Transparent Superimposition of Graphics on Digital Aerial Images

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Abstract

Transparent superimposition means that graphical objects are overlaid in such a manner that the digital image can be seen through the graphics. The transparent superimposition of graphics is suitable for visualizing objects that have an area dimension on the image. While in use it does not disturb interpretation of images. A detailed algorithm, based on transformation from the hue, saturation, intensity (HSI) representation to the red, green, blue (RGB) colour space, for the transparent superimposition is given. The intensity component for this transformation is from the original image. The theme is drawn to the chrominance channels, i.e. hue and saturation. Examples of superimposed digital aerial images are presented. A combination of transparent superimposition and wireframe techniques is seen as an optimal method for many purposes.

1 INTRODUCTION

The graphical display of object data on the image is called superimposition of data. In stereoscopic viewing the corresponding term is stereoscopic superimposition. The fusion of vector and image data by superimposition was first realized in analytical plotters in the late 1980s (see e.g. /1/, /2/ and /3/). In these systems the graphics were injected into the optical path of the analytical plotter. This type of solution was, and still is, quite complex to build, and so the price of a superimposition peripheral for an analytical plotter is high. In digital photogrammetric workstations, however, the superimposition of graphics does not require any accessory devices; it is a property that is always available in each image window of the system.

The superimposition of graphics is a powerful visualization tool that can be used to present the geometric information of a GIS database to digital aerial images (see also /4/). Its use typically requires that the object data is in 3-D and the geometry of the imagery is known. When these requirements are met the vectors can be projected correctly to the images. The resulting overlay of graphics is an easy way of checking the consistency between the projected objects and the reality on images. In the data collection phase the user immediately recognises those targets that have not yet been mapped. Note that the superimposed objects may also describe the situation of the physical reality at some point in the future. The requirement for realism in planning applications is, however, sometimes so high that simple overlay techniques are no longer adequate. The rendering methods then needed are beyond the scope of this work.

Graphics are typically superimposed with wireframe techniques. The superimposition of wireframes alone is not, however, ideal for visual perception, especially if we want to visualize objects that have an area dimension on the image. An alternative is to superimpose the objects so that the whole graphical object is coloured not merely the edges. Purely covering colours are not, however, suitable for this purpose, as vision of the image parts under the graphics is blocked if the objects are painted as such. An alternative method is to use a transparent overlay that enables the image to be seen through the graphics.

A graphical layer that does not totally block the vision of the image is achieved by a technique called halftone approximation /5/. Halftone approximation (or dithering in computer graphics) is a common method in printing technology, where it is used to provide more tones from a limited set of possibilities. This increase in the range of tones is based on the spatial integration performed by the human eye. In graphics superimposition the dithering pattern is moved over the area of the graphical object. In each position the pattern is injected to the image. The pixels set are given the desired colour while the rest of the pixels are left untouched. The result is a digital image with a grid-like superimposition of graphics. Although this overlay technique does not totally hide the image under the graphics, it does hide a significant amount of information. Moreover, more pixels are hidden by a bright colour surface than by a light colouring. If this method is used for zoomed images, the graphics should be newly superimposed at each level of zooming; otherwise the grid pattern will disturb the user.

A truly transparent graphical layer is achieved by transforming the digital image into a colour space other than red, green, blue (RGB) and overlaying the graphics in this new colour space. The colour space transformation applied has to be such that it separates the luminance and chrominance values of the image. The desired objects are then drawn into the chrominance channels, keeping the luminance unchanged. The inverse transformation gives the superimposed result. When the transparent superimposition is done as described the result is technically optimal.

In this paper we concentrate on use of the hue, saturation, intensity (HSI) colour space for transparent superimposition. Throughout the paper we are working with full-colour images, or, more correctly, with images presented by

