Optimizing Anaglyph Colors

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Abstract

An anaglyph is a 3D stereo image that uses color to present both left- and right-eye views of a scene in a single image. Color filter glasses are used to direct the views to each eye. The "anaglyph problem" is, given the characteristics of the display and filters, find the color for each pixel in the anaglyph that best delivers the stereo pair. "Best" in this context is to avoid undesirable visual artifacts such as retinal rivalry and stereo crosstalk while maximizing perceived color fidelity. A vector formulation of the anaglyph problem for additive displays is presented and solutions for it that minimize rivalry and minimize crosstalk are identified. Factors such as adaptation and display range clipping are included in the solutions. Example anaglyph images using the methods described are presented.

Keywords: anaglyph, retinal rivalry, stereopsis, crosstalk, dichoptic color, binocular color.

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Introduction

An anaglyph is a stereographic image that combines two views encoded by color. They are viewed through color filters that separate and direct the left and right images to the corresponding eye and stereopsis provides the perception of depth. Anaglyphs have been around for many years and have enjoyed periods of great popularity. Amusing pictures of 3D-glasses-clad movie audiences attest to prior fads, and there is a resurging interest in them as new color displays and imaging techniques become available

There are numerous drawbacks to using color as the means to encode the two views into a single image, but one strong benefit of anaglyphs is their low cost, both to publish and to view. Because of this, there is incentive to mitigate the viewing difficulties that anaglyphs present. Although one can expect color fidelity to be compromised by the viewing filters, there are other detracting artifacts known as retinal rivalry, and stereo crosstalk.

Retinal rivalry is the experience that occurs when the two eyes receive different stimuli. If they are sufficiently distinct, a "flashing" sensation will occur as each eye seems to take turns delivering its view of the world. It is an uncomfortable side effect of viewing a poorly designed anaglyph.

Crosstalk is just that—image information intended for one eye leaks into the other, the stereopsis effect is weakened, and a "double vision" effect is experienced.

Despite its long history, the production of anaglyphic prints and displays has been somewhat ad-hoc until quite recently. Understanding the relationships between anaglyph colors and their perception can assist in making tradeoffs in anaglyphic display systems. This paper will address some of the color requirements for making anaglyphs that minimize retinal rivalry and crosstalk, while preserving as much color as the anaglyph filters will allow.

We will focus on additive color displays where the relationships can be easily modeled with linear algebra. The same principles apply to printed anaglyphs, but the solutions will be harder to solve.

A framework for the anaglyph problem

The "anaglyph problem" is: given two (left and right view) source images, knowledge of the display and filter characteristics, determine the best color for each pixel in the anaglyph. "Best" is taken to include optimizations and tradeoffs in the effects of retinal rivalry, stereo crosstalk, and color fidelity.

A vector space approach to the anaglyph problem has been presented by Eric Dubois [1], and his student Vu Tran [2]. This paper will follow their structure, making a few notation changes and additions.

The linear RGB values of the left and right source images are represented by 3-vectors $V_{src,l}$ and $V_{src,r}$. When displayed on a CRT or LCD display, the tristimulus representation of the source colors, U_{src} are obtained via a 3x3 RGB to XYZ transformation matrix **C**.

$$\mathbf{U}_{\mathbf{src,l}} = \mathbf{C}\mathbf{V}_{\mathbf{src,l}}$$

$$\mathbf{U}_{\mathbf{src,r}} = \mathbf{C}\mathbf{V}_{\mathbf{src,r}} \tag{1}$$

If we had a true stereoscopic display, the left and right images would be directed to the appropriate eye. We could represent the pair of tristimuli by a 6-vector formed by concatenation:

$$\mathbf{U}_{\mathbf{src}} \equiv \begin{bmatrix} \mathbf{U}_{\mathbf{src,l}} \\ \mathbf{U}_{\mathbf{src,r}} \end{bmatrix} = \begin{bmatrix} \mathbf{C} & \mathbf{0}_{\mathbf{3x3}} \\ \mathbf{0}_{\mathbf{3x3}} & \mathbf{C} \end{bmatrix} \begin{bmatrix} \mathbf{V}_{\mathbf{src,l}} \\ \mathbf{V}_{\mathbf{src,r}} \end{bmatrix} \equiv \mathbf{C}_2\mathbf{V}_{\mathbf{src}} \tag{2}$$

Viewing the display through a filter modifies the spectral energy delivered to the retina in a way that can also be represented by an RGB to XYZ matrix. We represent the two filters (viewing a specific display) by $\mathbf{A_l}$, and $\mathbf{A_r}$. If we were able to perfectly direct the left and right images through their assigned filters to reach their target eye, we would have:

$$\mathbf{U}_{\mathbf{filt}} \equiv \begin{bmatrix} \mathbf{U}_{\mathbf{filt,l}} \\ \mathbf{U}_{\mathbf{filt,r}} \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{\mathbf{l}} & \mathbf{0} \\ \mathbf{0} & \mathbf{A}_{\mathbf{r}} \end{bmatrix} \begin{bmatrix} \mathbf{V}_{\mathbf{src,l}} \\ \mathbf{V}_{\mathbf{src,r}} \end{bmatrix} \equiv \mathbf{A}_2\mathbf{V}_{\mathbf{src}} \tag{3}$$

