Fast Anaglyph Retinal Rivalry Reduction Algorithm

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Abstract – **In this paper is presented an optimized retinal rivalry reduction algorithm for stereoscopic anaglyph image production and 3D visualization. The used color separation of the images for the left and the right eye is by means of Red-Cyan glasses. A rigorous and a fast non-rigorous approaches for reduction of flickering effects, associated with binocular rivalry, are suggested and compared. A correctly reproduced colour gamut is used for this purpose. The results of the retinal rivalry reduction gamut transformation are also compared to the basic anaglyph creation method.**

Keywords – **stereoscopic image, 3D image, anaglyph algorithm, retinal rivalry, uniform vector quantization.**

I. Introduction

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

When there is too much difference between the left and the right eye images, a common artifact, called retinal/binocular rivalry, occurs. Instead of fusing them, the perception alternates between the left and right eye images [4]. A form of rivalry called binocular luster may be observed when the images presented to each eye differ mostly in their luminance and there is a minimal contour difference, as it should be for stereoscopic purposes with correctly chosen stereo basis. The object seems to flicker or shine. Though normal for glossy surfaces, with the color separation based anaglyph method this happens always for objects of certain colors outside of the correctly reproduced color gamut.

The literature on the production of anaglyph images is limited and what exists is empirical mostly. Recent works of E. Dubois [2] and W. Sanders and D. McAllister [1] on the subject are focused mainly on the elimination of ghosting/crosstalk and region merging effects. Our team has published a paper on the subject [6], the used algorithm implementation there is rigorous and precise, but there is a more elegant, simpler and faster approach as we will demonstrate. 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 as a physiological phenomenon extensively [3], [4].

Our main goal is to create an alternative faster non-rigorous arithmetic implementation of the method from [6] at the minor expense of some precision. In Section II the anaglyph gamut transformation algorithm is explained. In Section III a new non-rigorous implementation is suggested and compared to the rigorous one. The test results and conclusions are shown in Section IV.

II. Retinal Rivalry Reduction Algorithm Using the Anaglyph Gamut

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. The set of colours correctly reproduced by the anaglyph method, besides the monochromatic ones, is defined in [6]. These colours form a plane in the RGB-cube - Fig.1.

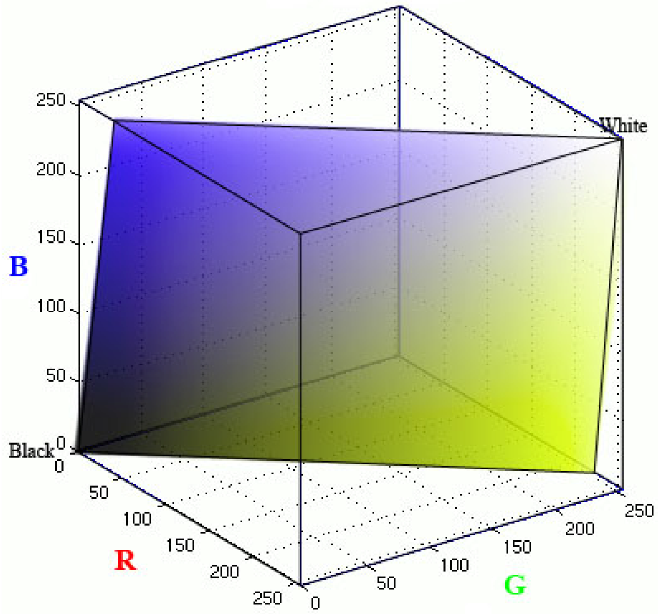

Fig. 1. The plane of colors, forming the defined anaglyph gamut

These colors satisfy the condition:

$$R = \frac{7G + B}{8} \quad (1)$$

This preserves the luminance ratio between the left and the right channels observed in a monochrome anaglyph. The objects, with colors outside of this plane, show different

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degrees of flickering when viewed through the anaglyph glasses, especially objects of bright cyan, red and green colors. The monochrome colors are placed diagonally from the lower left to the upper right corner, varying from black to white.

The purpose of the anaglyph gamut transformation algorithm is to substitute the colors from the stereo pair with colors within the plane from Fig. 1. Each time the closest color from the plane is used. In the next section we will discuss the process of finding this nearest color value.

