Eastern Academic Journal

ISSN: 2367–7384
Issue 4, pp. 50-57, December, 2016

AUTOMATED STEREOSCOPIC IMAGE CONVERSION AND RECONSTRUCTION. DISPLAYING OBJECTS IN THEIR REAL DIMENSIONS (STEREOSCOPIC IMAGE CONVERSION)

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ABSTRACT— *In this paper a software prototype that is able to convert a single image into a stereoscopic image pair is discussed. The prototype uses methods of image analysis and self-developed algorithms to aid the reconstruction of pixel information between 2D-3D conversions, the details of which are discussed in depth. The prototype obtains estimated depth values from a single still image and computes a most likely recreation of the original scene in the image based on regional clustering, lighting and camera focus information. New theoretical improvements to enhance accuracy during the depth map estimation process focusing on a Statistical Depth Map are discussed as well. The last aim of this paper is to give an approach for creating 3D images that contain objects which have to be displayed and appear on autostereoscopic screens in their real dimensions. For example, we have a picture or 3D model of a museum artefact, tool or whatever and we want to display it on an autostereoscopic screen in its real dimensions, so viewer may perceive the most of the real object.*

Keywords: stereoscopy, image, conversion, real, dimensions, autostereoscopic, display

1. INTRODUCTUON

3D reconstruction is a both time-consuming and resource-heavy task when done manually, often requiring skills of the artistic kind [9]. While this automated conversion is not disposable for projects that are well supplied with time, visual references, and artistic abilities, it is aimed at those that have a lack of any of these. We are presenting a prototype that achieves 3D conversion of an image with no additional information or other picture references, at a press of a button.

1.1. About conversion process and reconstruction

The conversion process has to add an extra dimension to that found in the image. Since this information can only be approximated, certain assumptions have to be made in order to create a basis on which the algorithms deliver aesthetically pleasing results. Assumption I states that Objects in focus are likely to be closer to the camera than others, whereas assumption II is that objects that are brighter are likely to be in the foreground of an image. Trivial examples of this are photos taken with flash.

Reconstruction of missing information in the images is solved by the presented concept of Stencil Filtering, which introduces the new concept of a Recursive Von Neumann Stencil [10], uniting approaches of pixel graphics and 3D rendering into a novel, powerful tool. Stencil Filtering is discussed in depth and its further independent applications are presented, as well.

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Issue 4, pp. 50-57, December, 2016

1.2. About Objects in Real Dimensions on Autostereoscopic Screens

Two types of 3D displays are wildly used: stereoscopic and autostereoscopic displays [4,5,11, 12]. Stereoscopic screens need a pair of two images witch they display at “a same time” in front of the observers [8]. Autostereoscopic screens need an image plus depth map image in order to represent stereo image in front of the viewer [4].

The depth perception that is perceived from the stereoscopic displays depends on both the 3D image and the distance of the observer to the screen as well. The depth perception that is perceived from the autostereoscopic displays depends only on the 3D image. The specific volume of 3D representation of these displays can be seen in [7]. This means that the size of the presented object on the screen does not depend on where the observer watches from but its size is a constant. On that base we made an assumption that an approach for displaying objects in their real dimensions could be developed. Of course, the dimensions of the object, which we want to display, cannot be larger than the dimensions of the screen.

2. CONVERSION STEPS

2.1 Qualitative Depth Map (QDM)

A QDM estimates a likely depth map for the input image [1,10]. In order to generate a QDM the image is segmented using a Mean Shift algorithm. Based on Assumption II, the prototype will assume that brighter colours receive more light, therefore are closer to the point of view. It needs to be realised that a colour's brightness is independent of the actual hue of the colour (fig. 1). That is the reason for me basing this step of the conversion on the colour's Euclidean Distance from the colour white.

Fig. 1: Input image before and after Mean Shift Segmentation.

2.2. Focus Map (FM)

The Focus Map is the result of an extraction process of the main objects in an image based on their local focus or blur [3]. It can be interpreted as a Grayscale image where values show the relative amount of focus with respect to the camera. The prototype uses an algorithm [3] previously developed at the Distributed Events Analysis Research Laboratory of the Institute for Computer Science and Control of the Hungarian Academy of Sciences, as a module for this task.

2.3. Depth-Focus Map

One of the goals of this study was to combine the advantages of QDMs and those of a Focus Map into an innovative Depth-Focus Map (DFM). Once both a Qualitative Depth Map and a

ISSN: 2367–7384
Issue 4, pp. 50-57, December, 2016

Focus Map is available, the next step for the prototype computes the DFM as a linear combination of those aforementioned maps (fig. 2).

