

Creating a Color Anaglyph from a Pseudo-Stereo Pair of Images

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ABSTRACT

Anaglyphs provide an inexpensive method for the 3D visualization of a scene by superimposing a pair of stereo images in different color planes of single image, for subsequent viewing through colored glasses,. For example, the left image may be viewed through a red filter and the right image through a green or cyan filter. The resulting scene may appear in monochrome (yellow or grey), or in color with possibly some ghosting visible. In this paper we present a method of filtering the color of the anaglyph and controlling the amount of saturation in order to eliminate the ghosting effect while maintaining the 3D visualization. We, also describe the method we use to construct pseudo stereo pair images from two more general views, for use in an anaglyph.

Key Words: Anaglyphs, Hue, Saturation, Intensity, Stereopsis, Ghosting.

1. INTRODUCTION

Stereopsis is the term that refers to the combination of images presented to both eyes to achieve a 3D perception of the world according to Steinman et al [1].Several technologies have been developed for 3D visualization including glasses independent auto stereoscopic displays, glasses dependent Time-Multiplexed stereo rendering and glasses dependent Time-Parallel stereo rendering. The first method may use a parallax technique within the display to prevent one eye seeing the image intended for the other. The second

method displays the left and right images alternatively and views through synchronized shuttered glasses, while the third method views the left and right images at the same time through polarizing or colored filters. The latter anaglyph technique is the simplest and least expensive way to generate and view stereoscopic images. An anaglyph is generated by superimposing a pair of stereo images in different color planes of a single image which is then viewed through suitable colored glasses so each eye sees only the appropriate image. Red and green or red and green/blue are the

colors often used in the left and right sides of the glasses respectively.

The 2D anaglyph is viewed as a 3D scene when the red filter blocks the blue/green components of the anaglyph image, so the left eye sees only the red image formed from the left image and in similar way the blue/green filter blocks the red component of the anaglyph and thus the right eye sees only the blue/green component formed from the right image. This technique allows the visual cortex to fuse the viewed images so our brain interprets them as a 3D impression with combined colors resulting from the colors in the superimposed images.

The first anaglyph image was produced in 1853 by Wilhelm Rollmann in Leipzig and by J.C.D Almedia as mentioned in [2], but it was patented in 1891 by Louis Ducos du Hauron. Anaglyphs can be used in many applications including video games, theatrical films, DVDs and in science. In science the depth perception has many uses. It can reveal geologic features by improving the visualization quality of geomorphological maps [3]. It is used in NASA applications such as the 2003 Mars Exploration Rover Mission [4] and the current STEREO mission for solar investigation which uses two spacecraft orbiting around the Sun to provide the two different views of the sun at the same time [5]. In medical applications anaglyphs are used for exploring budding viral particles [6], and for visualizing the heart in 3D using ultra-sound. In this paper we propose a method to generate color or monochrome anaglyph images from un-calibrated image pairs. This method applies filters to control the color content of the left and right components of the anaglyph to eliminate ghosting effects while allowing the amount of saturation to be adjusted in order to ensure corresponding features are presented to both eyes so a 3D visualization results. In section 2, we discuss problems related to generating anaglyphs, in section 3 we survey the previous work, in section 4 we present our method and in section 5 we show some experimental results. Some

suggestions for future work are indicated in section 6.

2. Related Problems

Although anaglyphs provide an inexpensive means of 3D visualization, there are some drawbacks related to their use. The primary disadvantage is that, unlike the shuttered or polarizing glasses techniques, the use of a fixed pair of color filters does not allow the generation of arbitrary ghost free full-color 3D visualizations. Each pixel in an anaglyph gets its color from both left and right images and the result is grey for equal red/cyan combination and yellow for the equal red/green combination. It is a challenging task to accurately display the colours of the original stereo image into a single pixel in the anaglyph image. The problems which may cause degradation of the quality of the anaglyph are, ghosting or crosstalk, retinal rivalry or called binocular rivalry, and colour merging. Ghosting reduces, and might sometimes prevent the viewer perceiving depth [7]. This phenomenon occurs when the eye sees the image it is supposed to see and also a part of the other image which should be totally blocked from the sight of this eye. This may result in a double image in some parts of the scene. Retinal rivalry or binocular rivalry occurs when all colours are not displayed by the display device. Color merging is the phenomenon which occurs when color components of the left and right images are transferred to the same color [8].