III. Finding the Nearest Distance Colour Value from the Anaglyph Colour Plane

The previously utilized approach was to divide the plane hierarchically and uniformly into smaller and smaller regions, each represented by its centroid. B increases horizontally from left to right, G-vertically upwards and R, as a function of these two, diagonally. The first and second hierarchical levels are shown on Fig. 2. G and B channels each have 256 colour values ranging from 0 to 255 - 8bit per channel. That's why the segmentation is performed 8 times for maximum precision on increasingly smaller regions from 256x256 to 2x2. The Euclidian distance Eq. (2) is calculated to each one of the four centroids and the nearest one is chosen, thus narrowing the search to its corresponding region. This approach is similar to a uniform vector quantization technique.

$$dist = \sqrt{(R - R_0)^2 + (G - G_0)^2 + (B - B_0)^2} \qquad (2)$$

Here R_0, G_0 and B_0 are the coordinates of a colour from the image and R, G and B - the coordinates of a point from the plane.

The new approach we propose is a numerical one. We will define an equation which calculates the nearest colour from the anaglyph colour plane, instead of choosing from a set of predefined values.

The equation of a plane is given by Eq. (2), d=0 since the beginning of the coordinate system (0, 0, 0) belongs to the plane:

$$\begin{aligned} aR + bG + cB + d &= 0 \\ d &= 0 \end{aligned} \qquad (3)$$

The parametric equations of a line passing through a point (R_0 G_0 B_0) in the RGB color space and perpendicular to the plane from Eq. (3) are:

$$\begin{aligned} R &= R_0 + at \\ G &= G_0 + bt \\ B &= B_0 + ct \end{aligned} \qquad (4)$$

Here *t* is an independent variable.
The nearest colour to (R_0 G_0 B_0) from the plane is the cross-point between the line and the plane.

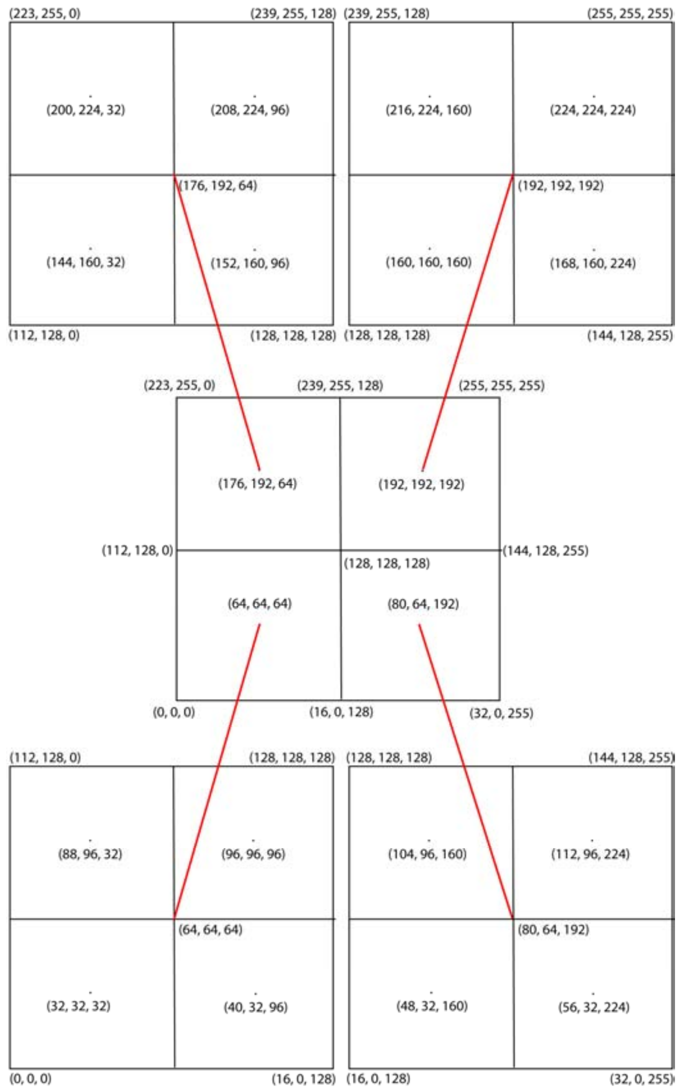

Fig. 2 First and second level hierarchical segmentation of the color plane

We substitute Eq. (4) into Eq. (3):

$$a(R_0 + at) + b(G_0 + bt) + c(B_0 + ct) = 0 \qquad (5)$$

After we solve for *t* we get:

$$t = -\frac{aR_0 + bG_0 + cB_0}{a^2 + b^2 + c^2} \qquad (6)$$

For this value of *t* the line crosses the plane.

