Robustness of automated mura inspection versus measurement conditions

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Abstract

Mura inspection of LCD panels using 2D luminance meters is a difficult task because it must compete with the human eye's sensitivity. In the present paper, we use a Mura generator system in conjunction with a high quality 2D luminance meter to simulate and measure different types of Mura defects in variable conditions. The influence of various measurement conditions like background signal or tilt angle is examined and the limits of the automated detection is demonstrated. We show that a high sensitivity and high resolution luminance meter is capable to detect the great majority of mura defects that we have simulated. The experimental conditions necessary for quality control without performance degradation have been also defined.

1. Introduction

The large extension of the LCD TV market requires improvements of the performance measurements and quality control of the panels directly at the end of the production facility. Up to now, measurements of a large variety of specifications such as luminance, chromaticity or viewing angle is already made using automated instruments. However, local non uniformities on LCD called Mura are still evaluated by human operator. Automated Mura detection and quantification is facing two major problems. First the quality of the measurements using 2D luminance meters must be comparable to the human eyes sensitivity, must be compatible with on line quality control and must not introduce additional artifacts independent of the panels. First the quality of the measurements using 2D luminance meters is mandatory; to be compatible with on line quality control it must be comparable to the human eyes sensitivity without introducing additional artifacts independent of the panels. Second, the great variety of Mura defects in different shapes, size and sharpness makes necessary a very efficient automated detection and quantification. Recently ELDIM has proposed a complete solution for Mura detection and quantification[1-2]. It includes the use of a high quality luminance meter to take the images and the analysis using different types of numerical algorithms included in the same software. The great majority of mura defects can be detected and quantified by standard SEMI[3] or customer proprietary rules. In the present paper we propose to evaluate the sensitivity of ELDIM solution using a Mura generator system recently developed by AUO corporation[4].

2. Description of the technique

The mura generator system consists of a SXGA-LCD panel, a personal computer, an adapter and a power supply.

2.1 Panel settings

The circuit design of LCD panel results in the changed gamma curve, which leads to a lot of gradations from 10 to 50 cd/m^2 . So it can show very small luminance variations in 10~50 Cd/m^2 to simulate low contrasted mura defects. Moreover the gamma has been set to 1 so as to make the luminance vary linearly with the grey level. A summary of these settings is presented in figure 1.

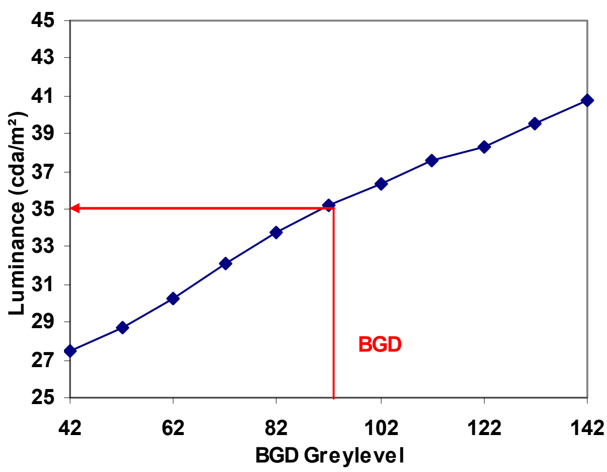

Fig. 1: This curve shows the luminance range and linearity behavior versus grey level of the re-worked mura generator system.

2.2 Mura generator

In the following results, the background level of the panel has been fixed to 92 gradations which results in about 35 Cd/m^2. Different types of defects have been investigated: blob and line, with very sharp or Gaussian frontiers, with different size…. Some examples are presented in figure 2.