3. Previous Work

Several methods have been proposed to generate anaglyphs. The Photoshop method (PS) [8] is the simplest for implementation. In this method for every pixel in the anaglyph image, the red value is the red color component of the left image and the blue/green value is the blue/green color component of the right image. However, for example, if an imaged region is red then it will only be visible to the left eye and will not produce a 3D effect.

In the modified Photoshop method (MPS), the same technique is followed, but the red and blue/green anaglyph values are the intensity values calculated from the left and right color images respectively. This produces a grey anaglyph when corresponding left and right image features have equal intensity. The original PS algorithm and its variant the modified PS method don't take into account the transmission function of the filters, as a result the generated anaglyph will be the same regardless of the type of glasses we use.

Another linear method for generating anaglyphs was proposed by Dubois [8], who took into account the fact that the color transmission properties of the glasses in the computation of the anaglyph. Based on a least squares approach, another method was proposed by Zhang and McAllister [9]. This takes into account the spectral distribution of the display primaries and the transmission function of the filters in attempting to improve the quality of the anaglyph. In [8] Sanders and McAllister introduced a method to create anaglyph which depends on minimizing the distance between colour channels visible through the glasses. In [10] a study -generating colour anaglyph takes into account three functions: the transmission properties of the filters, the spectral density function of the display primaries and, the color metric properties of the human visual system. This attempted to generate anaglyph images which are as similar as possible to the original stereo-pair images.

The work in [8] demonstrates some of the problems which afflict the generation of anaglyphs with high color quality. They used a stereo pair of images of an Indian mother and her daughter of size 443 x 389 pixels, to test the performance of the three algorithms PS method, Midpoint method, and the least square method. Creating an anaglyph using the PS method resulted in a ghosting problem. The results of applying the midpoint algorithm to generate anaglyphs show that, there are some

resulting colors out of the RGB color range. For this reason a clipping process is performed. Although this method takes into account the properties of the filters, it still suffers from ghosting. Analyzing the anaglyphs that resulted from Eric Dubois method (Least square) shows that, this method requires the clipping process, but on the other hand no ghosting was detected in the tested anaglyph image. While the Midpoint algorithm is the best for forming anaglyph with high quality colours and good details, it still suffers from ghosting. On the other hand, the least square method produces anaglyph image which is a bit dark with less details, and this can be solved by applying gamma correction, but the advantage of this method is that, there is little ghosting. Finally, the PS method is the simplest method for executing, but it suffers ghosting and poor colour quality representation as shown in [8]. From the previous comparison we found that none of the previous described methods can produce colour anaglyph without any ghosting or region merging.

This motivated some researchers to find methods to solve the ghosting problem and generate anaglyph with better quality. In [11], the authors proposed three methods to produce anaglyphs with high quality and minimize the undesired ghosting artifacts. They achieved this by employing the following three methods, Stereo Pair Registration, Colour Components Blurring, and Depth Map Manipulation and Artificial Stereo Pair Synthesis. In [12] the authors proposed a new method for panorama visualization, which is based on a colour anaglyph technique. This new method has the advantage, of providing binocular depth cues, over the classical panorama visualization method which provides only monocular depth cues. To achieve their aim they presented a new reprojection method to enhance the quality of anaglyphic panoramas.