After we substitute this value of *t* into Eq. (4) we can calculate the coordinates (R, G, B) of this point:

$$R = \frac{(b^2+c^2)R_0 - bG_0 - cB_0}{a^2+b^2+c^2}$$
$$G = \frac{(a^2+c^2)G_0 - aR_0 - cB_0}{a^2+b^2+c^2} \qquad (7)$$
$$B = \frac{(a^2+b^2)B_0 - aR_0 - bG_0}{a^2+b^2+c^2}$$

Or in a matrix form:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \frac{1}{a^2+b^2+c^2} \begin{bmatrix} b^2+c^2 & -b & -c \\ a^2+c^2 & -a & -c \\ a^2+b^2 & -a & -b \end{bmatrix} \begin{bmatrix} R_0 \\ G_0 \\ B_0 \end{bmatrix} \qquad (8)$$

From Eq. (1) we can get the exact a, b and c values for our case:

$$8R - 7G - B = 0$$
$$a = 8;\ \mathrm{b} = -7; c = -1; \qquad (9)$$

Using these exact values in Eq. (8) we get the equation (10), used in the alternative implementation of our algorithm:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \frac{1}{114} \begin{bmatrix} 50 & 7 & 1 \\ 65 & -8 & 1 \\ 113 & -8 & 7 \end{bmatrix} \begin{bmatrix} R_0 \\ G_0 \\ B_0 \end{bmatrix} \qquad (10)$$

IV. Experimental Results and Conclusions

All the experiments are implemented in Matlab 7.0.3 working environment. An algorithm detecting flickering objects in stereo pairs/cyclopean images, implemented on Matlab, is used. The implemented algorithm produces maps of the retinal rivalry effect - grayscale images, the brighter colors of which indicate flickering regions.
The formula used for this detection now is:

$$Y = \left| R - R_{expected} \right|$$
$$R_{expected} = \frac{7G + B}{8} \qquad (11)$$

R is the Red channel value from the actual image, $R_{expected}$ is the Red channel value, for which there would be no rivalry. Y is the grayscale value from the map of the flickering regions. It ranges from zero ($R = R_{expected}$) to 255 (for pure Red [255, 0, 0] or Cyan [0, 255, 255] colors).

As an example of how does a binocular rivalry map work see Fig. 3. White and gray squares yield black squares on the map, cyan and red – white squares, which indicates that they would cause strong flickering in an anaglyph image [6].

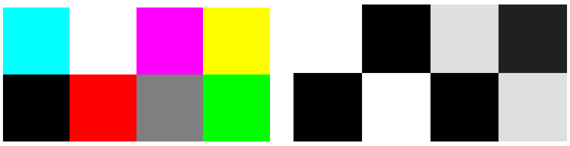

Fig. 3. A test image (left) and its retinal rivalry map (right)

On Fig.4 we see a stereo pair of a brain. The intense red parts appear lighter on the map, while the background and the grayish/whitish parts of the brain appear darker. The retinal rivalry map is not a negative image – if it was, the background would appear white.