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Of course, this is the whole problem, we *can't* direct the left and right source images to their respective eyes from a single display surface. We must compromise in some way to decide what single anaglyph color, $\mathbf{V_a}$, will be used to represent the two colors $\mathbf{V_l}$ and $\mathbf{V_r}$, at each pixel in the anaglyph. That single color, when filtered, will result in two different tristimuli, contained in $\mathbf{U_a}$.

$$\mathbf{U_a} \equiv \begin{bmatrix}\mathbf{U_{a,l}}\\ \mathbf{U_{a,r}}\end{bmatrix} = \begin{bmatrix}\mathbf{A_l}\\ \mathbf{A_r}\end{bmatrix}\mathbf{V_a} \equiv \mathbf{AV_a} \tag{4}$$

We would like $\mathbf{U_a}$ to represent the source images in the best way possible, given the color transforms of the filters, $\mathbf{A_l}$ and $\mathbf{A_r}$. This means that we must solve for $\mathbf{V_a}$ as a function of the filters (which implicitly includes the display), and the source colors.

$$\mathbf{V_a} = f(\mathbf{A}, \mathbf{V_{src}}) \tag{5}$$

What does "best" mean? The Dubois algorithm finds the closest colors to the original source color tristimuli, $\mathbf{U_{src}}$. This had a beneficial side-effect of reducing retinal rivalry. Vu Tran's work further considered issues of crosstalk as pre- or post-processing operations.

This work will solve for the anaglyph color that is closest to the source color (or filtered source color, $\mathbf{U_{filt}}$) in a way that explicitly includes constraints for minimizing rivalry and crosstalk. An example anaglyph system will be used based on the author's laptop display (Toshiba Tecra 15" LCD, calibrated to D50) and a common red-cyan viewing filter (American Paper Optics). The filter transform evaluates as:

$$\mathbf{A} = \begin{bmatrix} 0.17833 & 0.04370 & 0.00112 \\ 0.11470 & 0.03064 & 0.00071 \\ 0.00000 & 0.00135 & 0.00142 \\ 0.01320 & 0.07529 & 0.08436 \\ 0.01353 & 0.22502 & 0.03681 \\ 0.02870 & 0.25185 & 0.44545 \end{bmatrix}$$

The example anaglyphs presented in this paper will perform differently on other displays and with other viewing filters, and so the artifacts will be more or less as described, depending on the similarity to the example system.

Adaptation and normalization

Our visual state while viewing anaglyphs is very unnatural. Each eye has a strongly color-distorted view of the scene. Neither eye fully adapts to its apparent illuminant. Yet some adaptation clearly occurs. Viewing a monochromatic anaglyph delivers an effective stereo effect and is usually quite comfortable. And even though each eye is delivering a different tristimulus value for white, it is accepted by the viewer as the whitepoint in the scene.

A well-designed pair of anaglyph filters will yield the same luminance when viewing neutral colors. If there is a slight difference, the eye's light and dark adaptation mechanisms will adjust the retinal gains to reduce, if not eliminate it.

There will also be gain adjustments in the chromatic channels. We do not address them in this paper, but conceptually, they can be included, along with the luminance adaptation, in a general adaptation stage in our anaglyph system. The RGB to XYZ conversion contained in the filter matrices $\mathbf{A_l}$ and $\mathbf{A_r}$ will be concatenated with adaptation matrices $\mathbf{D_l}$ and $\mathbf{D_r}$ to make "adapted filter" matrices $\mathbf{A_{al}}$ and $\mathbf{A_{ar}}$. For the simple case of luminance normalization, the adaptation matrices are diagonal. They result in left and right Y values of 1.0 when viewing RGB white (1,1,1).

$$\mathbf{A_{al}} = \begin{bmatrix} D_{l11} & 0 & 0 \\ 0 & D_{l22} & 0 \\ 0 & 0 & D_{l33} \end{bmatrix}\mathbf{A_l}; \qquad D_{lnn} = \frac{1.0}{A_{l21} + A_{l22} + A_{l23}} .$$

$$\mathbf{A_{ar}} = \begin{bmatrix} D_{r11} & 0 & 0 \\ 0 & D_{r22} & 0 \\ 0 & 0 & D_{r33} \end{bmatrix}\mathbf{A_r}; \qquad D_{rnn} = \frac{1.0}{A_{r21} + A_{r22} + A_{r23}} \tag{6}$$

In subsequent expressions we assume that the filter matrices A and A_2, utilize the luminance-adapted (or in general, the full chromatic-adapted) filter matrices as their components. This brings the RGB source colors to a common XYZ tristimulus space where rivalry and crosstalk calculations can be meaningfully performed.