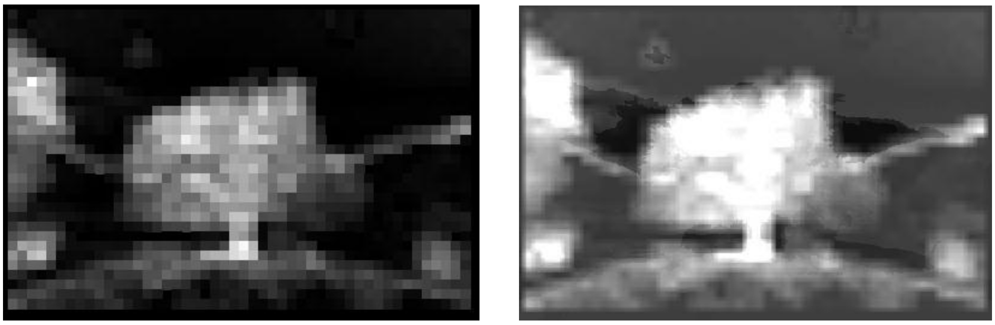

Fig. 2: Focus Map and DFM for the input image.

2.4. Parallax Shift

The pixels of the original image are shifted by parallax values obtained from the DFM to generate the stereoscopic left and right images (fig. 3).

Fig. 3: Stereoscopic Images with blank areas to be reconstructed.

3. RECONSTRUCTION STEPS

To reconstruct blank areas in the resulting stereoscopic images, an innovative method named Stencil Filtering was developed.

3.1. Recursive Von Neumann Stencil (RVNS)

Gathering pixel data from neighbouring pixels in order to reconstruct a value for the starting pixel fails when the pixels to be reconstructed appear in clusters. The concept of the RVNS solves the problem by bypassing all blank pixels and redefining neighbouring pixels as those on the edges of a blank cluster in each of the four main directions [10].

3.2. Filtering Kernel

The neighbouring pixels gathered by the RVNS are subjected to a filtering kernel to compute the final reconstructed value for the starting pixel. A median filtering kernel is used in order to enhance the perceived realism of the generated stereoscopic images. This is due to the fact that using a median kernel the resulting pixel values are instances of values already present in the image whereas other experiments had resulted in interpolated values and less realism in the image (fig. 4).

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Fig. 4: Image pair reconstructed with RVNS and median filtering.

4. STATISTICAL DEPTH MAP (SDM)

It is planned that the development of a SDM will both improve depth accuracy and eliminate any visual artefacts that arise from the integration of QDM and FM. By bypassing the DFM's pixel-based approach with an area-based approach where the areas are obtained from the QDM and a single corresponding value is attained as a result of statistical analysis performed on pixels of the FM that correspond to the pixels contained in said area of the QDM.

4.1. Comparative Tests

The prototype has been tested by preparing 3D scenes and rendering a conventional depth map as a means for a control group. While it can be said that the DFM produces a significant achievement in estimation, it does not yet reach the precision of a calculated depth map. However, as the DFM was not planned as a replacement for situations where a conventional depth map is easily obtainable, results show considerable progress (fig. 5). It is expected that the introduction of the SDM into the testing environment will improve the precision of the estimation process.

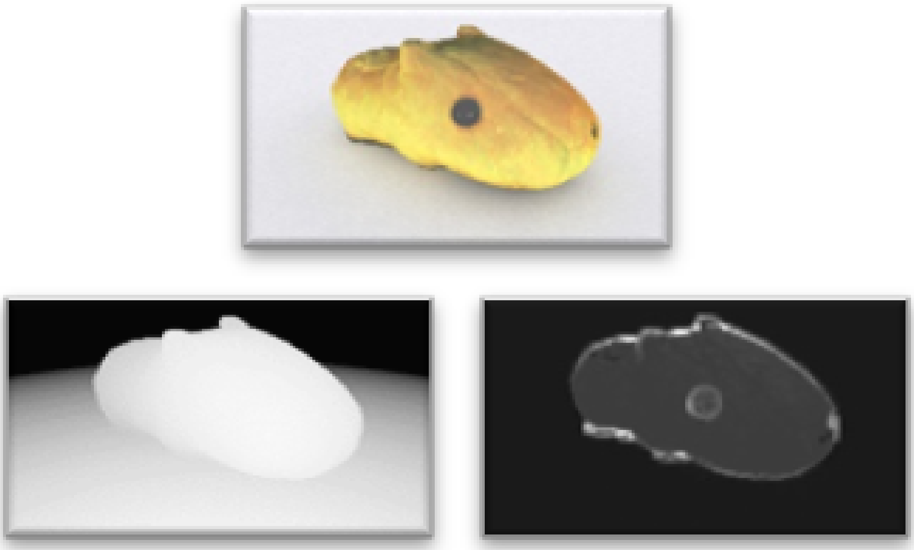

Fig. 5: A 3D rendered image (top) and its corresponding depth maps: conventional (left), DFM (right).