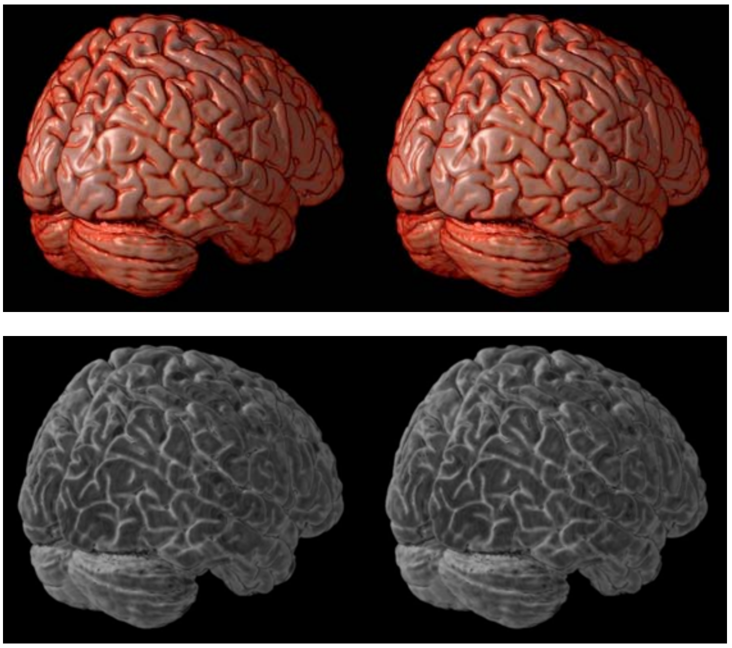

Fig. 4. A stereo pair (Up) and the map of its flickering regions (Down)

On Fig. 6 we see a processed stereo pair with colors from the anaglyph color gamut. The processing is done with the new fast algorithm. There are no noticeable flickering regions on its retinal rivalry map. The resulting anaglyph from Fig. 7 demonstrates no binocular rivalry also as expected.

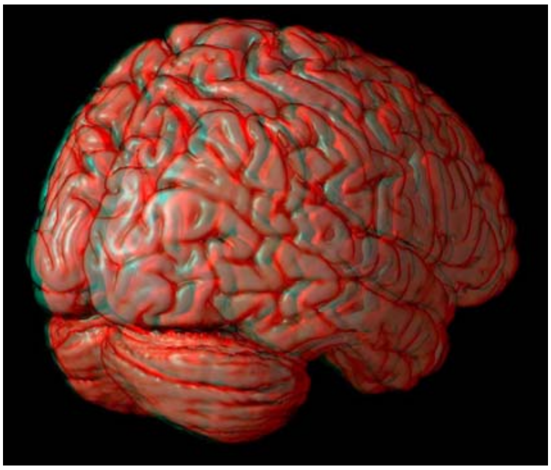

Fig. 5. Anaglyph images of a brain using the stereo pair from Fig. 4

The same cannot be said about the anaglyph from Fig. 5, produced by the stereo pair from Fig. 4 using the basic common PS algorithm, without any further processing. Unnatural shining is most obvious in the cerebellum area, being most reddish in the stereo pair.

Fig. 6. Processed stereo pair from Fig. 4. with colors of the suggested anaglyph gamut (Up), its binocular rivalry map (Middle) and binarized version of the map (Down)

The retinal rivalry map in Fig. 6 is not perfectly black, though. Due to rounding errors in the fast rivalry reduction algorithm parts of it have values up to 2 (very dark gray). When the map is binarized with a threshold of 1, these parts become obvious (Fig.6-Down).

That's because the new implementation doesn't use predefined color values from the anaglyph color plane to choose from like, but calculates new values. They are close enough to the plane not to introduce visible flickering.

An example: orange color (222, 121, 30) – its nearest color of the anaglyph color plane is (159, 176, 37) selected by the rigorous algorithm, but the new fast algorithm calculates (158, 176, 37) which is quite close. The authors consider the precision acceptable for practical purposes.

Considering that the new method is about 9 times faster (0.5 versus 4.5 seconds for the Brain stereo pair with resolution 1806x768), not very computationally intensive and its results are comparable to the rigorous one, we encourage its use for anaglyph binocular rivalry reduction.

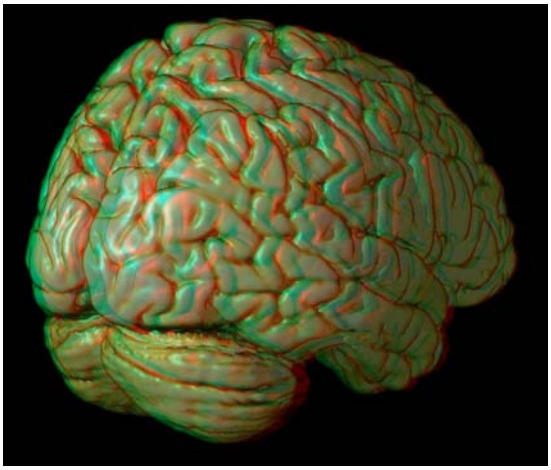

Fig. 7. Anaglyph images of a brain using the stereo pair from Fig. 6

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