Flickering Reduction Algorithm in Anaglyph Stereoscopic Images

Alexander A. Krupev[1] and Antoaneta A. Popova[2]

Abstract – **In this paper are presented optimized algorithms for stereoscopic anaglyph image production, color & depth adjustment and 3D visualization. The color separation of the images for the left and the right eye, by means of Red-Cyan filters (glasses) is used. Algorithms for analyses and reduction of flickering effects are suggested. A correctly reproduced color gamut is defined for this purpose. The results of the flickering reduction with Red and/or Green greyscale transformation and anaglyph gamut transformation are compared to the basic anaglyphs method and other known methods.**

Keywords – **stereoscopic image, 3D image, anaglyph algorithm, flickering reduction, retinal rivalry**.

I. Introduction

In this work will be discussed the anaglyph stereoscopic method based on color separation of an image by means of color filters (anaglyph glasses) into two images, intended for the left and the right eye respectively. Anaglyph images are made up of two superimposed color layers (Red - R and Cyan - C being most common), representing two slightly different views of a scene, in order to produce a depth effect.

A common artifact called binocular rivalry occurs when there is too much difference between the left and the right eye images. Perception alternates between different images presented to each eye instead of fusing them [4]. When the images presented to the eyes differ mostly in their luminosity and there is only a slight or no contour difference (as it should be for stereoscopic purposes with correctly chosen stereo basis), a form of rivalry called binocular luster may be observed. The object seems to flicker or shine. It’s normal for glossy surfaces, but with the anaglyph method, which as we mentioned is based on color separation, this happens always for objects of certain colors like pure Red and Green.

There is very little literature on the production of anaglyph images, and what exists is very empirical. Recently E. Dubois [2] and W. Sanders and D. McAllister [1] have published some works on the subject, but they are focused mainly on the elimination of ghosting/crosstalk and region merging effects. The works by R. Turnnidge, D. Pizzanelli [5] and others focus on the practical aspects of anaglyph production in Photoshop, but retinal rivalry problem is ignored. Older works focus on monochrome anaglyphs, which lack retinal rivalry. Apart from anaglyphs, retinal/binocular rivalry has been studied extensively as a physiological phenomenon [3], [4].

[1]Alexander A. Krupev is with the Faculty of Communications, Technical University- Sofia, Kliment Ohridski 8, 1000 Sofia, Bulgaria, E-mail: asfalot@abv.bg

[2]Antoaneta A. Popova is with the Faculty of Communications, Technical University - Sofia, Kliment Ohridski 8, 1000 Sofia, Bulgaria, E-mail: antoaneta.popova@tu-sofia.bg

Our main goal is to suggest and implement algorithms for flickering reduction and to compare them to the already existing ones. In Section II is defined the mathematical model used. In Section III a gamut of the correctly reproduced colors by the anaglyph method with Red-Cyan glasses is defined to be used for the production of a non-flickering color anaglyph. A Red and Green channel greyscale transform for anaglyph production is suggested as well. Other common methods including the algorithm of Dubois [2] are given and implemented for comparison purposes. In Section IV an efficient flickering detection algorithm is demonstrated. The algorithms from the previous chapter are tested on a stereo pair and the results are compared.

II. Mathematical Model of the Anaglyph Roduction

The set of representable colors on a display using the *RGB* (Red, Green and Blue) color system is the unit *RGB* cube (3-cube). The cube lies in the 3 dimensional vector space *R3*. The "RGB color solid" in the six dimensional vector space *R6* is a unit hypercube (6-cube) with 64 vertices corresponding to the RGB corners of the cube in *R3* for the left and right eyes. Counting base 2 we can order the vertices of the 6-cube: [*0,0,0,0,0,0*] = [*black*, *black*], [*0,0,0,0,0,1*] = [*black*, *blue*], …, [*1,1,1,1,1,1*] = [*white*, *white*]. Anaglyph methods compute a map from the 6-cube in *R6* to *R3*. A vector is defined $v = [r_l, g_l, b_l, r_r, g_r, b_r]^T$ with RGB coordinates of the left and right eye color channels. The linear algorithms compute $[r,g,b]^T = Bv$, where v represents the color of a matching pair of pixels in the left and the right images of the scene, B is a 3-by-6 matrix of the transformation and $[r,g,b]^T$ is the resulting color of the pixel from the anaglyph to be observed through the color filters. The most common transform matrix (Photoshop - PS algorithm) is:

