CONSISTENT COLOR RESAMPLE IN DIGITAL ORTHOPHOTO PRODUCTION

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ABSTRACT
Orthophoto map, ortho-rectified image, constitutes a central component of the mapping and GIS activities in general and of photogrammetric mapping products in particular. Technological developments of recent decades lead to the ability to produce color digital orthophotos from aerial and satellite imagery. As the source imagery acquired by the sensors are of high quality and density, radio metrical quality of the orthophoto products is dependent on the ability to perform a high quality sampling of the colors from the original image into the target ortho-rectified image. This dependency is due to the nature of the geometrical transformation from the orthophoto coordinate system to the image (camera) coordinate system and vice-versa. In this transformation, the source location of a point (pixel) in the target orthophoto is positioned on at least four adjacent pixels in the source image (when the density of the orthophoto is of the same or higher than the source image density). In this case, the color selected for the pixel in the orthophoto is calculated by interpolating the colors of these source image pixels. This interpolation is performed on each of the components of RGB (red, green, blue) values representing the color. The interpolation of this representation of the color by its components is not consistent. Therefore, the interpolated color is not an accurate mix of the source colors.

A new algorithm is proposed for calculating the colors of pixels in the target orthophoto. The algorithm is aimed at achieving an accurate and consistent mix of the source colors and it is based on using a different approach to representing the colors, namely, HSI (hue, saturation, and intensity). In Contrast with the current relatively inaccurate methods of interpolating colors, the proposed algorithm facilitates an accurate mix of the source pixel colors by interpolating its components.

Key words: Orthophoto, RGB, HSI, Color, Re-sampling.

INTRODUCTION

Remote Sensing imagery in general and Aerial photographs in particular is captured using perspective projections. Such that the image presents a perspective view of the world. In an aerial photograph, objects which are located one the same planar location but at different heights will be projected to different positions in the image. Ortho-rectification is a process that eliminates these relief displacements and results with an orthographic projection. As a result of the rectification, the orthophoto is an image that has a consistent scale and can be used as a planimetric map. Orthophoto rectification by backward projection is done by re-projecting the terrain onto the image using the mathematical model of the camera while copying the color of the source image into the target ortho-image. Orthophoto production is widely discussed in the photogrammetic literature in general; among others it is found in Wolf & de Witt (2000) and in Mikhail, et al. (2001).

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Interpolating colors is mostly dealt with in the context of digital cameras which uses a color filter array (CFA) in order to capture images with a single sensor array (CCD), resulting in a sub-sampled raw image with a single R, G, or B component for each pixel of the image. In this case, to reconstruct a full color image from the raw sensor data, a color interpolation of the neighboring samples is required in order to fill in the missing two colors of each pixel. This operation is called de-mosaicking – Kimmel (1999), Gunturk et al. (2002). For this matter a common method is to perform the color interpolation by separating the colors into luminance and chrominance channels while performing the interpolation on these channels rather than on the source R, G, B channels. One approach is called smooth hue transition, which is based on the assumption that hue does not change abruptly between neighboring pixels locations – Ramanath et al. (2002). Other approaches suggests

PROPOSED COLOR RESAMPLE APPROACH

Orthophoto maps are compiled by applying a geometrical transformation from the orthophoto coordinate system to the image (camera) coordinate system and vice-versa while copying the color information using re-sampling methods. In this transformation, the source location of a point (pixel) in the target orthophoto is positioned on at least four adjacent pixels in the source image. Particularly, when the density of the target orthophoto is the same or higher than the source image density. In this case, the color selected for the pixel in the orthophoto is calculated by interpolating the colors of these source image pixels usually by a bilinear interpolation. This interpolation is performed on each of the components of RGB (red, green, blue) values representing the color.