Some studies tackle the problem of crosstalk reduction. The first method for crosstalk reduction was introduced by Lipscomb and

Wooten [13]. In this method they divided the area of display horizontally into many parts, and then they applied a subtractive function for each horizontal part separately. This method suffers from loss of contrast which is a result of the contrast reducing mapping process applied to permit for some subtractive reduction in uncorrectable areas. Konrad et al. [14] introduced a user-calibration subtractive reduction method. Konrad et al. assume that the crosstalk is constant over the whole display region, and this doesn't guarantee that the algorithm will work properly on bottom bands of the display area. This method might require a contrast reduction to allow for some amount of intensity reduction in uncorrectable region. Another real-time method was proposed by Klimenko et al. [14]. As this approach is based on the Lipscomb and Wooten method [13], it will have the same drawbacks which are related to the loss of contrast resulting from applying a contrast reducing mapping to enable it to perform more reduction in the uncorrectable regions. Smith et al. [15] introduced a user calibration method. He considered in his study that crosstalk is varying over the whole display area which allows crosstalk reduction over the whole display area. However, it still suffers some drawbacks resulting from the nature of the subtractive reduction method.

The previously described methods are performed on the RGB colour space, and all have a similar technique which is based on reducing crosstalk for every colour component separately, and this causes in failure of the method in regions including more than one colour. This motivates the improvement of the crosstalk reduction software methods. In [16], the authors presented three methods to reduce the ghosting or crosstalk; his methods operate on the CIELAB color space, and reduces crosstalk for all colour components at the same time. The results of applying the three proposed methods show improvement over the results of the traditional subtractive method.

Sanders and McAllister [8] presented a similar method in synthetic anaglyphic stereo image. In this method color components of interest of the corresponding left and right pixels are transferred into the CIELAB color space, and then we the single resulting color found which is viewed in the anaglyph image. This technique seeks to produce anaglyph image visible through the colour glasses which is as similar as possible to the original input stereo images. This achieved by reducing the difference between the colors of interest and the color visible through the filters.

In [17], the authors seek to identify the crosstalk in anaglyph 3D images. They base their study on the fact that ghosting phenomenon can occur because of many factors such as: display spectral response, anaglyph glasses spectral response, image compression, image encoding and transmission. They tested in their projects several combinations of many types of filters and different types of display devices.

4. Proposed Method

In this study the algorithm for generating anaglyph image is incorporated into a windows-based application, using the Microsoft visual C++ compiler version 6. This method can handle both monochrome and color pair images of the same scene. Our algorithm for generating an anaglyph image can be described as the following:

1. Find a minimum of eight corresponding points across the image pairs. In this work these points are found manually.
2. Find the fundamental matrix. This matrix is a 3x3 matrix of rank 2. It encapsulates the geometrical relationship between positions for the two cameras.
3. Rectify the pair of images. The aim of rectification is to make the epipolar lines parallel and horizontal with the same vertical position in the rectified pair of images.

4. Finally, generate the anaglyph image by a method which involves simple modifications of the PS methods described in the literature. The color components used for the left and right components of the anaglyph can be adjusted manually to suite the filter in the glasses used. These are usually red and green or red and red and cyan.

In this work we used red/cyan/ glasses. We are mainly concerned with achieving good 3D visualization while maintaining the original colors as far as possible. We have chosen to do this by modifying the saturation of the original color images. Reducing the saturation to zero would give an anaglyph with a grey appearance with and good 3D visualization. Leaving the saturation unaltered will, if some of the original colors in the images are the same as those in the filters result in poor 3D visualization. Reducing the saturation for this case will weaken the color but improve the 3D visualization. So our software provides the ability to modify the color of the anaglyph by controlling the amount of saturation. We use the mathematical calculations described below to adjust the saturation. We denote R, G, B the color components of an image pixel before modifying the saturation, and R', G', B' the color components of the pixel after applying the modification. The saturation of a color is denoted by S and it is determined by a combination of light intensity I which can be calculated from (1) and how much it is distributed across the spectrum of different wavelengths. The purest colour is achieved by using just one wavelength at a high intensity, such as in laser light. If the intensity drops, so does the saturation. To de-saturate a colour in a subtractive system (such as watercolor), you can add white, black, gray, or the hue's complement.