Minimizing rivalry

It is a common psychophysical experiment to present different stimuli to our two eyes in an attempt to understand our visual system. Yet after more than a century of performing such binocular comparisons [3], we do not have a simple model to describe the perceptions that result. It may be that there is no such simple model. In this work, we utilize some of the hints that the data suggests.

Retinal rivalry, a wonderfully apt name, occurs when the two eyes see different colors for the same spatial position in a scene. Under normal conditions, this occurs because of parallax; the edges of objects will obscure or reveal information in one eye but not the other. The disparity is processed by the brain to provide depth information. When there are large incongruent differences however, they are perceived as a visual dissonance, an uncomfortable oscillation of conflicting signals.

The amount of rivalry experienced depends in a complex way on the color differences presented to each eye and is actively being investigated by vision researchers [4]. One component that seems to be very important is the luminance difference. We may find that the dominant axis for retinal rivalry is indeed luminance, or it may be some other direction in our visual color space.

Until this phenomenon is better understood, we assume that there is *some* direction in tristimulus space that represents the dominant axis of rivalry sensation. We will be able to minimize the rivalry by constraining the left and right color values projected onto this axis to be equal.

In this paper, as a proxy for whatever the true rivalry axis is, we will use luminance. We therefore seek the constraint that the luminance delivered to left and right eyes are the same for all colors used in the anaglyph.

Dubois used a least squared error projector between the higher dimension original source image color space and the lower dimension color space of the filtered anaglyph. A variation of least squares projection is the "constrained least squares problem" which has been studied and has published solutions [5]. We do not detail the solution here, but outline its components.

Basically, we have constraint equations, and we have a distance metric. The problem is to find the minimum distance solution subject to meeting the constraint equations. In matrix form, we try to find the vector x subject to the constraint:

$$\mathbf{Kx} = \mathbf{d} \tag{7}$$

that minimizes the distance:

$$\left\| \mathbf{Ex} - \mathbf{f} \right\| \tag{8}$$

Our unknown **x** is the anaglyph RGB color $\mathbf{V_a}$.

For the rivalry minimization constraint, we require that the anaglyph result in equal components along the rivalry axis, which we are using tristimulus Y to represent. So the constraint equation is:

$$U_{a2} = U_{a5}$$

$$A_{21}V_{a1} + A_{22}V_{a2} + A_{23}V_{a3} = A_{51}V_{a1} + A_{52}V_{a2} + A_{53}V_{a3}$$

$$\left[(A_{21} - A_{51}) \quad (A_{22} - A_{52}) \quad (A_{23} - A_{53}) \right] \mathbf{V_a} = 0 \tag{9}$$

The distance metric can be the same one used by Dubois, the distance from filtered anaglyph tristimulus values to the original image tristimulus. An alternate metric is the distance from the filtered anaglyph to *filtered* views of the originals. The Dubois metric measures from the original true color of the scene, while the modified metric is a little less ambitious, comparing the anaglyph to filtered views of the original scene delivered separately to each eye. The latter gives up on perfect color reconstruction as the goal and replaces it with the goal of looking at the original scene as if wearing anaglyph glasses.

