3DTV 2009 IEEE proceedings, ISBN 978-1-4244-4318-5, pp.1-4, 2009

CROSS-TALK MEASUREMENT FOR 3D DISPALAYS

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ABSTRACT

3D displays are coming phenomenon of the nearest future and it is expected that 3D displays will be widely available soon. There are currently some 3D displays available and also some notebooks with 3D display as Sharp AL3D. The viewing position is quite restricted spatially in the case of 3D displays and also the (visual information for the left eye is taken by the right eye and vice versa) causes some severe problems in 3D image perception.

This paper addresses several issues concerning 3D perception based on stereo-images. Another issues related to 3D stereo video perception, like discontinuities between frames etc. are not described here.

Index Terms - 3DTV, 3D image perception, cross-talk, 3D display, human perception, pattern generation.

1. INTRODUCTION

There are some 3D display systems available or under development, a 3D display is a part of Sharp AL3D notebook intended to be used by a single user. During the last period this notebook was used for different kind of activities, especially in the fields of visualization, CAD/CAM/GIS systems etc. Unfortunately in many cases the zone of the proper 3D perception is limited that causes severe problems within some fields of applications, especially in CAD/CAM/GIS systems when a person is performing some activity. On the other hand in the case of visualization, application oriented just for a display, this limitation is not severe. There are some promising approaches, like display developed at Henrich Hertz Institute (HHI) Berlin, when a user position is tracked by a camera and the display corrects the image on a screen so the observer has a correct perception. Nevertheless in the future multiuser 3D displays are to be considered only. Of course, the holography 3D displays seem to be an ultimate solution, but today's technology is not at such level even for experimental construction and use [12]. Also the amount of data transfer is prohibitive. 3D displays based on stereoscopy seems to be a reasonable compromise. Such a display is being developed in the frame of the EU STREPS project MUTED.

In this paper cross-talk test will be described that should help to evaluate quality of 3D displays. The comfort of a user in 3D image perception was tested using static images and video frames as well [8].

2. CROSS-TALK TEST

Let us assume that 3DTV systems are targeted to a situation, when several viewers watch a 3D scene, their position is detected and proper 3D image for each viewer is generated. Such approach is currently explored under many research projects, e.g. EU STREPS MUTED [9].

Cross-talk in stereoscopy is the leaking of image information from the left eye channel to the right eye channel, and vice versa; in other words, being able to see a dim view of the right eye image in the left eye and vice versa. This is one of significant factors causing viewer eye strain. There are other factors, like fixed focus that forces a user to a given viewers position etc. The purpose of the cross-talk test is to determine the level of cross-talk over the display. It means that it is necessary to evaluate several display regions. To measure the cross-talk a new pattern consisting of vertical white stripes on a black background for the left eye, and horizontal white stripes on a black background for the right eye is used.

In the ideal case there will be no cross-talk at all. This means that when viewing a cross-talk free image you would see white vertical stripes via your left eye and white horizontal stripes via your right eye. It also means that the intensity of the left eye image (region A) in right eye image is zero because there are no vertical stripes visible, and the intensity of the right eye image (region B) in left eye image is also zero, as no horizontal stripes are visible.

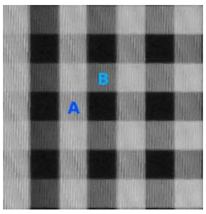

Figure 1

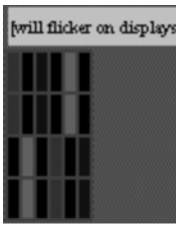

Figure 2

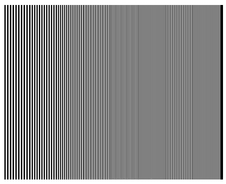

Figure 3

Fig.1 shows a display the cross-talk pattern as viewed by the left eye or the captured image. Note that some cross-talk is present as faint horizontal strips are also visible from the right eye image.

The level of the light of an image (C in the equation below) leaking from the right eye channel to the left eye channel is determined as ratio of intensity of region B (I_B) to intensity of region A (I_A), hence:

$$C_{R\to L} = \frac{I_B}{I_A} \quad (1) \qquad C_{L\to R} = \frac{I_A}{I_B} \quad (2)$$

Calculated ratios $C_{R\to L}$ or $C_{L\to R}$ are finally visualized as region based test, Fig.1.

Also flickering can appear on LCD panels when showing certain images or patterns [10]. Slightly modified test "Line-paired RGB sub-pixel dot-inversion pattern" was used for the flickering test in order to reflect specific Sharp AL3D hardware, see Fig.2.

In the cross-talk test, an ordinary camera was used for image capture, and evaluation was done per a single image.