$$B = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

which means that the Red channel of the left image and the Green and Blue channels of the right image are superimposed (Fig. 1).

When viewed with the glasses the anaglyph’s left and right eye images get separated again, albeit not perfectly (there is usually some degree crosstalk), each eye sees its intended image, the images get fused and a virtual 3D object is reconstructed by the brain.

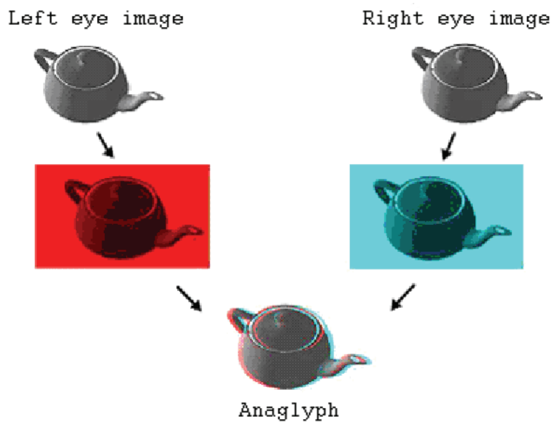

Fig. 1. The used basic principle of anaglyph production

III. Flickering Reduction Algorithms

The anaglyph method is used mainly for 3D representation of monochrome images. The monochrome anaglyph is not a monochrome image itself, but it's perceived as such. It's an interesting question which colors, besides the monochromatic ones, are correctly reproduced by the anaglyph method.

TABLE I
SOME ANAGLYPH GAMUT COLOR VALUES

R	G	B	R	G	B
0	0	0	131.25	150	0
6.25	0	50	137.5	150	50
12.5	0	100	143.75	150	100
18.75	0	150	150	150	150
25	0	200	156.25	150	200
31.88	0	255	163.12	150	255
43.75	50	0	175	200	0
50	50	50	181.25	200	50
56.25	50	100	187.5	200	100
62.5	50	150	193.75	200	150
68.75	50	200	200	200	200
75.62	50	255	206.87	200	255
87.5	100	0	223.12	255	0
93.75	100	50	229.37	255	50
100	100	100	235.62	255	100
106.25	100	150	241.87	255	150
112.5	100	200	248.12	255	200
119.37	100	255	255	255	255

An approach to define the anaglyph color gamut is suggested by us in following steps. If we use the luminance formula $Y=0.2R+0.7G+0.1B$ then the luminance of the right C channel is $Y_{right}=0.7G+0.1B$. The luminance of the left R channel $Y_{left}=0.2R$. For monochrome stereo pairs $R=G=B$, hence $Y_{left}/Y_{right}=1/4$. To define the gamut of the anaglyph method are found the colors, for which this ratio is preserved. We have $4*Y_{left}=Y_{right}$, then $4*0.2R=0.7G+0.1B$ and finally $R=(7G+B)/8$. The sets of calculated values of R, together with their corresponding values of G and B in steps of 50, are shown in Table I and as a color palette on Fig. 2. The achromatic colors are diagonally placed.