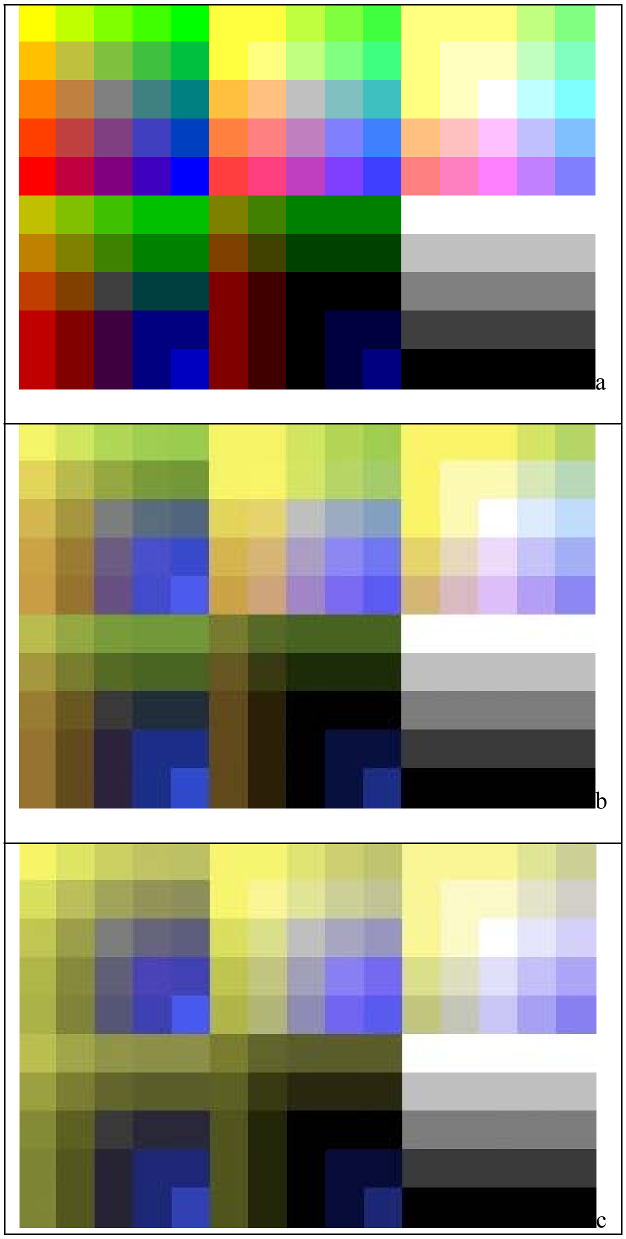


Figure 1a. *A collection of anaglyph test colors for evaluating retinal rivalry. The anaglyphs presented in this paper were computed for a specific LCD display (Toshiba Tecra 15" laptop, calibrated to D50) and viewed through red-cyan filter glasses (American Paper Optics). The effects described will be different on other display/glasses combinations.*

1b. *The colors resulting from the Dubois anaglyph method, including post-normalization to restore neutrals. Rivalry is reduced, but not minimized, by the least squares projection.*

1c. *The minimum rivalry colors that result from constraining the component along the rivalry axis (adapted luminance) as described in this paper. The view of these colors through either filter yields the same luminance, except where the display limits clip the color. Neutral is automatically preserved in this case (no post normalization step required).*

The original scene distance metric:

$$\| \mathbf{W}(\mathbf{U}_{\mathbf{a}} - \mathbf{U}_{\mathbf{src}}) \| = \| \mathbf{WAV}_{\mathbf{a}} - \mathbf{WC}_2\mathbf{V}_{\mathbf{src}} \| \qquad (10)$$

The filtered scene distance metric:

$$\| \mathbf{W}(\mathbf{U}_{\mathbf{a}} - \mathbf{U}_{\mathbf{filt}}) \| = \| \mathbf{WAV}_{\mathbf{a}} - \mathbf{WA}_2\mathbf{V}_{\mathbf{src}} \| \qquad (11)$$

W is an optional diagonal weighting matrix that can be used to place more importance on selected components of the difference. **WA** corresponds to **E** in equation (8), and the target **f** is derived from the source colors as $\mathbf{WC_2V_{src}}$ or $\mathbf{WA_2V_{src}}$.

The solution to the constrained least squares problem will include a matrix **M**, and a vector **b**, that reduces the six dimensions of the left and right originals, to the 3-dimensions of the final anaglyph colors we seek. The solution for $\mathbf{V_a}$ will look like:

$$\mathbf{V}_{\mathbf{a,minRivalry}} = \mathbf{M}_{\mathbf{minRivalry}}\ \mathbf{b}_{\mathbf{minRivalry}}(\mathbf{V}_{\mathbf{src}}) \qquad (12)$$

where matrix $\mathbf{M_{minRivalry}}$ and vector $\mathbf{b_{minRivalry}}$ are derived from the constraint (matrix **K**, vector **d**), and the target (matrix **E**, vector **f** and optional weighting **W**). The functional dependence of **b** on the source color is indicated as $\mathbf{b(V_{src})}$.

The anaglyph colors that result will yield the same Y value when viewed through either left or right filter. The X and Z components will be such that the distance to the desired color (either original scene color or filtered scene color) is minimized.

Although there is a minimum rivalry solution for all source colors, not all solutions are physically realizable in the anaglyph medium. In an RGB display we will encounter solutions with RGB components less than zero or greater than 1, forcing us to clip the anaglyph color to the available range. This results in an increase in retinal rivalry (the filtered luminances will no longer be equal in each eye).

Minimizing stereo crosstalk

Minimizing retinal rivalry optimizes the colors when the same source color is in both left and right images at the same position in the scene. This helps make the viewing of the anaglyph comfortable, suppressing the flashing effects of large binocular color differences. But presenting the same colors in the same positions to both eyes defeats the purpose of using anaglyphs to create a depth perception. It is only when there are color disparities that we can appreciate the stereo effects of parallax.

When we are looking at two differently colored objects in the scene at the same retinal position, we are faced with an additional problem. We want the anaglyph color that is selected to represent the two objects, to have low retinal rivalry, but we also want it to maintain color consistency with the colors of the two objects, as if we were seeing each object separately, when there is no disparity. These are conflicting requirements.

Consider a light colored object on a dark background. Where the left and right views of the foreground object share the same retinal position, we can find the minimal rivalry color to represent it. It will usually yield a high luminance. We can do the same with the background; the anaglyph color will be dark. In those areas where there is left and right disparity, the anaglyph color will have a compromise luminance. The combined view will show a luminance step in this area, appearing as an artifact in the coloring of the object, or as a ghost object in the background. This is an example of stereo crosstalk.

