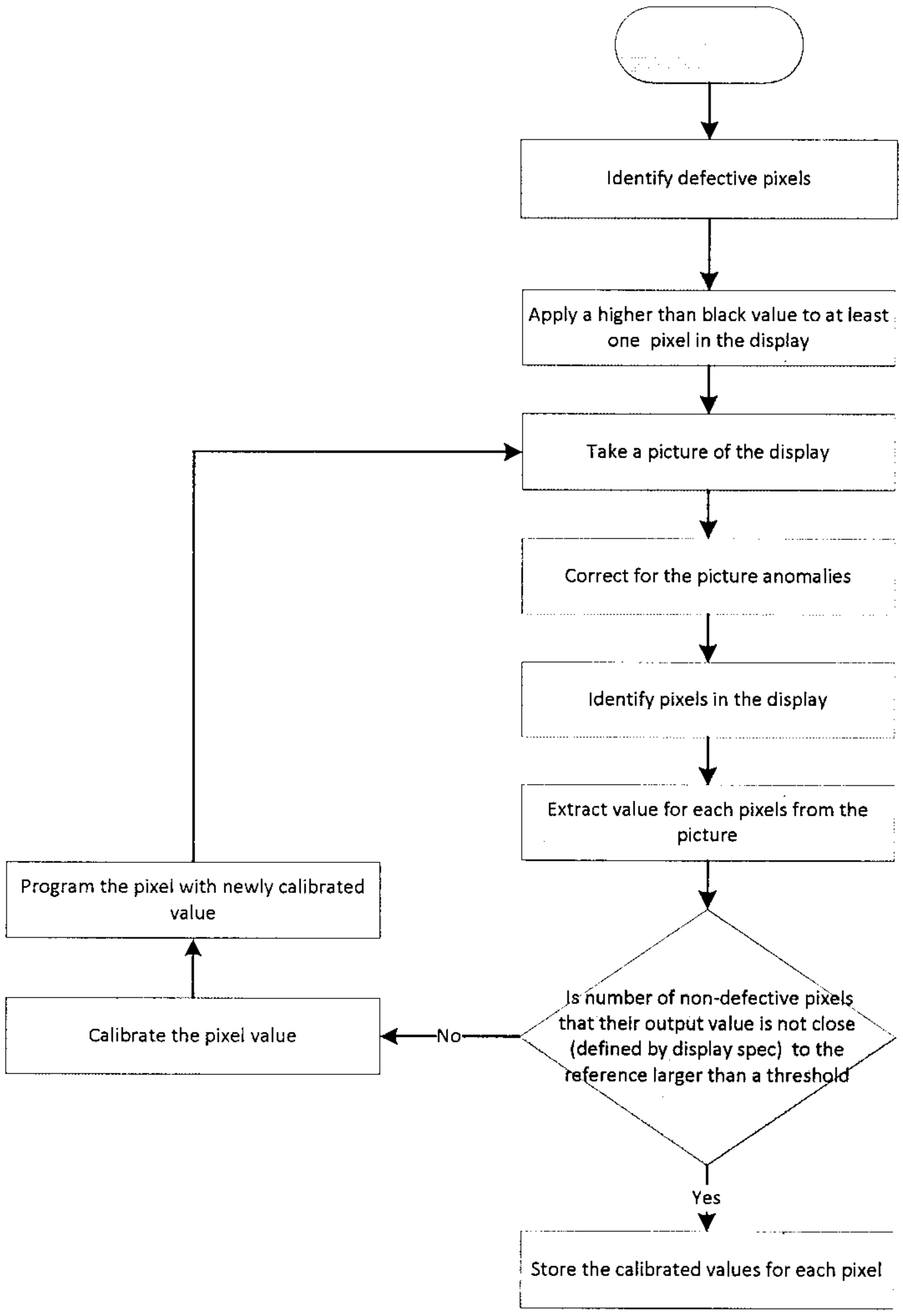

Figure 5: Data calibration to tune each measurement

The method of Figure 6 is similar to that of Figure 5. The only difference is the way the defective pixels are identified. Here the response to the programming voltage in the feedback loop is used to identify the defective pixel. It is easy to combine the two methods of the identifying defective pixels in one. Also, block (step) identifying the defective pixels can be placed in different places in the feedback loop.