We have three cases to handle; firstly, if the minimum value for colour component is B , then the calculation will be done in this framework. We have R, G, B known values,

and we want to find out the values of R', G' . We can calculate the saturation value before and after colour modifying as in (2, 3).

$$I = \frac{R+G+B}{3} \quad (1)$$

$$S = \frac{B}{I} \quad (2)$$

$$S' = \frac{B'}{I} \quad (3)$$

The hue is computed using (2) and (3) for the old image and the modified saturation image as shown in (4) and (5).

$$H = \frac{R-B}{G-B} \quad (4)$$

$$H' = \frac{R'-B'}{G'-B'} \quad (5)$$

We want to modify the value of saturation, but at the same time we want to keep the same hue and intensity before and after the modification. So we have to find out B' , and G' which satisfy the following equations:

$$\frac{R'-B'}{G'-B'} = \frac{R-B}{G-B} \quad (6)$$

$$R' + G' + B' = 3I = R + G + B \quad (7)$$

so we find B' as shown in (8).

$$B' = I(1 - S') \quad (8)$$

From equations 6 and 7 we calculate R' as shown in (9)

$$R' = \frac{B'(G+B-2R)+3I(R-B)}{(R+G-2B)} \quad (9)$$

By substituting R' in (6) or (7) we find G' as shown in (10)

$$G' = \frac{B'(R+B-2G)+3I(G-B)}{(R+G-2B)} \quad (10)$$

Secondly, If R' is the minimum value, then by similar computation we find the values of B' and G' as shown in (11, 12).

$$G' = \frac{R'(R+B-2G)+3I(G-R)}{(B+G-2R)} \quad (11)$$

$$B' = \frac{R'(R+G-2B)+3I(B-R)}{(B+G-2R)} \quad (12)$$

Finally, if G' is the minimum value, we derive the values of R' , and B' in similar way to that used in the first case as shown in (13, 14).

$$R' = \frac{G'(G+B-2R)+3I(R-G)}{(R+B-2G)} \quad (13)$$

$$B' = \frac{G'(R+G-2B)+3I(B-G)}{(R+B-2G)} \quad (14)$$

5. Experimental Results

In our work we are investigating aerial images of rural and urban scenes and architectural images. But we present our results for two rural scenes corresponding to archaeological sites, these images were taken from a light aircraft flying freely over the sites. It is important to note that these images are subject to changes for different reasons such as weather and the growing of a crop, etc. In Fig 1, we present anaglyph images created from rectified versions of color images of a hill fort in Scotland. The original image pair was captured at 2674 x 2664 pixels show a flat topped hill with burnt sloping slides. First of all, the fully saturated color anaglyph shown in Fig 1.a was generated. Then the saturation of the anaglyph was modified in step to zero to improve the 3D visualization. The results are shown in Fig 1 (a, b, c, d, and e) with saturation decreasing gradually 1, 0.7, 0.5, 0.3, and 0. A second archaeological rural scene is shown in Fig 2 (a, b, c, d, and e) saturated

values 1, 0.7, 0.5, 0.3, and 0 respectively. In both cases the saturation value of 0.5 gave a good compromise between good 3D visualization and color content.

6. Conclusion

None of the existing methods can produce an anaglyph using color filters which will accurately reproduce the original colors without ghosting for a combination of arbitrary colour image and a fixed pair of coloured glasses, although they may work well in some cases. Some of the existing methods also have significant computational overhead. Given this, our approach is computationally simple and flexible, allowing the user to select the level of compromise between the amounts of colour and ghosting in the anaglyph appropriate for different cases. Users who have access to only a standard pair of color glasses should find the proposed approach very useful. The quick and flexible output of 3-D information, given some known 3D points in a scene of any type, using the fusing ability of the human eye rather than software attempting to find correspondences could also be useful in some circumstances.

7. Future Work

The main target of this study is to enhance the anaglyph visualization of uncalibrated pairs of images of a scene. Before generating the anaglyph we used rectification, and after generating the anaglyph we used the saturation to reduce ghosting effect. In future work we will focus on enhancing the original images before generating the anaglyph using a super resolution technique to show more details. We also intend to automate the search for corresponding points for the rural type scene as an alternative to the current manual search.