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4.2. Display Tests

The resulting images were tested with the following three different 3D delivery methods: anaglyph, active stereoscopic glasses, and autostereoscopic display, each with their respective input requirements. The prototype performed with expected and consistent results on all three platforms, demonstrating both the unique advantages and disadvantages of each delivery method.

The Anaglyph conversion uses a single image's RGB channels to display all of the stereoscopic information. The left image has been coded to the red channel and the right image into the green and blue channels. This method of delivery, while having the advantage of being the most wide-spread and easily accessible of these methods, suffers from a distortion of color fidelity.

For an active stereoscopic system, we used NVidia 3D Vision, which required a side-by-side format and was flexible in matters of resolution, leading to an easily configurable and aesthetically realistic viewing experience.

For an autostereoscopic system, we used a Philips WOWvx screen and its guidelines regarding preferred input formats [2]. For the purposes of this study, we used a 2D+Z format that relied only on the DFM and did not need reconstruction by Stencil Filtering. This method resulted in a heightened experience of realism, but proved to be inflexible in terms of image resolution.

The prototype is equipped to provide stereoscopic information in all of the abovementioned formats in an optimised way, taking advantage of mid-calculation maps.

5. AN APPROACH FOR DISPLAYING OBJECTS IN THEIR REAL DIMENSIONS ON AUTOSTEREOSCOPIC DISPLAYS

Every autostereoscopic display has the following features: dimensions (width and height), resolution of the 3D image (width and height in pixels), depth of the volume of the 3D image and distance where the observer has excellent 3D image from. Let mark them respectively: W_D, H_D, WI_D, HI_D.

We want to visualize an object taken by a camera or virtual camera (having it on an image, obtained from a 3D model in 3D software). Let the object has the following dimensions: W_{Obj} (width), H_{Obj} (height), L_{Obj} (length), concerning the position of the camera. We have the following condition: $W_{Obj} \le W_D$ and $H_{Obj} \le H_D$.

We have to determine the resolution of the image only of the object (rectangular boundary) so when it is displayed on the screen it may have the dimensions W_{Obj} and H_{Obj}. Let these values mark with wi and hi. After this we make the following correlations:

$$\begin{cases} \dfrac{W_{Obj}}{W_D} = \dfrac{wi}{WI_D} \\ \dfrac{H_{Obj}}{H_D} = \dfrac{hi}{HI_D} \end{cases} \tag{1}$$

Then we find that:

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$$\begin{cases} wi = \dfrac{W_{Obj}.WI_D}{W_D} \\ hi = \dfrac{H_{Obj}.HI_D}{H_D} \end{cases} \tag{2}$$

Finally, when the image is created, a method for development of depth images for autostereoscopic display mentioned in the present paper or another one [2] has to be applied.

Example: We want to make a 3D image of a crown found at a museum and display it on an autostereoscopic screen in its real dimensions so the observers may experience more from the artefact that is presented virtually in front of them.

We use 42’’ Philips autostereoscopic display with the following features:

$$W_D = 930\ mm,\ H_D = 523\ mm,\ WI_D = 960\ px,\ HI_D = 540\ px.$$

The size of the crown is:

$$W_{Obj} = L_{Obj} = 300\ mm,\ H_{Obj} = 297.3\ mm.$$

Following (2) we receive:

$$\begin{cases} wi = \dfrac{W_{Obj}.WI_D}{W_D} = 309.67 \approx 310\ px \\ hi = \dfrac{H_{Obj}.HI_D}{H_D} = 306.96 \approx 307\ px \end{cases}.$$

This means that the image of the crown and its depth image must have resolution of 310x307 px. Every one of them must be inserted in two background images (one image and one depth map image) with same resolutions of 960x540 px. The result is shown on figure 6.