Due to the nature of the RGB color space, where the components constitutes a three dimensional coordinate system forming a cube without any relation to the nature of colors, the interpolation of this representation of the color by its components is not consistent. Therefore, the interpolated result color is not an accurate mix of the source colors. This is due to the nature of the RGB color space where every color is represented as a point in the spatial three-dimensional space. Thus four points form a bilinear surface on a quadrilateral base. The bilinear interpolation of these points in space, results with a point on the bilinear surface which is not the accurate mix of colors. Hue, which is defined as the property of colors determined by the dominant wavelength of the light, is not preserved when interpolating the RGB components.

The proposed algorithm is to use HSI color representation when calculating the re-sampled color (mix of colors) from the source image rather than using the colors in RGB representation. Meaning, the color of the target orthophoto pixel will be calculated using interpolation of the HSI representations of the pixel colors from the source image. When the target color is calculated as HSI, it then can be converted back to RGB representation in order to get recorded in the target orthophoto image. This is under the assumption that the color values are stored in target ortho-image as RGB component values, which is the most common method of storing the colors in a digital image. Equations (1) - (3) below describes the conversion of the color representation from RGB color space to the HSI color space. The backward conversion from of the color from HSI color space to RGB color space is described by equations (4) - (6). These conversions defines a one-to-one mapping between RGB and HSI color spaces.

RGB to HSI Conversion

A color specified using its RGB components, is given where each component is given in the closed-range $[0..1]$; such that the value 0 represents the minimal intensity (black) and the value 1 represents the maximal intensity (white). Conversion of the color from it's RGB to HSI representation is done as follows:

⇒ The Intensity is defined as the average intensity of the color components $\{r, g, b\}$:

$$I(r, g, b) = \frac{r + g + b}{3} \tag{1}$$

⇒ The Saturation S is defined by the length of the vector between the point representing mean intensity, which is lying on the grey axis, to the color point in the RGB color space given by the color components $\{r,g,b\}$. That is, the Euclidian distance between the points $\{I,I,I\}$ and $\{r,g,b\}$:

$$S(r,g,b)=\sqrt{(r-I)^2+(g-I)^2+(b-I)^2} \tag{2}$$

⇒ The Hue, which denotes the base color, is given by an angle in the closed-range $[0..2\pi]$ (which is $[0°..360°]$). It is calculated as follows:

$$H=\begin{cases} arctg\left(\frac{\sqrt{3}(g-r)}{2b-g-r}\right) & |(2b-g-r)\neq 0 \\ \begin{cases} \frac{3\pi}{2} & |g<r \\ \frac{\pi}{2} & |g\geq r \end{cases} & |(2b-g-r)=0 \end{cases} \tag{3}$$

HSI to RGB Conversion

Converting a color represented by its HSI components to RGB representation where each component is given in the closed-range $[0..1]$, such that the value 0 represents the minimal intensity (black) and the value 1 represents the maximal intensity (white), is done as follows:

$$r(H,S,I)=I-S\left(\frac{\cos(H)}{\sqrt{6}}+\frac{\sin(H)}{\sqrt{2}}\right) \tag{4}$$

$$g(H,S,I)=I-S\left(\frac{\cos(H)}{\sqrt{6}}-\frac{\sin(H)}{\sqrt{2}}\right) \tag{5}$$

$$b(H,S,I)=I+\frac{\sqrt{6}}{3}S\cos(H) \tag{6}$$

Different methods to perform RGB to HSI conversion are detailed, among others, in Foley et al. (1999) and in Gonzalez & Woods (1993).

TESTS AND RESULTS

Among the numerous test regions that were used in this work, an area of agricultural region surrounding a small village in a hilly terrain was selected to be presented as a test case. In this area two orthophoto maps were created using the source image of 17 cm per pixel and a DTM (Digital Terrain Model) of 10 meters density. These orthophoto maps were created at the same resolution of the source image – 17 cm per pixel. One orthophoto map was created using the proposed algorithm of using HSI color representation for interpolating colors. The other orthophoto was created using the common method by interpolating the RGB components as a way to interpolate the color values of the source image into the target ortho-image. Figure 1 presents these two ortho-images along with the source image that was used for this matter. In this figure, it is clear that the colors in the ortho-image that was created using HSI color interpolation (Figure 1a) are better matching to the colors of the source image shown in Figure 1b, than the colors in the ortho-image that was created using RGB color interpolation shown in Figure 1c. In addition, it is clear that the colors in the RGB interpolated ortho-image are a filtered version of the source image colors. In this image, the contrast is different than the source image.