The flickering frequency depends on the LCD refresh frequency, usually 60Hz, and a high-speed still-image capturing camera is required.

3. APPLICATION ARCHITECTURE

This section describes the architecture of the application for the cross-talk measurement. It is based on display image capture by a digital camera and the captured image is processed by the application.

The application consists of several modules:

- Loader – loads captured images
- Distortion correction – it corrects distortions caused by optics
- Registration – captured and geometrically corrected image is "registered" with the reference position for further processing
- Brightness correction – eliminates lighting conditions in order to enable repetitiveness of experiments
- Testing module – process captured images and display test results

The input to the application is a captured image and a configuration file containing information about the captured image. Application produces a CSV file as an output. In this file parameters of the captured image (such as camera position) and results of appropriate test module (such as cross-talk levels over display) are stored.

Image Loader module loads a captured image into the application in the RAW format to avoid lousy compression artifacts. The RAW image data is then transformed using an appropriate Bayer pattern into a RGB image. If required, the data may also be transformed into gray scale.

Registration and screen transformation is used for input image (such as a screen photograph) preprocessing before any tests are made. The module is composed of three smaller modules whose final output is a new image containing only the transformed screen data. This new image **must have the same resolution** as the test image and the transformation module also must ensure that all image features have (approximately) the same location within the image. Fig.4 shows incorrect registration of a checker board pattern – note the horizontal stripes are not as clear as the vertical stripes, while Fig.5 shows an image of a registered screen – note both horizontal and vertical stripes are evenly illuminated.

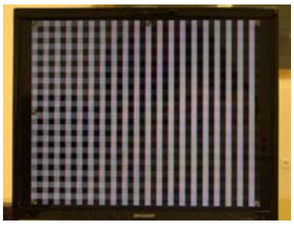

Figure 4: Captured image before registration and correction

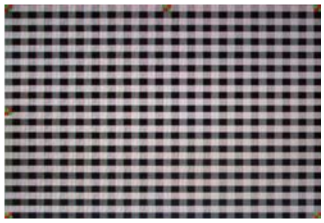

Figure5: Registered screen (corrected captured image, distortion corrected)

Camera optics correction module corrects distortion caused by imperfect camera optics. Typically barrel distortion occurs when taking photos at the widest angle of a lens. The position of the camera lens causes images to look outwardly curved or skewed when straight edges are near the side of the frame. Lines expected to appear perpendicular are not, and instead are curved, or barreled, in form, this is illustrated in Figure 6a. Equally, pincushion distortion may occur where straight lines are skewed inwards this is illustrated in Figure 6b.

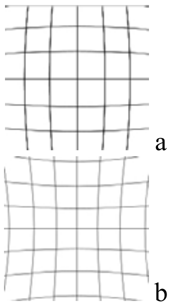

Figure 6: Barrel and pincushion distortion

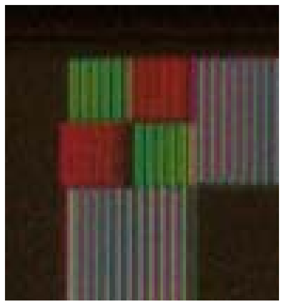

Figure 7: Registration red-green mark

The captured image is transformed and optical imperfections are corrected, see [7] for details.

Registration and screen transformation module is designed to detect and recognize markers for the four screen corners on a given photograph, see Fig.7. To accomplish this four special red-green marks which are inserted into the corners of images to identify the precise

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location of the image corners. These marks are used for accurate calibration and they are part of the test image and minimize any errors caused by inaccurate image positioning on the monitor rim (mainly because the screen edge is often embedded into monitor surround slightly). The module takes the corner coordinates of the image and remaps the screen image from the photograph to a new image respecting the perceptivity influence, see [7] for details. After remapping the screen from the photograph to the rectangle, the module may then linearly remap it to an output image with a given resolution.

Brightness correction module provides an image intensity adjustment for the captured images. This captured image intensity adjustment is based on using a brightness distortion function, which expresses the camera brightness distortion of the captured image. Camera image brightness correction consists of two parts; creation of a camera intensity function and the subsequent adjustment of image intensity. The camera brightness distortion function is created by displaying a gray-scale image with vertical strips of constantly increasing intensity across (left to right for example) the screen of a calibrated monitor, see Fig.9. The difference between the intensity of neighboring strips is constant, with the most left stripe having an intensity value 0 and the most right strip has value of 255 (in the case of using 8 bits per pixel), see Fig.8.