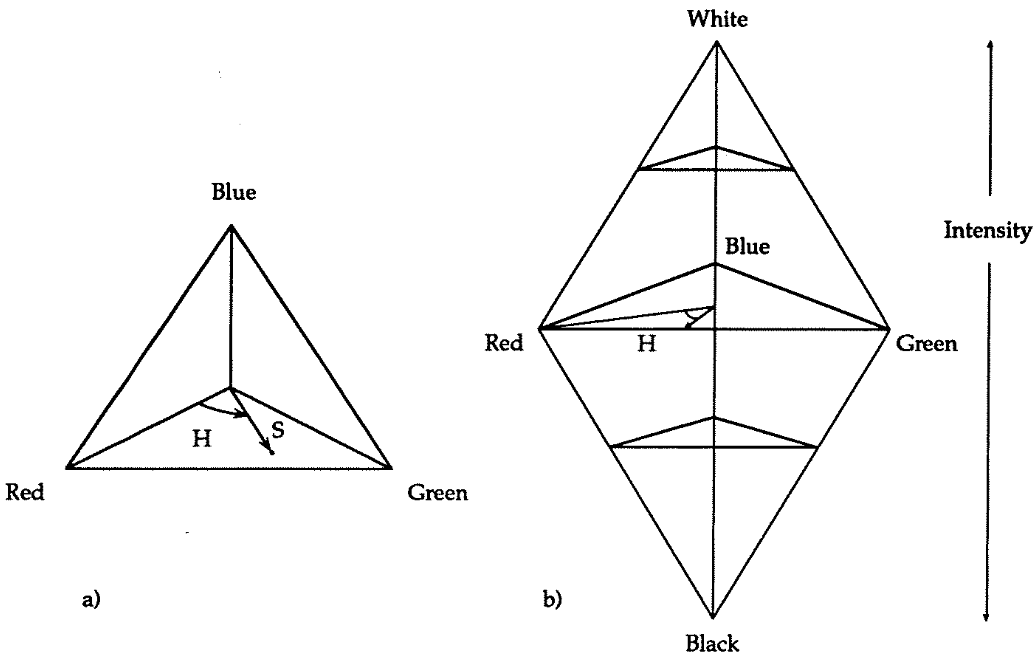

Figure 1. The HSI colour triangle (a) and the HSI colour solid (b) /6/.

three channels (RGB). Note that a grey-scale image (8-bit) can easily be transformed to a full-colour image (24-bit) by copying the pixels from the original channel to the two extra channels. An algorithm for implementing the transparent superimposition is given in detail. Finally, we present some examples of transparent superimposition on digital aerial images.

2 TRANSPARENT SUPERIMPOSITION OF GRAPHICS

The HSI colour space (see e.g. /6/, /7/ and /8/) is a suitable colour model for transparent superimposition of graphics. The components of this colour coordinate system - hue, saturation and intensity - are easy to perceive because of the similarity to human vision. It also fulfils the requirement that luminance values (intensity) should be separated from chrominance values (hue and saturation). In fact, there are rather many colour spaces (e.g. HLS, HSB and HSV) with the same or similar concepts, but they differ from the HSI model in the coordinate system used /5/.

The chrominance components (hue and saturation) of the HSI model form a triangle in 2-D, see Figure 1a. The hue (H) is a measure of the average wavelength of a light reflected from an object. In other words, the hue component defines the colour. Red, green and blue are in the vertices of the HSI triangle. The hue component is given by an angle measured with respect to the centre of the triangle and the direction combining the centre and the red