SUMMARY

This paper suggests a new approach and an algorithm for re-sampling color values of a source image into the target ortho-image. Based on using interpolation of color values represented by HSI components, the algorithm is aimed at achieving an accurate and consistent mix of the source colors. Compared with the common method of mixing colors by interpolating their RGB components, the proposed algorithm facilitates an accurate mix of the source pixel colors.

In continuation of this research, the use of terrain break-lines in conjunction with edges on the source image should be explored in order to produce an ortho-image eliminating the filtering effect of interpolation as much as possible.

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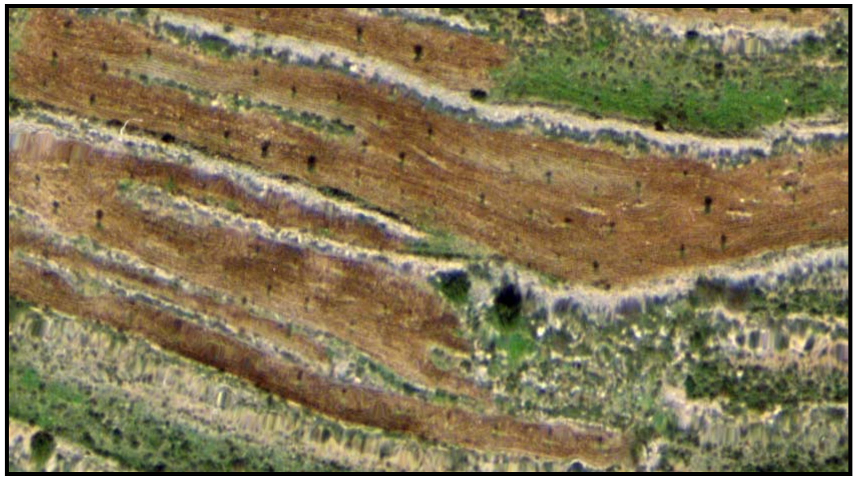
(a)



(b)

(c)

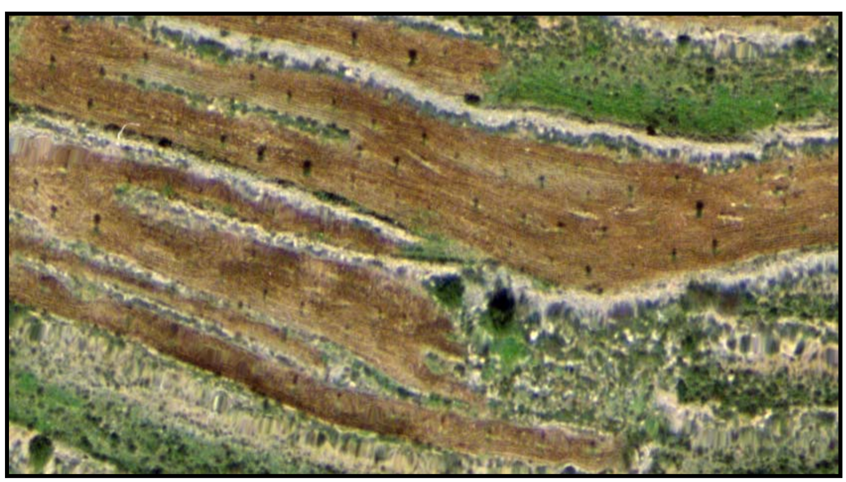


Figure 1. RGB versus HSI color interpolation comparison in orthophoto production.

(a) Orthophoto produce using HSI color interpolation – the proposed method (top).
(b) Source image used for the orthophoto production (middle).
(c) Orthophoto produced using RGB interpolation (bottom).