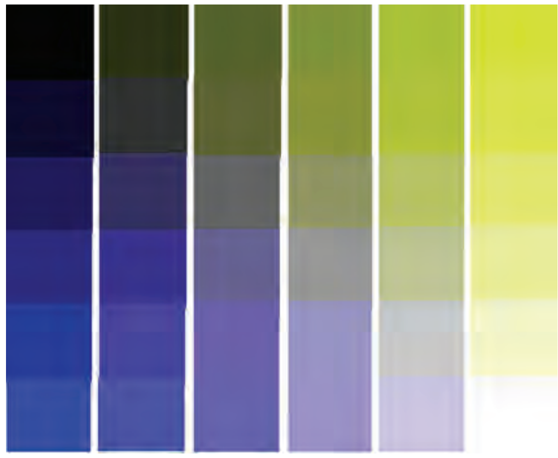

Fig. 2. Defined gamut of the correctly reproduced colors by the anaglyph method

In the RGB cube these colors form a plane (Fig. 3).

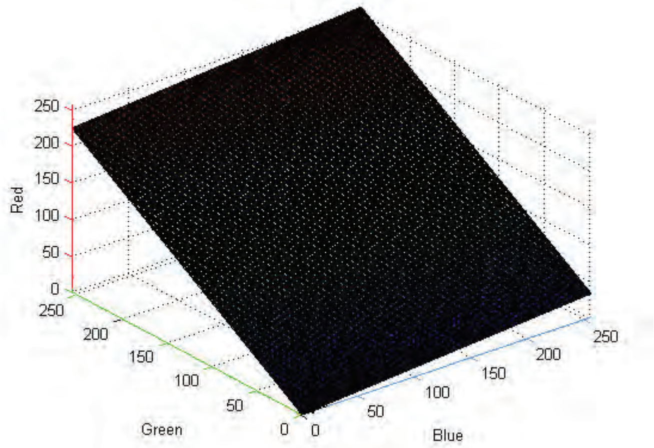

Fig. 3. The plane of colors, forming the defined anaglyph gamut

The objects, with colors outside of this plane, show different degrees of flickering when viewed as anaglyphs, especially bright R, C and G colored objects.

Common practice to reduce the flickering effect is to take the luminance (gray) values of the left image and to use them as a Red channel of the produced anaglyph [1]. The transform matrix looks like this:

$$B=\begin{bmatrix}\alpha_1 & \alpha_2 & \alpha_3 & 0 & 0 & 0\\ 0 & 0 & 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 0 & 0 & 1\end{bmatrix} \quad (2)$$

α_1 α_2 α_3 represent the weights in the luminance formula. This tends to gray out the flickering objects.

We further propose a grayscale transform of the G anaglyph channel as well, which increases the effectiveness of this method and yields brighter images:

$$B = \begin{bmatrix} \alpha_1 & \alpha_2 & \alpha_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha_1 & \alpha_2 & \alpha_3 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \qquad (3)$$

Another suggested approach by us is to calculate the closest color (Euclidian distance) from the anaglyph color gamut plane from Fig. 3 and use it.

The results from the suggested by us algorithm is compared with Eric Dubois [2] method which takes into account the properties of the media and the filters. The purpose here is to be minimized the Euclidian length of the vector $R[r,g,b]^T – D$ in CIE, where

$$R = \begin{bmatrix} A_l \\ A_r \end{bmatrix} \qquad D = \begin{bmatrix} C & 0 \\ 0 & C \end{bmatrix} v \qquad (4)$$

C is the conversion matrix from RGB to CIE color space for a given medium. Al and Ar are the transmission functions of the filters in CIE. In other words the difference between the colors, observed through the filters, and the colors of the stereo pair is minimized. An example of anaglyph transform B matrix, used in the current work, computed with this method for an average CRT screen and anaglyph glasses is shown below:

$$B = \begin{bmatrix} 0.4561 & .500484 & .176381 & -.0434706 & -.0879388 & -0.00155529 \\ -.0400822 & -.0378246 & -0.157589 & .378476 & .73364 & -.0184503 \\ -.0152161 & -.0205971 & -.00546856 & -.0721527 & -.112961 & 1.2264 \end{bmatrix} \qquad (5)$$

The flowchart of the implemented Dubois anaglyph production algorithms for the comparison is shown on Fig. 4.