If we give up for the moment on rivalry minimization in these areas of stereo disparity, we can minimize the object coloring and background ghosting artifacts. We once again assume that someday we will understand incomplete chromatic adaptation well enough to identify a direction in the filtered tristimulus space that yields the greatest perceptual errors between two colors. But for today, we take that direction to be the adapted luminance, and proceed to find the anaglyph color that minimizes the error in this component in both left and right views. This will be the anaglyph color that minimizes crosstalk.

We can apply the same constrained least square fit method to solve for the minimum crosstalk condition. This time there are two constraint equations. The filtered luminances of the anaglyph color selected for that disparity region where the two objects overlap, must be the same as the luminances in the regions where there is no disparity. For the moment we set those luminances to be the same as the filtered source colors:

$$\mathbf{U}_{\mathbf{a2}} = \mathbf{U}_{\mathbf{filt,2}}\ ;\ \mathbf{U}_{\mathbf{a5}} = \mathbf{U}_{\mathbf{filt,5}} \qquad (13)$$

which is a constraint represented by:

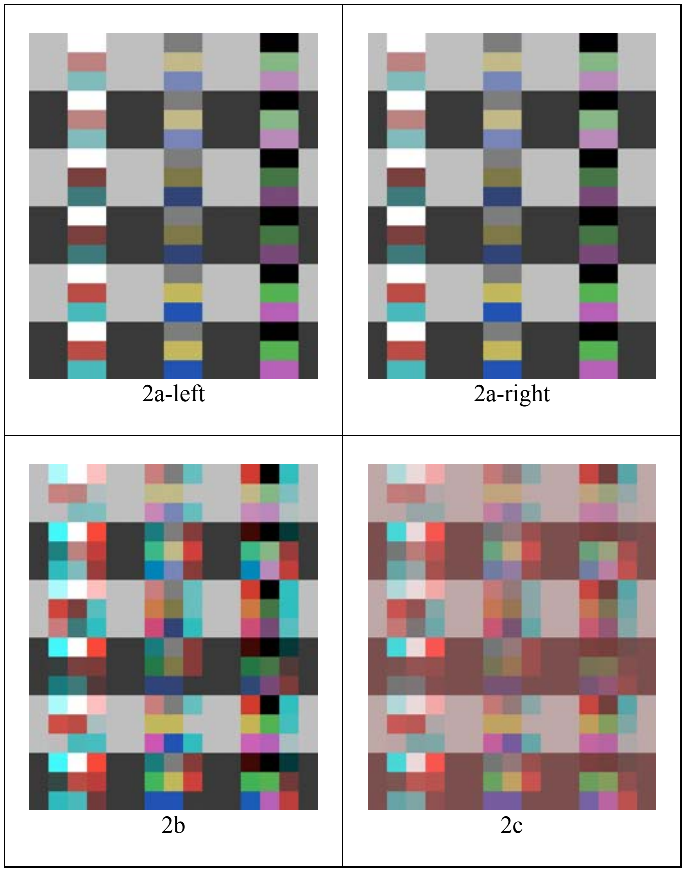
$$\begin{bmatrix} \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23} \\ \mathbf{A}_{51} & \mathbf{A}_{52} & \mathbf{A}_{53} \end{bmatrix} \mathbf{V}_{\mathbf{a}} = \begin{bmatrix} \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23} & 0 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{A}_{51} & \mathbf{A}_{52} & \mathbf{A}_{53} \end{bmatrix} \mathbf{V}_{\mathbf{src}} \qquad (14)$$

Solving this system of equations (the constraints here, augmented by the distance metric), yields an anaglyph color that has zero crosstalk (in the crosstalk axis). There may still be some small perceived color differences that result, which are along the other non-crosstalk-dominant directions.

The form of the solution is the same as before, but we now have a different solution matrix and a different function for obtaining the b vector:

$$\mathbf{V}_{\mathbf{a,minCrosstalk}} = \mathbf{M}_{\mathbf{minCrosstalk}}\ \mathbf{b}_{\mathbf{minCrosstalk}}(\mathbf{V}_{\mathbf{src}}) \qquad (15)$$

As we saw in the rivalry minimization, the solution may not be physically realizable. When the anaglyph color must be clipped to the available range, crosstalk will return. This is especially true for situations that include text or high contrast vector drawings (figure 3). The crosstalk solution provides some insight toward selecting color combinations that retain high contrast, but yield anaglyph colors that will fall within the range of the display.