Appendix

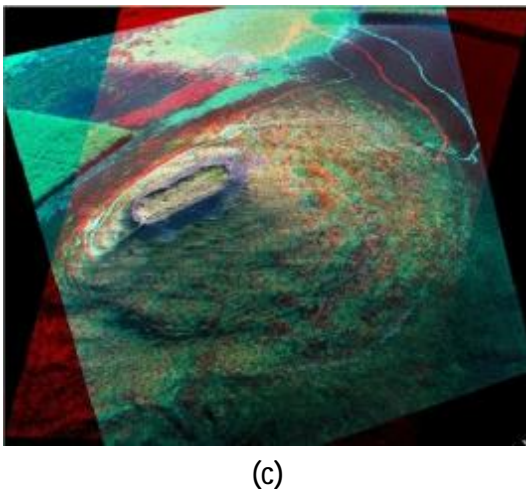
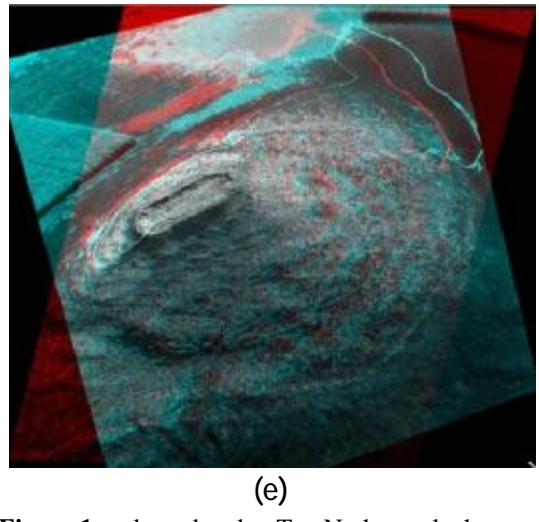
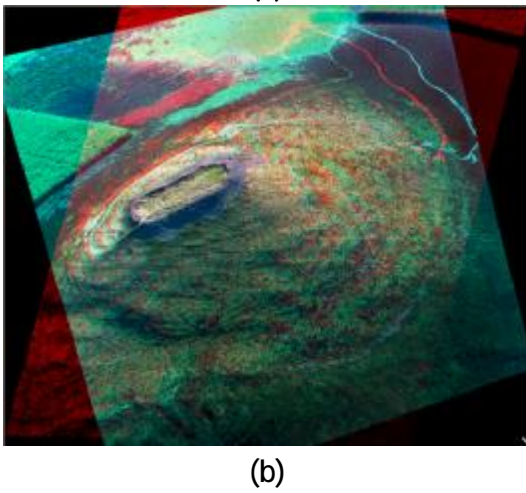
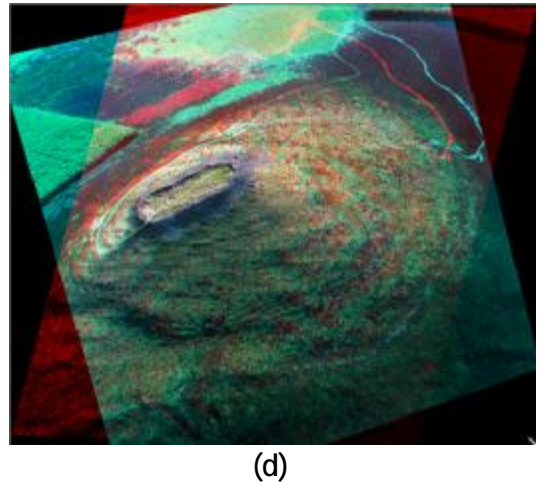