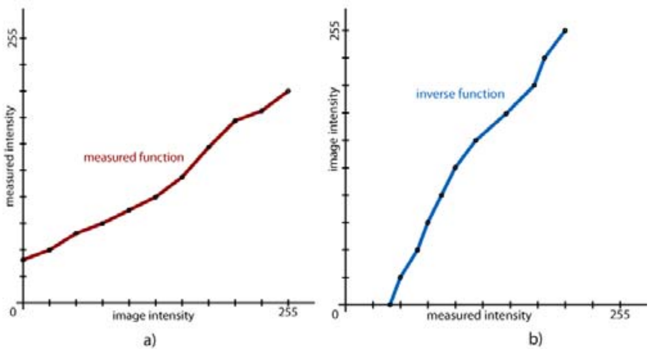

Figure 8: a) Camera brightness distortion function, b) Inverse camera brightness distortion function.

The number of strips in the image is known and is one of the module parameters. The image is captured by the measuring camera and it is preprocessed by the previous modules. Then for each strip random samples are taken over strip area, from these samples the median value, which characterizes the strip intensity, is calculated.

Image intensity adjustment is done on the basis of a camera brightness distortion function. Adjustment is then applied to each pixel of the processed image to correct for brightness distortion from the camera.

Testing module is the final module in the computational pipeline. This module is distinct for each specific test and performs the necessary operations to give the final test results. Once these results are computed, the test module stores the results in a CSV file, and also stores other data from the experiment configuration (such as camera position in front of screen) in a separate file.

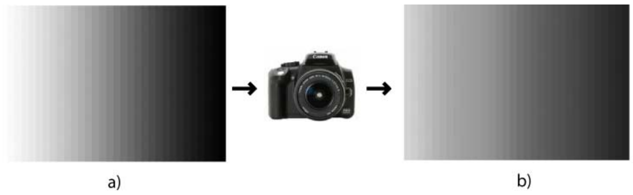

Figure 9: a) Displayed image, b) Captured image

5. EXPERIMENTAL RESULTS

This part explains briefly the cross-talk tests made. Presented results are based on captured images from a single user stereo notebook Sharp AL3D.

This test is designed to provide information on measured values dependent upon the position of each viewer (taking into account left and right eye perception). The test can be used to evaluate display performance from all possible viewer positions within the range supported by the head-tracker system. The test application will provide a map of measured values across the whole range of the head-tracker. Fig.10 illustrates an output sample from the test. In the image the x and y position of a cell in the figure corresponds to the position of the viewer in front of display, and the brightness of a cell represents a test metric value (which may be determined at the start of the test). In the case of a cross-talk test, the black cells represent viewer positions where no cross-talk is present.

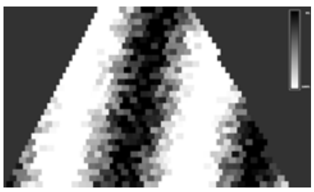

Figure 10: Test result at one position

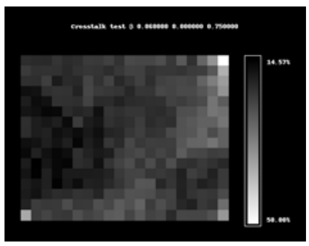

Figure 11: Cross-talk map visualization

In some cases, an evaluation may not be required over the complete screen. In these cases, the screen may be divided into several regions set by a user which may be evaluated individually. The results are displayed in the same way as a full-screen test, see Fig.10.

This part describes cross-talk results in detail using data obtained by capturing Sharp AL3D single user stereo notebook. The captured testing image is on the left and levels of cross-talk for particular screen regions on the right of the Fig.12. Each region is represented as square filled with particular color or shade.

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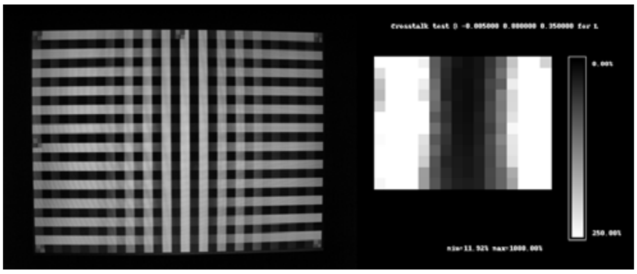

Figure 12: Sample screen-map

In order to use a uniform brightness to map values across all images, a fixed value to gray-scale intensity mapping function was used. This function linearly maps cross-talk values from range $\langle 0;2,5\rangle \times \langle 0;255\rangle$ of gray-scale intensity.

Cross-talk values greater than 2.5 are automatically mapped to level 255 of gray-scale intensity. Uniform mapping across all images allows us comparing certain images against each other.

Note that all three coordinates are measured in meters. In experiments the origin <0,0,0> was in the middle of the screen, see Fig.13.