2a-left

2a-right

2b

2c

Figure 2a*. Colors used for testing stereo crosstalk. These are various color patches shifted right and left on a gray background to make left and right source images.*

2b*. Anaglyph colors optimized for minimal crosstalk. Viewing through anaglyph glasses will show them floating above the background. Some computed colors fall outside the 0 to 1 range of the display and are clipped (left), resulting in residual crosstalk (uneven color patches and side ghosts). To eliminate it, the source image must be scaled and offset to provide "head- and foot-room" for those cases (**2c**).*

Combining rivalry and crosstalk optimization

We now have a means to find anaglyph colors which yield minimal retinal rivalry, and another means to find anaglyph colors that yield minimal left-right visual crosstalk. The rivalry minimization operated on colors that were identical in both left and right fields. The crosstalk minimization operated on the case where the two colors were different. We can combine the two solutions by concatenating them.

The crosstalk minimization constrained the "crosstalk axis component" of each color to match the value it would have when there is no difference in left and right fields. We are free to set those target values, since the constraints only called for a match, but not what the match target was. If we take that target to be the one prescribed by the rivalry minimization procedure (instead of the filtered source color luminance, as we did previously), we will have accomplished both objectives.

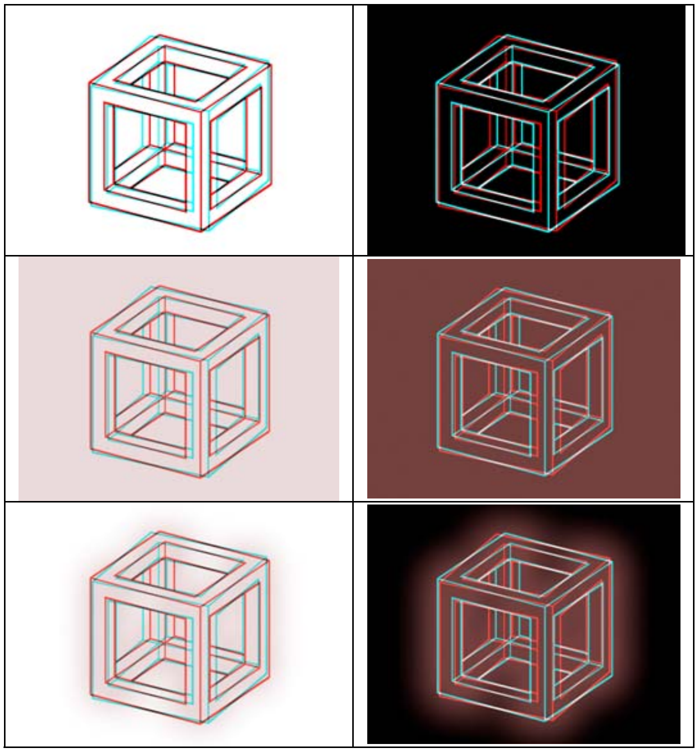


Figure 3*. Crosstalk can be eliminated, but only when the anaglyph colors are within the range of the display medium. In this example, high contrast edges map to anaglyph colors that have components falling outside the 0 to 1 RGB range. The clipped values show up as residual crosstalk (upper images). The artifact can be completely eliminated by scaling and offsetting the source appropriately to avoid any clipping, but at the expense of reduced contrast (center). As a compromise, the clip error-induced crosstalk can be distributed over a spatial area that may be less distracting and allow retaining the global contrast.*

Our two stage solution starts with finding the minimum rivalry colors for the colors from each view

$$\begin{aligned}\mathbf{V}_{\mathbf{minRiv,l}} &= \mathbf{M}_{\mathbf{minRivalry}}\ \mathbf{b}_{\mathbf{minRivalry}}\left(\begin{bmatrix}\mathbf{V}_{\mathbf{src,l}}\\ \mathbf{V}_{\mathbf{src,l}}\end{bmatrix}\right)\\ \mathbf{V}_{\mathbf{minRiv,r}} &= \mathbf{M}_{\mathbf{minRivalry}}\ \mathbf{b}_{\mathbf{minRivalry}}\left(\begin{bmatrix}\mathbf{V}_{\mathbf{src,r}}\\ \mathbf{V}_{\mathbf{src,r}}\end{bmatrix}\right)\end{aligned} \qquad (16)$$

We then form a source color from these minimum rivalry colors, apply our zero crosstalk constraint, and solve for the final color to be used in the anaglyph. This is the optimized anaglyph color we seek.

$$\mathbf{V}_{\mathbf{a}} = \mathbf{M}_{\mathbf{minCrosstalk}}\ \mathbf{b}_{\mathbf{minCrosstalk}}\left(\begin{bmatrix}\mathbf{V}_{\mathbf{minRiv,l}}\\ \mathbf{V}_{\mathbf{minRiv,r}}\end{bmatrix}\right) \qquad (17)$$

Some examples of applying the combined anaglyph methods are shown in accompanying figures.

Summary and Conclusions

We have described the anaglyph problem framework introduced by Dubois, and extended it to include partial chromatic adaptation. Full luminance adaptation resulted in solutions that preserved neutral colors without a post-process normalization step.

The concept of a retinal rivalry axis in adapted tristimulus space was introduced, and the constrained least squares solution to minimize rivalry was outlined. We used luminance as a proxy for the rivalry axis, and obtained anaglyph colors that resulted in identical luminances in the filtered left and right views.