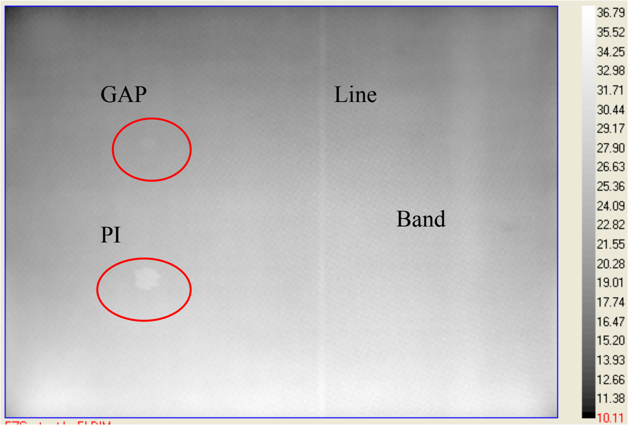

Fig. 2: Four families of defects are presented in white state: PI, GAP, line and band.

In the following we show results from the two major families: gap and line defects. Gap defects are blob defects with Gaussian profile. They are the most difficult to detect – all except the particle defects that require a special treatment-. Experiments have been led for 2 different sizes: 1/30 (named "Gap30") of the panel size and 1/120 of the panel size (named "Gap120") One example of GAP120 defects, with decreasing intensity, is reported in figure 3. The Mura generator has also a real Mura defect that appear on all the acquisitions superposed to the simulated defects.
Line defects have been also used with several pixels width and a Gaussian profile.

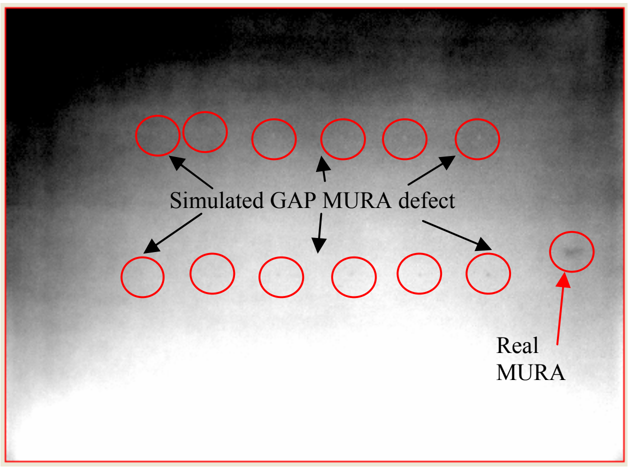

Fig. 3: GAP 120 defects of decreasing contrast and the real GAP defect.

2.3 The acquisition

2D luminance measurements are made with the ELDIM MURATest instrument. Its high quality optics ensures large optical MTF with low distortion/aberration. Furthermore, its -25°C cooled Kodak CCD sensor with 16bits A/D converter and dark current compensation ensures low noise and high dynamic range. The EZMURA software makes the measurement and then performs the analysis specified in a recipe in a completely automated way. After windowing the working area in the image, it can remove the Moiré pattern and go through a set of detection and quantification algorithms that each focus on a given kind of Mura defect. A maximum defect level customized by user can be defined for each algorithm to come directly to a final pass/fail panel assessment.

2.4 The MURA quantification

The following results have been obtained with the SEMI formula for MURA quantification (recalled below). The SEMI standard has been normalized so that 1 SEMU represents a just noticeable defect from an ergonomic viewing distance. For a fixed background with the panel described above, the MURA intensity of defect is then expected to vary linearly with the difference in grey level between the defect and the background.

SEMI D31-1102 :.

$$SEMU = \frac{\frac{\sum_{i \in blob}(I_i - BGD)}{BGD}}{\frac{1.97}{S_{blob}^{0.33}} + 0.72}$$

Below is presented an acquisition and the result obtained through EZMURA. The gamma factor and scale have been specially chosen to enhance the defect so as to make them as visible as possible, but the defect contrast is very small. The intensity of the simulated mura defect varies from 0.53 to 0.79 because of local background variations: the lower defect (cross-marked) is the black defect in the darker background.