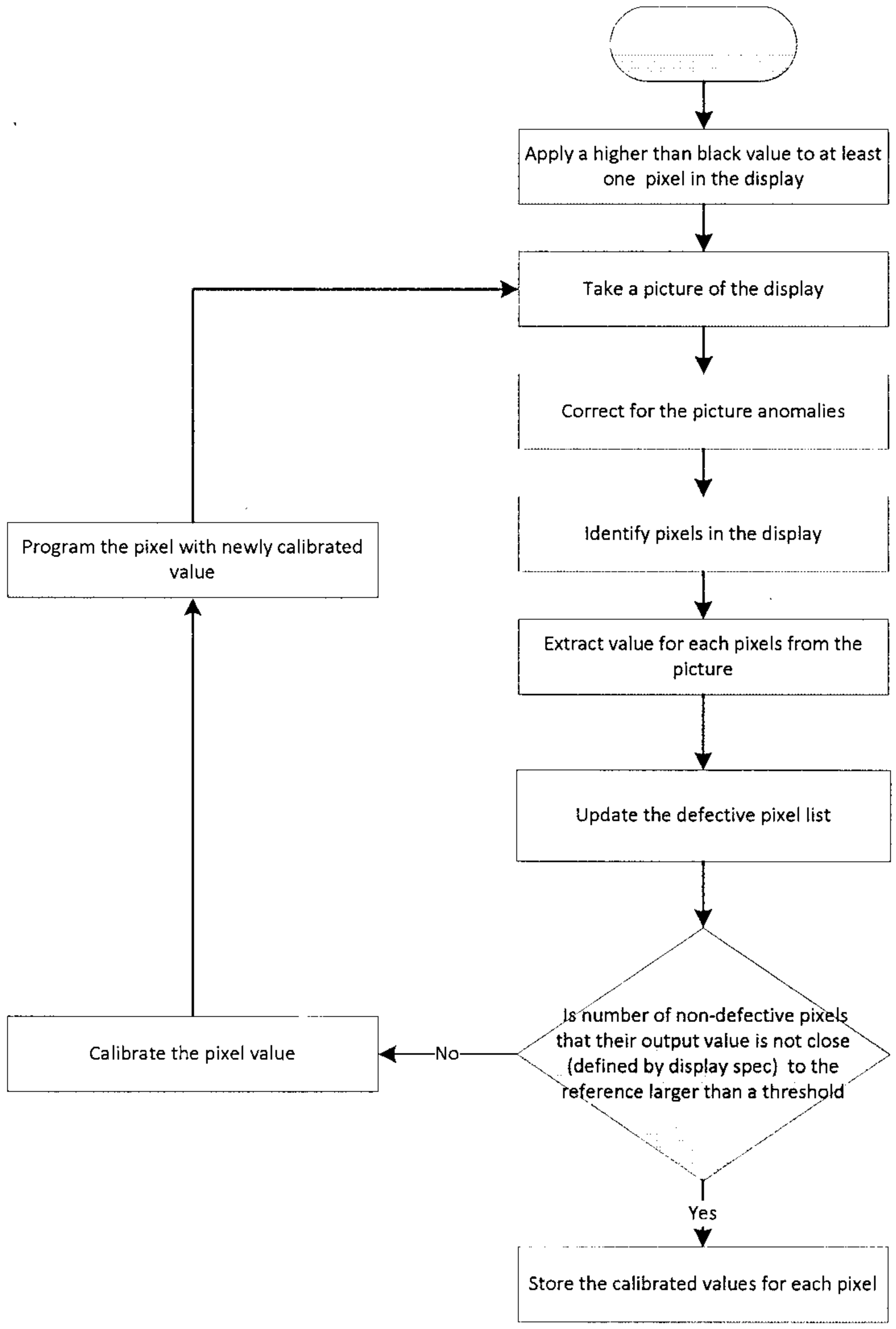

Figure 6: Another embodiment for data calibration to tune each measurement.

Figure 7, shows a method to accelerate the calibration of the pixel programming value. Here, first a course correction (calibration) is done first. During course calibration, two (or more) pictures of the pixels programmed with different values during each picture are taken. From the pictures a course input-output characteristic is extracted for each pixel. Then, a programming value for the intended pixels for calibration is calculated based on the in-out characteristic and a given reference output value. After that the display is programmed with the calculated values. A picture is taken from the display and the pixel values are extracted after identifying pixels. Then, the pixels' programming values are calibrated till most of the pixels (except the defective one) have close value to reference value. One can use the course curve to find the amount or the direction of the fine tuning in the feedback loop.