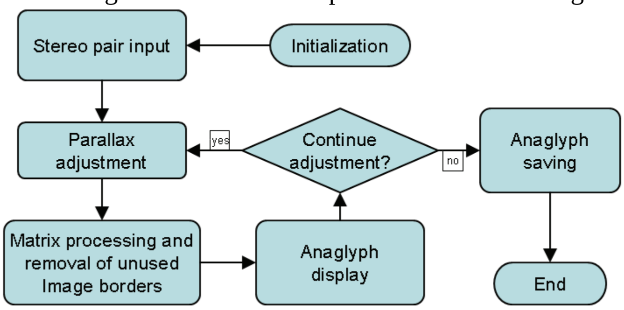

Fig. 4. Dubois anaglyph production algorithm

The flowchart of the developed by us anaglyph production algorithm with optional grayscale transforms of R, G and/or B channels is shown on Fig. 5. In the algorithm can be made a choice of the type of the input image - Anaglyph or Stereo pair. A parallax adjustment procedure is used after the transformation of the RGB channels (if any).

Since binocular rivalry is a stereoscopic effect its estimation within the anaglyph itself is complicated by the necessity to search for homologous points. This can be avoided if the estimation/detection is performed on a picture of the scene taken in between the left and the right view (sometimes referred to as “cyclopean image”) or on the stereo pair itself.

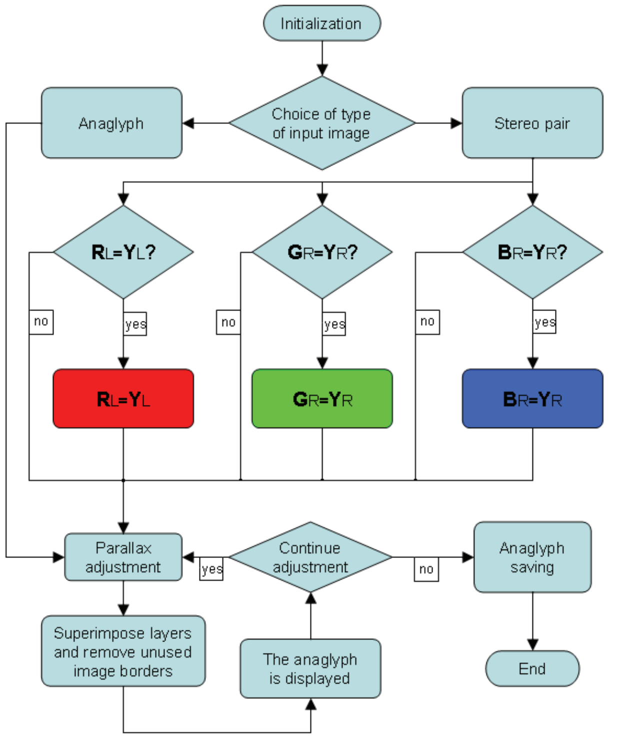

Fig. 5. Suggested algorithm with optional grayscale transforms of R, G and/or B channels

IV. Experimental Results

All the experiments are implemented in Matlab 7.0.3 working environment.

An algorithm detecting flickering objects in stereo pairs/cyclopean images has been implemented. The implemented algorithm produces maps of the flickering effect - grayscale images, the brighter colors of which indicate flickering objects (see Fig.6 - Cyan, Green, Red and Magenta squares and their corresponding bright squares on the right, indicating high degrees of binocular rivalry).

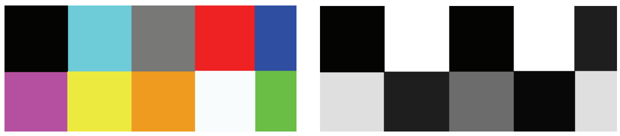

Fig. 6. A test image and a map of its flickering effect

Fig. 7. A stereo pair (Up) and its map of the flickering effect (Down)

The flickering map of a real world image reveals problematic objects, like the red scarf in the left of the image (Fig. 7). On the other hand the white box is perfectly black on the flickering map, which indicates the known fact that achromatic colors are correctly reproduced by the method.