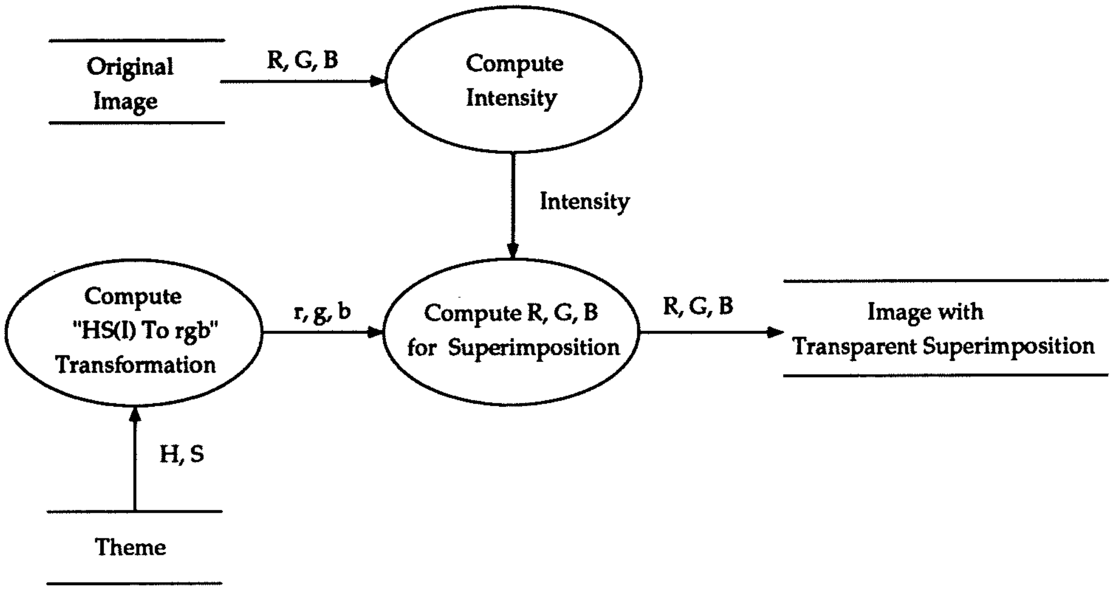

Figure 2. Functional model of transparent superimposition. Functional modelling is used to specify what happens in the process (see e.g. /9/). In the figure ◯ represents process, ‾‾ data store and ↗ data flow.

vertex. The hue value 0° means that the colour is red; 60° that it is yellow, and so on. The second chrominance component, saturation (S), is a measure of the purity of a colour. In the HSI triangle it is described by the distance from the centre of the triangle to the colour point. This distance is given as a proportion of the corresponding pure colour. The intensity component of the HSI model expands the 2-D colour triangle into a 3-D pyramid-like structure, see Figure 1b.

In the transparent superimposition of graphics we mainly utilize (inverse) transformation from the HS(I) model to the RGB model. The only value required of the original image is the intensity of the pixel currently being processed; the colour components (H and S) of the superimposed image will have been determined earlier by either the system or the user. The colour values are typically assigned to the themes of the objects and they can be edited during the work. The hue and saturation components (H, S) are transformed to the red, green and blue values (r, g, b), which are combined with the original intensity to give the superimposed result (R, G, B). The process for transparent superimposition is illustrated in Figure 2.

The formulas for the transformation from the HS(I) colour model to the RGB colour model are divided into three groups according to the sector where the current colour belongs in the HSI space. The equations are taken from the book by Gonzalez & Woods /6/, which also shows the derivation of formulas.

In the transformation equations the hue component is expected to lie between 0° and 360° and the saturation between 0 and 1. In the first sector (RG sector) the hue is between 0° and 120° giving the following formulas,

$$b = \frac{1}{3}(1-S)\,, \tag{1}$$

$$r = \frac{1}{3}\left[1+\frac{S\cos(H)}{\cos(60^\circ - H)}\right] \quad \text{and} \tag{2}$$

$$g = 1-(r+b)\,. \tag{3}$$

The corresponding equations for the sector GB ($120° < H \leq 240°$) are,

$$H = H - 120^\circ\,, \tag{4}$$

$$r = \frac{1}{3}(1-S)\,, \tag{5}$$

$$g = \frac{1}{3}\left[1+\frac{S\cos(H)}{\cos(60^\circ - H)}\right] \quad \text{and} \tag{6}$$

$$b = 1-(r+g)\,. \tag{7}$$

The formulas for the BR sector ($240° < H \leq 360°$) are written as,

$$H = H - 240^\circ\,, \tag{8}$$

$$g = \frac{1}{3}(1-S)\,, \tag{9}$$

$$b = \frac{1}{3}\left[1+\frac{S\cos(H)}{\cos(60^\circ - H)}\right] \quad \text{and} \tag{10}$$

$$r = 1-(g+b)\,. \tag{11}$$

Using these equations we can transform the H and S components of the theme into r, g and b. To finish the transformation, we still have to consider the effect of the intensity of the original image. The intensity (I) is calculated by simply adding together the pixel values for all the original channels, i.e.

$$I = R + G + B\,. \tag{12}$$

The final RGB components of the superimposed image are calculated by multiplying the pre-transferred rgb values with the intensity,

$$R = Ir \ , \tag{13}$$

$$G = Ig \quad \text{and} \tag{14}$$

$$B = Ib \ . \tag{15}$$

Note that the RGB values in equation (12) are different from the RGB values in equations (13)-(15).