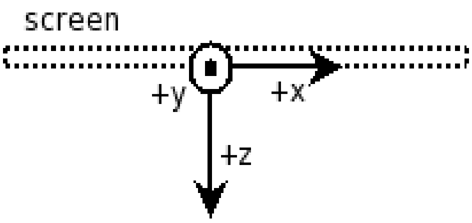

Figure 13: Top-view of coordinate system used for describing position of viewer in experiments

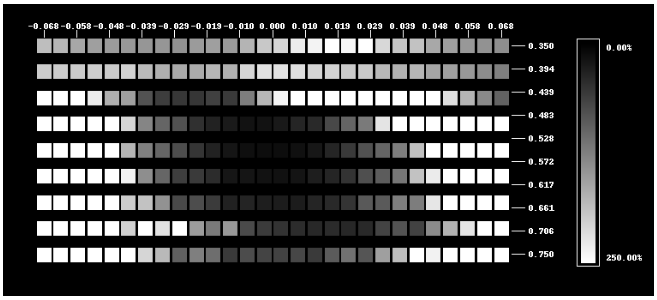

Figure 14: Cross-talk map according to a viewer position

The images on Sharp AL3D were captured by a Canon PowerShot G2 camera (settings: ISO 100, F/2.8, 1/25s), with the eye positions in the range $x \in <-0.1, 0.1>$, $z \in <0.35, 0.75>$, $y = 0$ with a step 0.005 [m] in the x-direction. Capture was performed in a dark room to avoid image contamination by other light sources, e.g. reflections etc.

6. CONCLUSION

A new methodology for the cross-talk of 3D stereo-images was introduced which is convenient especially for multi-user 3D display assessment. The main advantages of the proposed approach are: evaluation is based on measurement not on subjective perception, map of the cross-talk can be measured and evaluated automatically – camera used can be fixed to a robotic arm, if the multi-user 3D display is equipped with eye-observers tracking, the whole procedure can be used for **automatic** measurement and evaluation of the level of cross-talk for different viewers positions.

Automation of the whole process of measurement and evaluation is one of the most important features of the proposed approach and can be used in professional labs.

7. ACKNOWLEDMENTS

Author would like to express thanks to colleagues and students of Computer Graphics at the University of West Bohemia for their help and comments, especially to Bařtipán,J., Hladík,J., Novák,F., Štefány,J. for verification of results reached recently, to Čížek,P., Lobaz,P. for capturing and finalizing 3D film “The Plzen City Liberation” [8] and to Sharp Laboratories Europe (Oxford) for Sharp AL3D loan and to anonymous reviewers for their critical suggestions. The project was supported by the MSMT CR, project CPG N^{o} LC 06008 and by the EU MUTED project N^{o} 034099.

8. REFERENCES

[1] Blundell,B.G., Schwarz,A.J.: Creative 3D Display and Interaction Interfaces, John Wiley, 2006
[2] Dersch,H.: Correcting Barrel Distortion, http://www.all-in-one.ee/~dersch/barrel/barrel.html
[3] Favaro,P., Soatto,S.: 3-D Shape Estimation and Image Restoration, Springer, 2007
[4] Keller,P.A.: Electronic Display Measurement, John Wiley 1997
[5] Poynton,Ch.A.: A Technical Introduction to Digital Video, John Wiley, 1996
[7] Skala,V.,et al: Test images for 3D displays evaluation, CSTR 15-2008, University of West Bohemia, Plzen, 2008
[8] The Plzen City Liberation – 60th Anniversary celebration, 3D stereo/mono video, http://wscg.zcu.cz/Freedom, 2006
[9] EU STREPS MUTED project pages – http://MUTED.zcu.cz
[10] http://www.techmind.org/lcd/
[11] Boev,A., Gotchev,A., Egiazarian,K.: Crosstalk measurement methodology for Autostereoscopic screens, 3DTV conf., Kos, Greece, 2007
[12] Holography – http://HOLO.zcu.cz
[13] Jarvenpaa,T., Salmimaa,M.: Optical characterization methods for autostereoscopic 3D displays, Eurodisplay, 2007
[14] Salmimaa,M., Jarvenpaa,T.: 3-D crosstalk and luminance uniformity from angular luminance profiles of multiview auto, Journal of the Society for Information Display, 2008
[15] Uehara,S., Taira,K., Hamagishi,G., Izumi,K., Nomura,T., Mashitani,K., Miyazawa,A., Koike,T., Yuuki,A., Horikoshi,T., Ujike, H.: Methodology of optical measurement for autostereoscopic displays, 1107, IDW, (2008)