Since the display is measured before the feedback loop, one can use those values to identify the defective pixels prior to the feedback loop. However, these steps can be integrated in the feedback loop as well.

5. General terms

1) One can combined different methods to optimize the speed and performance of the calibration.
2) One can change the order of the steps in calibration if it does not affect the calibration process.
3) One can identify the pixel positions using a method describe in this document for one sample (can be a reference sample) and then use that template as pixilation for other pixels. In this case, one may use alignment step prior to taking picture. Here, showing some pattern in the panel along with the pictures can be used to align the stage.
4) The examples here are for description and one can easily expand the methods to different examples such as different pixel combination (RGBW, RGBG, etc.)
5) One can mix the examples here to create a new solution.

WHAT IS CLAIMED IS:

1. An optical feedback method for calibrating an emissive display system having pixels, each pixel having a light-emitting device, the method comprising:

iteratively performing a calibration loop until a number of pixels of the display determined to be uncalibrated is less than a threshold number of pixels, the calibration loop comprising:

measuring the luminance of pixels of the display generating luminance measurements for each pixel;

comparing luminance measurements for the pixels with reference values generating a difference value for each pixel measured;

determining for each pixel whether the difference value exceeds a difference threshold, and for pixels having a difference value which does not exceed the difference threshold determining the pixel to be calibrated and storing currently used calibration data for the pixel as final calibration data for the pixel, and for pixels having a difference value which exceeds the difference threshold determining the pixel to be uncalibrated and adjusting the calibration data for the pixel with use of the luminance measurement for the pixel and the previous calibration data for the pixel; and

programming each pixel whose calibration data was adjusted with the adjusted calibration data.

2. The method of claim 1 wherein measuring the luminance of pixels of the display comprises identifying the pixels of the display comprising:

activating at least one pixel of the display for luminance measurement;

generating a luminance measurement image of the pixels of the display after activating the at least one pixel;

identifying pixels of the display from the variation in luminance in the luminance measurement image; and

extracting luminance data for each pixel identified at a position within the luminance measurement image with use of the luminance data along at least one luminance profile passing through the position within the luminance measurement image to generate said luminance measurement for said pixel.

3. The method of claim 2 wherein activating the at least one pixel of the display comprises activating a sparse pixel pattern wherein between any two pixels activated for luminance measurement there is at least on pixel which is inactive, thereby providing luminance measurement data corresponding to a black area between the two pixels along the at least one luminance profile.

4. The method of claim 2 wherein activating the number of pixels of the display comprises activating a multichannel sparse pixel pattern wherein more than one channel of pixels is activated simultaneously and between any two pixels activated of any channel for luminance measurement there is at least on pixel of that channel which is inactive, thereby providing a luminance measurement data corresponding to a black area of that channel between the two pixels along the at least one luminance profile.

5. The method of claim 2, further comprising:

identifying defective pixels unresponsive to changes in calibration data for the defective pixels;

correcting the luminance measurement image after generated for anomalies; and

calibrating an optical sensor used for measuring the luminance of pixels of the display prior to measuring the luminance of pixels of the display.

6. The method of claim 3, further comprising:

identifying defective pixels unresponsive to changes in calibration data for the defective pixels;

correcting the luminance measurement image after generated for anomalies; and

calibrating an optical sensor used for measuring the luminance of pixels of the display prior to measuring the luminance of pixels of the display.

7. The method of claim 4, further comprising:

identifying defective pixels unresponsive to changes in calibration data for the defective pixels;

correcting the luminance measurement image after generated for anomalies; and

calibrating an optical sensor used for measuring the luminance of pixels of the display prior to measuring the luminance of pixels of the display.

8. The method of claim 1 further comprising:

prior to iteratively performing the calibration loop:

programming each of the pixels of the display with at least two unique values;

measuring the luminance of the pixels corresponding to each programmed unique value, generating coarse input-output characteristics for each pixel;

generating calibration data for each pixel based on the coarse input-output characteristics for each pixel; and

programming each of the pixels of the display with the calibration data for the pixel.

9. The method of claim 3 further comprising:

prior to iteratively performing the calibration loop:

programming each of the pixels of the display with at least two unique values;

measuring the luminance of the pixels corresponding to each programmed unique value, generating coarse input-output characteristics for each pixel;

generating calibration data for each pixel based on the coarse input-output characteristics for each pixel; and

programming each of the pixels of the display with the calibration data for the pixel.