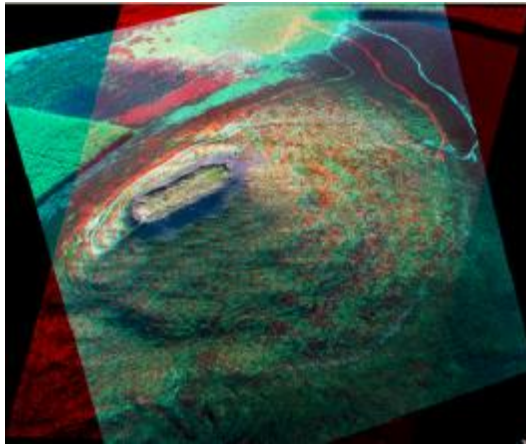
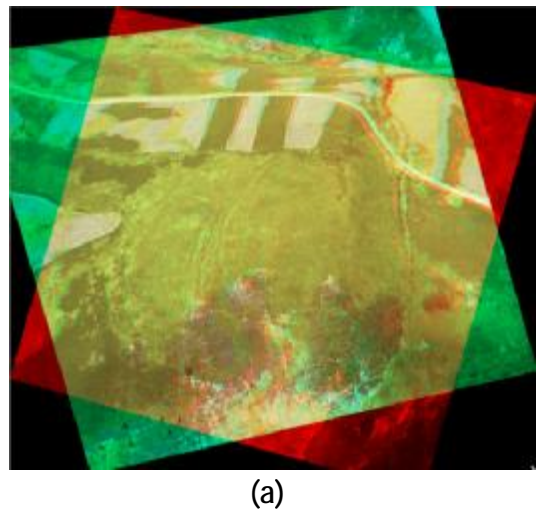
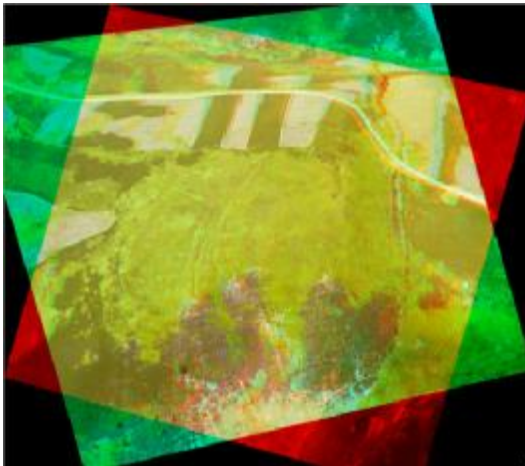
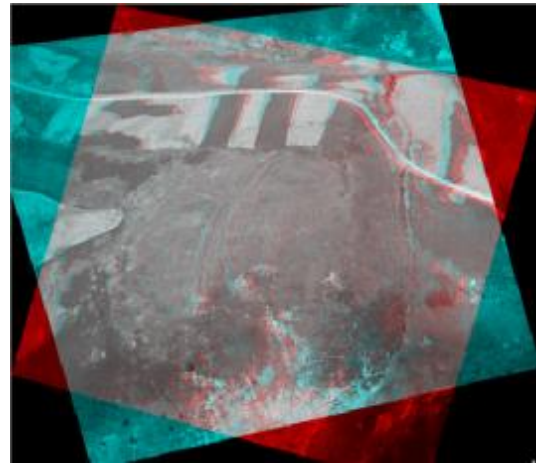