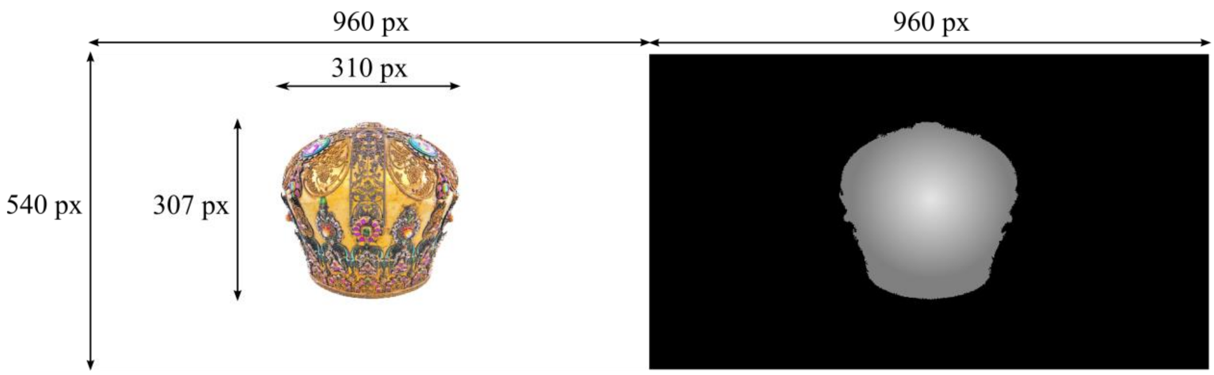

Fig. 6: 3D image (image plus depth) for 42” autostereoscopic display.

The composed 3D image now can be displayed on the autostereoscopic screen. This is shown on figure 7 – the crown is displayed in front of the viewers in its real dimensions.

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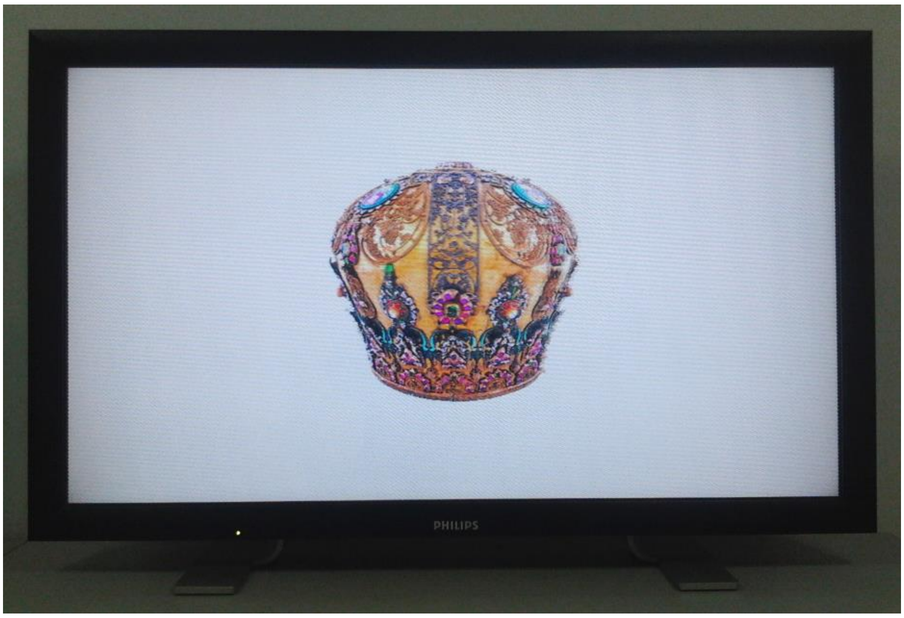

Fig. 7: The 3D image displayed on the 42'' Philips autostereoscopic display.

6. CONCLUSIONS

A software prototype that is able to convert a single image into a stereoscopic image pair has been deliberated in this paper. The prototype uses methods of image analysis and self-developed algorithms to aid the reconstruction of pixel information between 2D-3D conversions. New theoretical improvements to enhance accuracy during the depth map estimation process focusing on a Statistical Depth Map have been discussed as well. An approach for creating 3D images that represent objects which can be displayed on autostereoscopic screens in their real dimensions has been developed and presented here.

Further applications could be utilizing the prototype during the 3D conversion of image content of websites [6]. For example the website of the TEI of Crete (fig. 8) on the renowned Phaistos Disk project (http://disk.3dweb.hu/).

Fig. 8: Anaglyph Reconstruction of images on TEI's Phaistos Disk website.

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