10. The method of claim 9 further comprising:

identifying defective pixels unresponsive to changes in calibration data for the defective pixels;

correcting the luminance measurement image after generated for anomalies; and calibrating an optical sensor used for measuring the luminance of pixels of the display prior to measuring the luminance of pixels of the display.

11. An optical feedback system for calibrating an emissive display system having pixels, each pixel having a light-emitting device, the system comprising:

a display panel comprising said pixels;

an optical sensor operative to measure luminance of pixels of the display panel;

optical feedback processing coupled to the optical sensor; and

a controller of the emissive display system coupled to said optical feedback processing and for iteratively controlling a calibration loop until a number of pixels of the display panel determined to be uncalibrated is less than a threshold number of pixels, iteratively controlling the calibration loop comprising:

controlling the optical sensor and the optical feedback processing to measure the luminance of pixels of the display panel generating luminance measurements for each pixel;

controlling the optical feedback processing to compare luminance measurements for the pixels with reference values generating a difference value for each pixel measured;

controlling the optical feedback processing to determine for each pixel whether the difference value exceeds a difference threshold, and for pixels having a difference value which does not exceed the difference threshold to determine the pixel to be calibrated and store currently used calibration data for the pixel as final calibration data for the pixel, and for pixels having a difference value which exceeds the difference threshold to determine the pixel to be uncalibrated and adjust the calibration data for the pixel with use of the luminance measurement for the pixel and the previous calibration data for the pixel; and

programming each pixel whose calibration data was adjusted with the adjusted calibration data.

12. The system of claim 11 wherein the controller's controlling of the optical sensor and the optical feedback processing to measure the luminance of pixels of the display panel comprises controlling identification of the pixels of the display panel comprising:

activating at least one pixel of the display panel for luminance measurement;

controlling the optical sensor and optical feedback processing to generate a luminance measurement image of the pixels of the display panel after activating the at least one pixel;

controlling the optical feedback processing to identify pixels of the display panel from the variation in luminance in the luminance measurement image; and

controlling the optical feedback processing to extract luminance data for each pixel identified at a position within the luminance measurement image with use of the luminance data along at least one luminance profile passing through the position within the luminance measurement image to generate said luminance measurement for said pixel.

13. The system of claim 12 wherein the controller's activating the at least one pixel of the display comprises activating a sparse pixel pattern wherein between any two pixels activated for luminance measurement there is at least on pixel which is inactive, thereby providing luminance measurement data corresponding to a black area between the two pixels along the at least one luminance profile.

14. The system of claim 12 wherein the controller's activating the number of pixels of the display comprises activating a multichannel sparse pixel pattern wherein more than one channel of pixels is activated simultaneously and between any two pixels activated of any channel for luminance measurement there is at least on pixel of that channel which is inactive, thereby providing a luminance measurement data corresponding to a black area of that channel between the two pixels along the at least one luminance profile.

15. The system of claim 12, wherein the optical sensor is calibrated prior being used for measuring the luminance of pixels of the display, and wherein the controller is further for:

controlling the optical feedback processing to identify defective pixels unresponsive to changes in calibration data for the defective pixels; and controlling the optical feedback processing to correct the luminance measurement image after generated for anomalies.

16. The system of claim 13, wherein the optical sensor is calibrated prior being used for measuring the luminance of pixels of the display, and wherein the controller is further for:

controlling the optical feedback processing to identify defective pixels unresponsive to changes in calibration data for the defective pixels; and

controlling the optical feedback processing to correct the luminance measurement image after generated for anomalies.

17. The system of claim 14, wherein the optical sensor is calibrated prior being used for measuring the luminance of pixels of the display, and wherein the controller is further for:

controlling the optical feedback processing to identify defective pixels unresponsive to changes in calibration data for the defective pixels; and

controlling the optical feedback processing to correct for anomalies the luminance measurement image after generated.

18. The system of claim 11, wherein the controller is further for prior to iteratively performing the calibration loop:

programming each of the pixels of the display with at least two unique values;

controlling the optical sensor and the optical feedback processing to measure the luminance of the pixels corresponding to each programmed unique value, to generate coarse input-output characteristics for each pixel;

generating calibration data for each pixel based on the coarse input-output characteristics for each pixel; and

programming each of the pixels of the display with the calibration data for the pixel.

19. The system of claim 13, wherein the controller is further for prior to iteratively performing the calibration loop:

programming each of the pixels of the display with at least two unique values;

controlling the optical sensor and the optical feedback processing to measure the luminance of the pixels corresponding to each programmed unique value, to generate coarse input-output characteristics for each pixel;

generating calibration data for each pixel based on the coarse input-output characteristics for each pixel; and

programming each of the pixels of the display with the calibration data for the pixel.