A similar approach was used to minimize stereo crosstalk. The solution results in some colors that cannot be physically realized, and when clipped to the range of the anaglyph medium, cause residual crosstalk. It can be avoided by restricting the source color range, but this reduces the overall contrast of the anaglyph.

The two solutions can be combined to achieve a minimum rivalry, minimum crosstalk, anaglyph whose colors are perceptually closest to the original source colors, or to a filtered view of the original scene. To avoid residual crosstalk, the source colors can be scaled so that they remain in range of the display.

We used a linear display and filter set to present the anaglyph problem. The mathematics is tractable, and convenient to better understand the relationships involved between retinal rivalry, stereo crosstalk, and color fidelity. This may be useful in approaching the more difficult problems that will be posed by the non-additive colors of *printed* anaglyphs.

Acknowledgements

Thanks to Eric Dubois for assistance in reconstructing his anaglyph problem framework and understanding the vector space projections involved.

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Author Biography

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When not investigating the color behavior of printers, Thor pursues interests in astrophotography and stereo imaging, sometimes even combining them. Some of this work is presented at http://www.nightscapes.net/photos/stereo

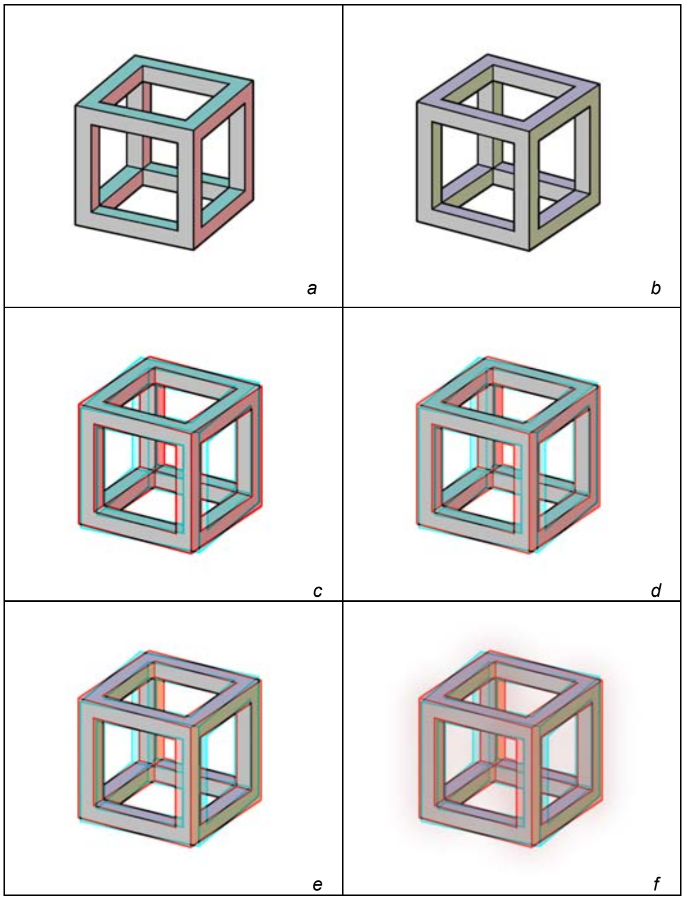

Figure 4 *Anaglyph development.* ***a:*** *Original scene (left view).* ***b:*** *Minimum rivalry version of the image (right view).* ***c:*** *Photoshop method (the red channel of the left image is substituted into the red channel of the right image to make this anaglyph).* ***d:*** *Minimum crosstalk (but no rivalry minimization). Clipping to the display range results in residual crosstalk, especially evident in the edge lines.* ***e:*** *Minimum rivalry combined with minimum crosstalk- no source scaling.* ***f:*** *The crosstalk effects of display range clipping are eliminated by source color scaling, in this case spatially distributed to maintain overall contrast.*