The flickering effect in the produced anaglyphs conforms to our initial expectations. The PS algorithm demonstrates the strongest flickering effect (Fig. 9. Left - L). The common PS algorithm with grayscale transform of the R channel strongly reduces the effect (Fig. 9. Right - R). This is further enhanced by the proposed algorithm with grayscale transform of the R and G channels (Fig. 10. Left - L). The monochrome anaglyph (grayscale luminance transform of all 3 channels - R, G and B) produces no binocular rivalry whatsoever, but it lacks color perception as well (Fig. 10. Right - R).

To realize our approach with the anaglyph gamut optimization we first processed the stereo pair in Matlab with an algorithm, searching for corresponding “nearest distance” colors on the suggested anaglyph gamut (Fig. 8).

Fig. 8. Processed stereo pair from Fig. 7 with colors of the suggested anaglyph gamut

This processed stereo pair was used to produce an anaglyph demonstrating no binocular rivalry at all - just like the monochrome anaglyph - but with color perception (Fig. 11. Right – R)! It’s brighter and objects with colors outside of the anaglyph gamut do not become darker or grayish (as in the grayscale conversion algorithms, Fig.9 - R, Fig.10 - L) or flickering/shiny (as in the simple PS algorithm, Fig. 9 - L).

Fig. 9. Anaglyph images: L) PS algorithm; R) PS with grayscale transform of R channel

Fig. 10. L) Suggested anaglyph with grayscale transform of R and G; R) Monochrome anaglyph (grayscale transform of 3 channels RGB)

Fig. 11. L) Dubois anaglyph image; R) Suggested gamut transform anaglyph

Dubois algorithm (Fig. 11 - L), though not optimized for the particular screen and glasses, shows similar results as our “nearest distance” anaglyph (Fig. 11 - R). The Dubois image perceived is a little bit darker and colors are less vivid, some flickering remains, but on the other hand almost no crosstalk is perceived. Crosstalk (ghosting) reduction is out of the scope of this work, though.

V. Conclusion

The achieved results can be used for stereoscopic imaging suitable for the printed media, Internet 3D application, art presentation and visualization on all currently widespread screens. Distance learning and virtual laboratory applications have motivated the use of inexpensive visual stereo solutions for computer displays. Our results show that each method has its advantages and disadvantages in faithful color representation. We recommend Dubois and the proposed anaglyph gamut transform algorithms as preserving color perception and brightness with no/almost no noticeable flickering. While the anaglyph 3D image method is cheap and accessible, its use requires a compromise in image quality.

Acknowledgment

This work was supported by National Ministry of Education and Science of Bulgaria under contract BY-I-302/2007 “Audio-Video information and communication system for active surveillance cooperating with a Mobile Security Robots”.

References

[1] W. Sanders and D. McAllister, “Producing Anaglyphs from Synthetic Images”, Proc. SPIE Vol. 5006, San Jose, California, pp. 348-358, 2003.

[2] E. Dubois, “A projection method to generate anaglyph stereo images” Acoustics, Speech, and Signal Processing, IEEE International Conference, Salt Lake City, UT, USA, 2001

[3] F. Tong and S. A. Engel, “Interocular rivalry revealed in the human cortical blind-spot representation”, Nature, 411, 195-199, 2001.

[4] R. Blake, “A natural theory of binocular rivalry”, Psychological review, Vol. 96. No. 1, pp. 145-167, Evanston, Ilinois, USA, 1989

[5] R. Turnnidge and D. Pizzanelli, “Methods of previsualizing temporal parallax suitable for making multiplex holograms. Part II: Greyscale and colour anaglyphs made in Photoshop^{TM},” Imaging Science Journal, vol. 45, no. 1, pp. 43–44, 1997.