20. The system of claim 19, wherein the optical sensor is calibrated prior being used for measuring the luminance of pixels of the display, and wherein the controller is further for:

controlling the optical feedback processing to identify defective pixels unresponsive to changes in calibration data for the defective pixels; and

controlling the optical feedback processing to correct for anomalies the luminance measurement image after generated.

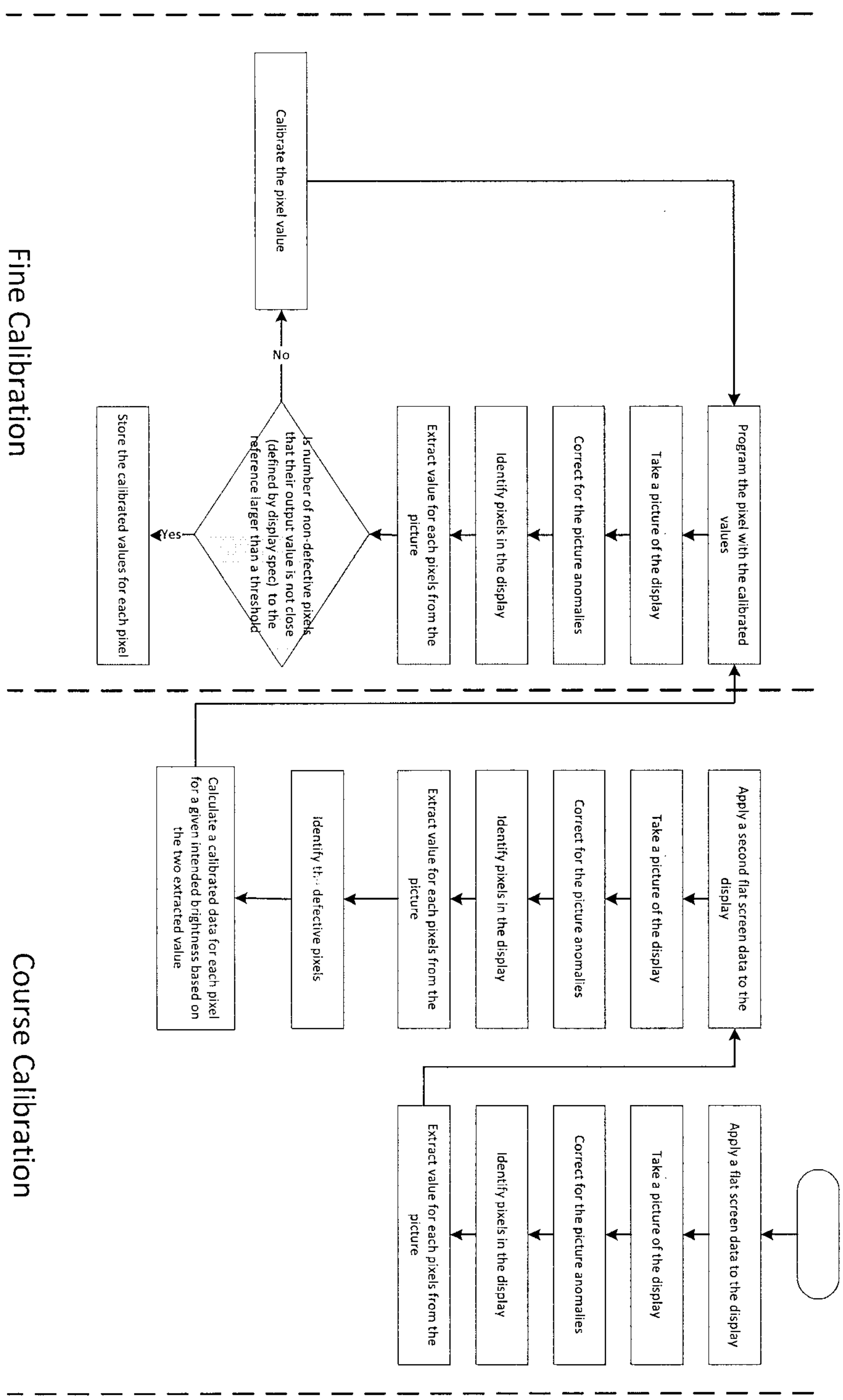

Figure 7: Another embodiment of data calibration for tuning each measurement