Figure 1: a, b, c, d and e, Tap Noth anaglyphs are shown with saturated values: 1, 0.7, 0.5, 0.3, and 0 respectively.

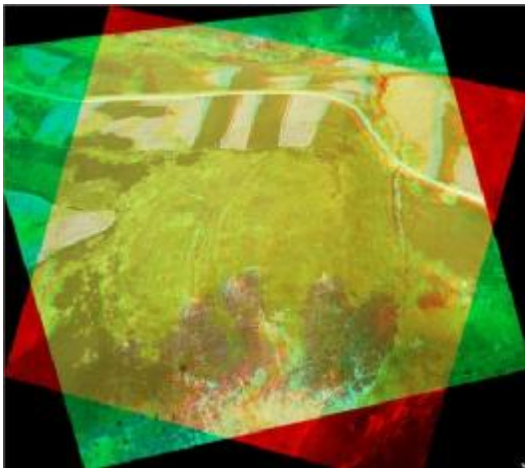




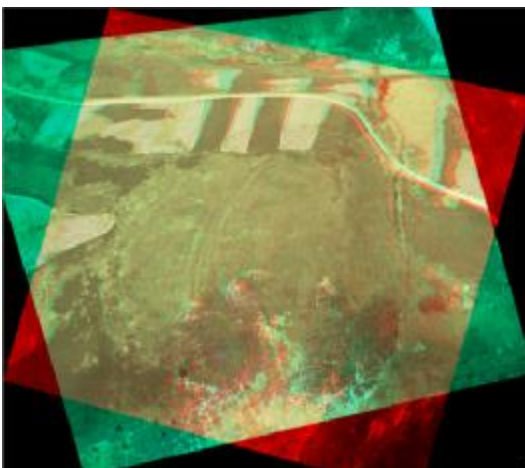
(b)



(e)



(c)



(d)

Figure 2: a, b, c, d and e, Thumber land anaglyphs are shown with saturated values: 1, 0.7, 0.5, 0.3, and 0 respectively.

REFERENCES

- [1] S. B. Steinman, *Foundations of binocular vision: A clinical perspective*: McGraw-Hill Medical, 2000.
- [2] H. Gernsheim and A. Gernsheim, *The History of Photography from the Camera Obscura to the Beginning of the Modern Era*: McGraw-Hill, 1969.
- [3] P. J. Styles, "The Production Of Anaglyphs From Spot-HRV Panchromatic Data For Geomorphological Mapping," 1988.
- [4] M. W. Powell, J. S. Norris, M. A. Vona Iii, P. G. Backes, and J. V. Wick, "Scientific Visualization for the Mars Exploration Rovers," 2005.
- [5] M. J. N. Aschwanden, Nariaki V.; Wuelser, Jean-Pierre; Lemen, James R, "First 3D Reconstructions of Coronal Loops with the STEREO A+B Spacecraft. II. Electron Density and Temperature Measurements," *The Astrophysical Journal*, Volume 680, Issue 2, pp. 1477-1495, 2008.
- [6] J. E. Heuser, "Membrane Traffic in Anaglyph Stereo," *Traffic*, vol. 1, pp. 35-37, 2000.
- [7] Y. Yei-Yu and D. S. Louis, "Limits of fusion and depth judgment in stereoscopic color displays," *Hum. Factors*, vol. 32, pp. 45-60, 1990.
- [8] W. Sanders and D. F. McAllister, "Producing Anaglyphs from Synthetic Images," 2003.
- [9] Z. Zhang and D. F. McAllister, "A Uniform Metric for Anaglyph Calculation," 2006.
- [10] E. Dubois, "A projection method to generate anaglyph stereo images," 2001.
- [11] I. Ideses and L. Yaroslavsky, "Three methods that improve the visual quality of colour anaglyphs," *JOURNAL OF OPTICS A PURE AND APPLIED OPTICS*, vol. 7, pp. 755, 2005.

- [12] S. K. Wei, Y. F. Huang, and R. Klette, "Three-dimensional scene navigation through anaglyphic panorama visualization," *LECTURE NOTES IN COMPUTER SCIENCE*, pp. 542-549, 1999.
- [13] J. S. Lipscomb and W. L. Wooten, "Reducing crosstalk between stereoscopic views," 1994.
- [14] J. Konrad, B. Lacotte, and E. Dubois, "Cancellation of image crosstalk in time-sequential displays of stereoscopic video," *Image Processing, IEEE Transactions on*, vol. 9, pp. 897-908, 2000.
- [15] F. A. Smit, R. van Liere, and B. Froehlich, "Non-Uniform Crosstalk Reduction for Dynamic Scenes," 2007.
- [16] F. A. Smit, R. van Liere, and B. Froehlich, "Three Extensions to Subtractive Crosstalk Reduction."
- [17] A. J. Woods and T. Rourke, "Ghosting in anaglyphic stereoscopic images," 2004.