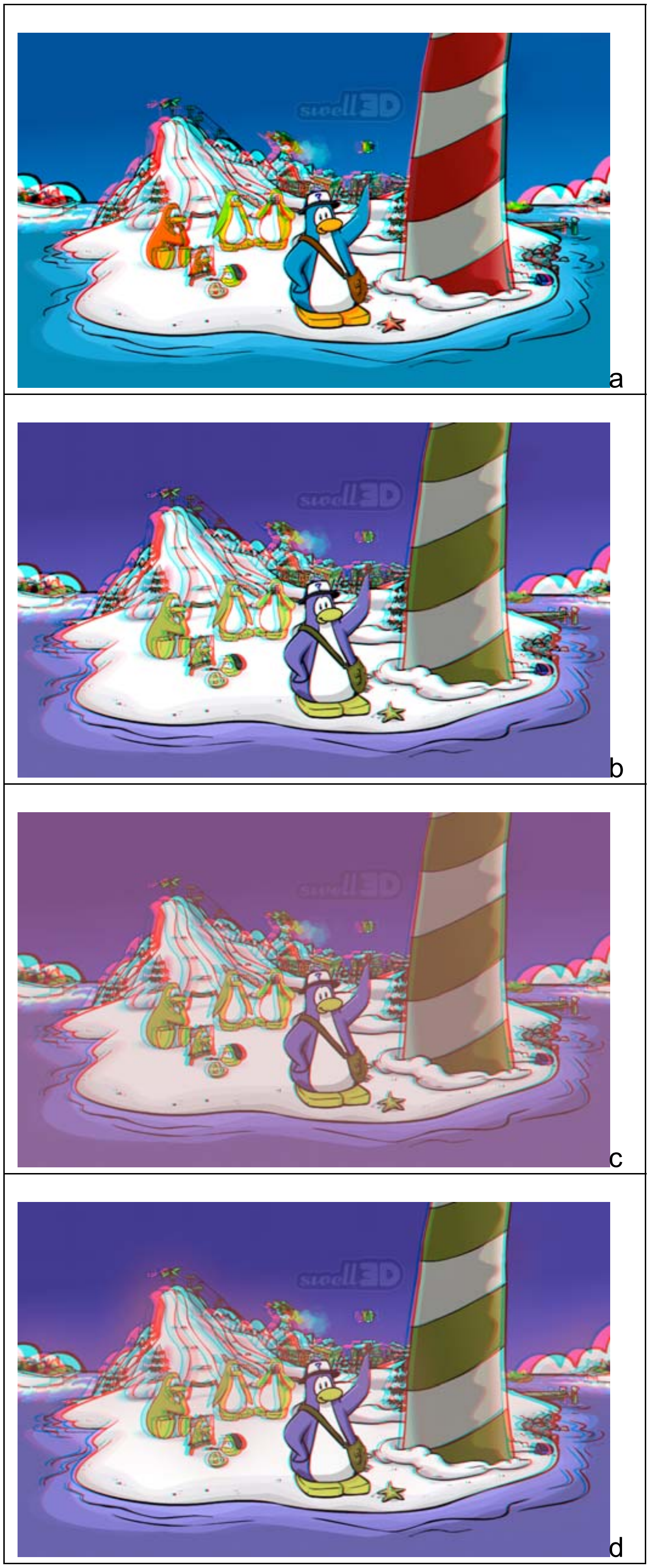

Figure 5. *An anaglyph challenge from swell3D.com [6],* ***a)****The Photoshop method. Color is fully preserved but retinal rivalry and crosstalk are severe.* ***b)*** *Minimized retinal rivalry and crosstalk method, but display range clipping results in significant crosstalk.* ***c)*** *Scaling and offsetting the source images to avoid crosstalk due to display range clipping. The crosstalk is eliminated but the overall contrast of the image suffers.* ***d)*** *Spatially selective application of source scaling in order to recover image contrast without re-introducing crosstalk*

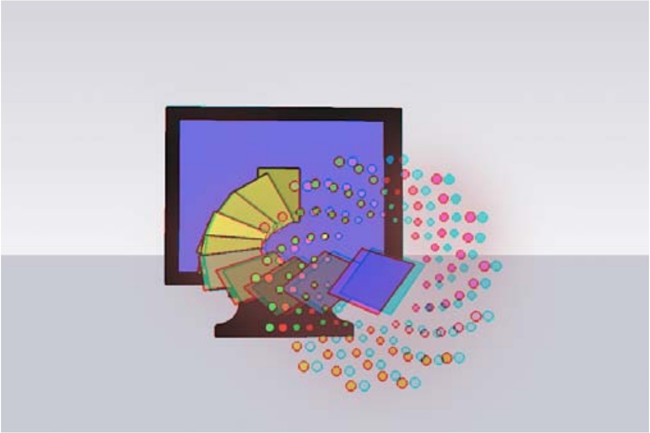

Figure 6*. An anaglyphic rendering of the CIC logo.*

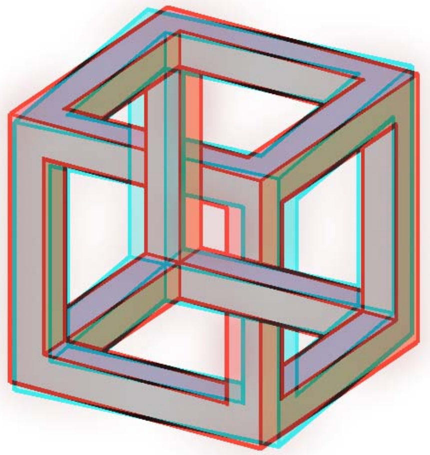

Figure 7*. By applying the methods described in this paper, the visual artifacts of retinal rivalry and stereo crosstalk can be reduced enough so that we can enjoy the higher level cognitive dissonance of viewing this Necker Cube as a 3D stereo anaglyph.*