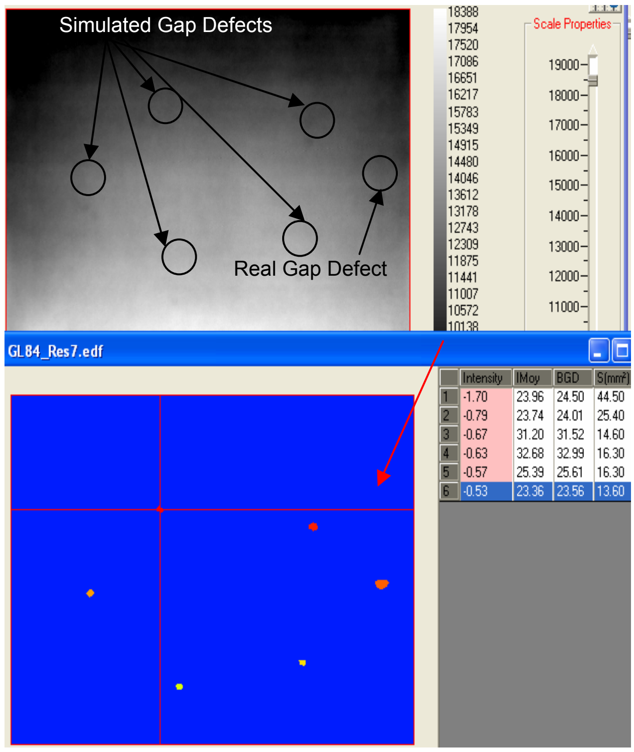

Fig. 4: Image acquired with the MURATest and result for 5 identical simulated GAP30 MURA defects (+ the real one)

3. Results

3.a. *Sensitivity*

The sensitivity of the experimental system has been checked by displaying some mura defects on a fixed background and changing the mura gray level intensity. For gap defects like in figure 4, results are reported in figure 5. After acquisition, each gap defect is automatically detected and its SEMU intensity evaluated. The resulting values versus the defect gray level are reported in the figure 5. As expected, the location of the defect does not much affect its SEMU and the value is proportional to the contrast.

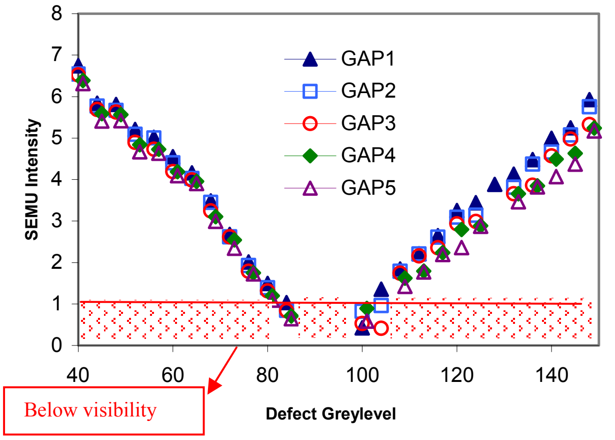

Fig. 5: Measured SEMU of the five gap defects versus defect gray level. The background level is fixed at 92.

Linearity and reproducibility are very good down to 0.5 SEMU which represents a very low intensity defect. The images from figure 4 have been enhanced to make the defects visible for readers. But the SEMI standard has been build so that 1 SEMU is the just noticeable defect. This means that every defect below 1 SEMU is supposed not to be visible by human eyes from an ergonomic viewing distance. The solution is then capable to cover a wide range of MURA defect. The small variations between each curve are linked to local background variations, since the generator panel doesn't have an ideal perfectly flat background. The defects have been checked with a step of 4 grey levels since the pixels of the generator panel are addressed through 6 bits only, the 2 remaining bits being obtained through dithering (=averaging in time) which would have given less secure results. The same kind of result has also been obtained on line defects.

3.b. *Effect of the environmental settings*

3.b.1. Stability in various ambient illumination conditions

One important aspect of the technique is its ability to be used routinely for quality control at the end of the fabrication process. We have examined here after three important aspects of this problem. First, the influence of the ambient illumination has been checked using an additional lighting in our black room and the ambient illumination near the 2D luminance meter has been measured separately. Results are summarized in figure 6 for gap defects (size 1/30) and ambient illumination from 0 to 120 lux. The ambient light has been measured with a photometer both nearby the panel and nearby the luminance-meter. No quantitative influence can be detected: the four trends for the simulated defects are independent of the ambient illumination. As evidence, the bright ambient measurement gives slightly less contrasted result. This can be observed from the 2 real mura (horizontal) trends. This means that the brighter the ambient is, more difficult it will be to detect defects of lower contrast. Fig. 6 shows however that the system remains very accurate, even facing ambient light of 120 lux.

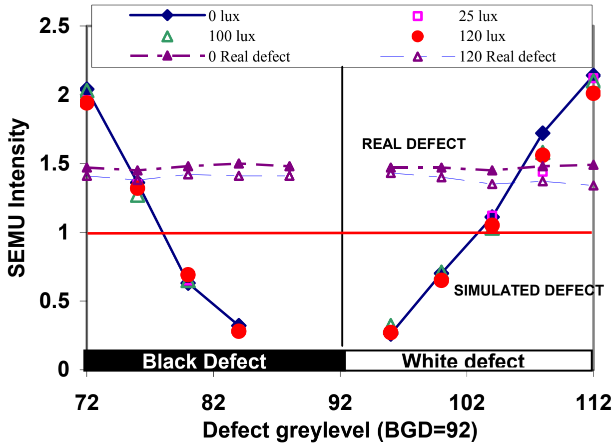

Fig.6: Influence of the ambient illumination near the sensor. The simulated defects are gap defects.

The same kinds of results and conclusions have been obtained for line defects.

3.b.2 Stability versus alignment

A second parameter is the adjustment of the panel or the tilt angle between the luminance meter and the normal of the panel: CCD plane and LCD are no more parallel and the image become trapezoidal. This test aims to check how precise the positioning needs to be. The tilt has been tested up to 6 degree from alignment which is very important. Results are reported in Fig. 7. But here also, no major influence is observed on any kind of defects: each curve remains quite stable.

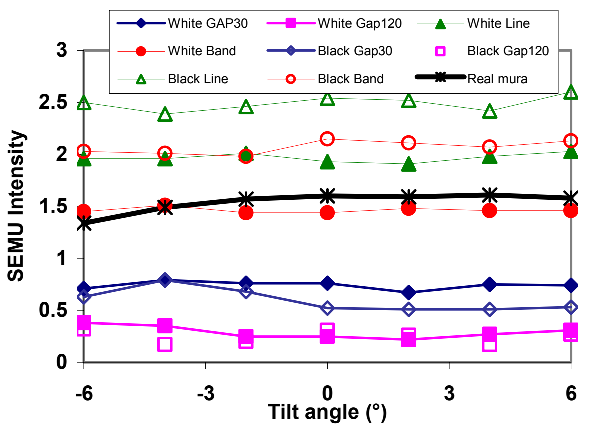

Fig.7. Influence of the luminance meter adjustment. The optical axis of the system is tilted from -6 to +6° from the normal of the panel.

Some Mura defects are almost not visible on axis and can be seen only at much wider angle. It is the case in particular for particle defects (dust defects). They then require a special acquisition, still on axis, but with an external oblique lightening.

3.b.3. Stability versus warm-up time

The last important parameter is the warm-up time influence on the defect detection and quantification. Because of backlight, the LCD luminance is changing after switching-on of the panels. Backlight based on a CCFL has an intensity that is generally increasing until raising temperature stability. The (☐) curve in fig. 8 is the combination of a CCFL warm-up behavior and a driving compensation. The mean luminance of the panel increases rapidly just after switching on the panel and then decreases progressively on a long time scale. As expected from SEMI formula the SEMU value increases while the background decreases. Moreover, the real MURA defect evolves more quickly than the simulated one. This can be explained by the fact that the simulated defect intensity is much more correlated with the background intensity. Derivating the SEMI formula, the theory forecasts that a defect which is perfectly correlated with the background (dI/I=dBGD/BGD) has a constant SEMU value. Acquisition and analysis perfectly follow the theory.

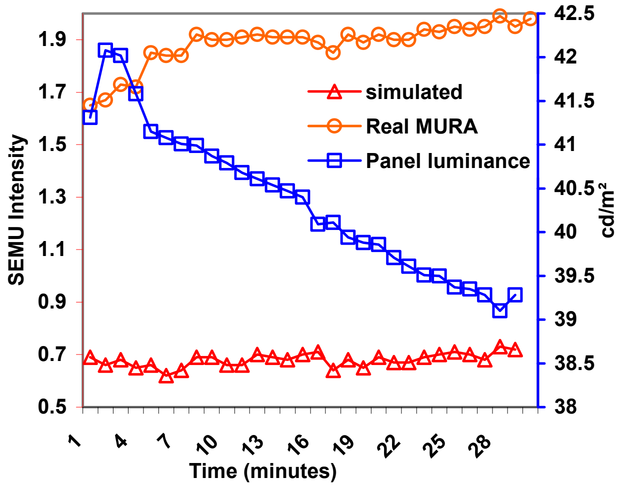

Fig.8. Influence of the warm-up time of the LCD panel on the mean luminance value and SEMU intensity of a gap defect of grey level around 96.

3.c . Photometric considerations

ELDIM MURATest can optionally provides luminance and color data depending on the filters that have been designed for it. Usually a MURATest has 5 filters: two for red, two for green -since the green CIE curve is impossible to fit with accuracy using a single filter- and one for blue. The SEMI standard requires a measurement in luminance, which means through the two green filters. We did some trials with a single from our green filters (the one with the larger bandwidth). The results are presented in fig. 9. It shows that the behavior of the system with a single filter is very close from the one through luminance measurements. Moreover, the result tends to be slightly more contrasted than the one with the 2 filters (☐ curves are in average above the Δ curves).

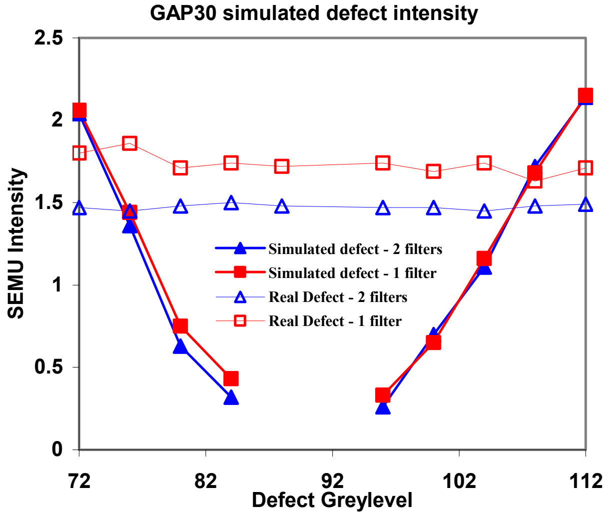

Fig. 9: Influence of the measurement bandwidth on mura quantification of a gap defect (size 1/30)

This means that the system with a single filter is even able to detect lower contrasted defects. From this, it appears that it is possible to turn to single filter measurements without lowering the quality of analysis whereas speed is improved by a factor 2.

This is not a surprise since the SEMI standard is based on a ratio and since the shape of the spectrum of a grey level from an LCD varies in a tiny way with its intensity.

4. Conclusions

An automated method for detection and quantification of mura defects on LCD panels has been used in conjunction with a mura generator system to evaluate the accuracy and repeatability of the system. We have verified that gap or line defects can be accurately detected and quantified even for very small contrasts (below than 2 grey levels of a usual panel and for SEMI quantification below 0.7 SEMU). We have also verified that the measurements are not much sensitive to parasitic illumination, panel warm-up and panel adjustment. All these results show that the method can be adapted to quality control at the end of the manufacturing process.

References

1. V. Gibour, T. Leroux, SID03, P53-3, 2003
2. V. Gibour, P. Boher, Display devices, summer 04, 34, 2004
3. SEMI D31-1102, Definition of measurement index (SEMU) for luminance MURA in FPD image quality inspection
4. J.J. Guo, B.H. Huang, K. Wang, C.. Chen, Development of Mura generator system, Taiwan Display conference, 2004 .