In Figure 3, an algorithm for transparent superimposition of graphics is given in C language. The code given as an example is divided into two functions. The function *set_rgb()* is designed for setting the hue and saturation values of the theme. These values are the same for all the objects of the same theme

```
void set_rgb(double H, double S, double *r, double *g, double *b)
{
  if ( H <= 120 ) {
    *b = (1.0 - S) / 3.0;
    *r = ( 1.0 + ( (S * cos(rad(H))) / cos(rad(60-H)) ) ) / 3.0;
    *g = 1.0 - (*r + *b);
  }
  else if ( H <= 240 ) {
    H = H - 120;
    *r = (1.0 - S) / 3.0;
    *g = ( 1.0 + ( (S * cos(rad(H))) / cos(rad(60-H)) ) ) / 3.0;
    *b = 1.0 - (*r + *g);
  }
  else {
    H = H - 240;
    *g = (1.0 - S) / 3.0;
    *b = ( 1.0 + ( (S * cos(rad(H))) / cos(rad(60-H)) ) ) / 3.0;
    *r = 1.0 - (*g + *b);
  }
}

void superimpose(double r, double g, double b,
                 long *R, long *G, long *B)
{
  long I;

  I = *R + *G + *B;

  *R = I * r;
  *G = I * g;
  *B = I * b;
}
```

Figure 3. Algorithm for transparent superimposition of graphics.

and so they do not have to be changed in calculations; to prevent unnecessary calculations, they can even be stored in advance. The actual superimposition is done in the routine *superimpose()*. As an input, this function gets the pre-transferred colour values for the theme (r, g, b) and the pixel value of the pixel from the original image (R, G, B). The output values are the R, G, B of the superimposed pixel.

3 EXAMPLES OF TRANSPARENT SUPERIMPOSITION

The transparent graphics superimposition was realized on the stereo workstation of the Finnish Geodetic Institute /10/. The workstation software was used to create the examples shown here. First, a group of 3-D objects was measured from a pair of digital aerial images. The objects measured - roofs of buildings and roads - were projected back to the images. The objects were superimposed using the transparent overlay technique with different chrominance parameters. Some examples are given in Plate 1. The upper-left image (a) is the original image area without any superimposed objects; it serves as a reference for comparing images with graphics. In the superimposed images (b, c and d) the colour of buildings was changed from image to image. For roads the same hue was retained, but the saturation was changed slightly. The exact values for hue (H) and saturation (S) in Plate 1 are: b) buildings(H=140°, S=0.6), road(H=5°, S=0.2), c) buildings(H=30°, S=0.6), road(H=5°, S=0.3) and d) buildings(H=60°, S=0.7), road(H=5°, S=0.4).

It is clear from the examples that even very large areas can be superimposed with this technique without disturbing the interpretation. During the overlay experiments inpure colours (colours with low saturation) often turn out to be better for transparent superimposition than pure colours (colours with high saturation); for wireframe superimpositions, the reverse might be true. The selection of colour (or hue) should depend on the theme of the object. For example, a blue road looks like asphalt, but it may also give an illusion of a canal in Venice. Although the colours are more pleasing to the human eye if they fit well into the surroundings, this is not normally the objective of visualization. On the contrary, superimposed graphics should present the theme clearly to the user. Further research is needed into achieving a balance between colour harmony and information.

Tests on the transparent overlay of graphics revealed that the method is not at its best in presenting the exact edges, or contours, of objects. Most engineering tasks are such that the position of corners, eaves etc. is of great importance. In such applications the use of wireframe graphics is thus favoured. However, the ideal superimposition method is one that combines transparent superimposition and wireframe graphics.

4 CONCLUSIONS

In this paper we have studied the transparent superimposition of graphics on digital aerial images. The method proposed is based on transformation from the HSI color space to the RGB color space. The color presenting the graphical object is shown in the hue (H) and saturation (S) channels while the intensity from the original image remains unchanged. In the algorithm for implementing the transformation, the colour of the theme is always pre-transformed into the rgb space. The transparent superimposition is then reduced to a simple multiplication. Note that graphics can also be superimposed in such a manner that the chromaticity components of the theme are slightly dependent on the colour of the original image.

The use of transparent superimposition is illustrated by examples. The method works well with digital aerial images. The vision through the graphics is possible without disturbing the interpretation. Although transparent superimposition techniques are in themselves valuable, the ideal superimposition method for many purposes combines transparent superimposition and wireframe graphics. The problem of selecting the correct colours and colour combinations is not addressed in this paper. It is a topic for further research.

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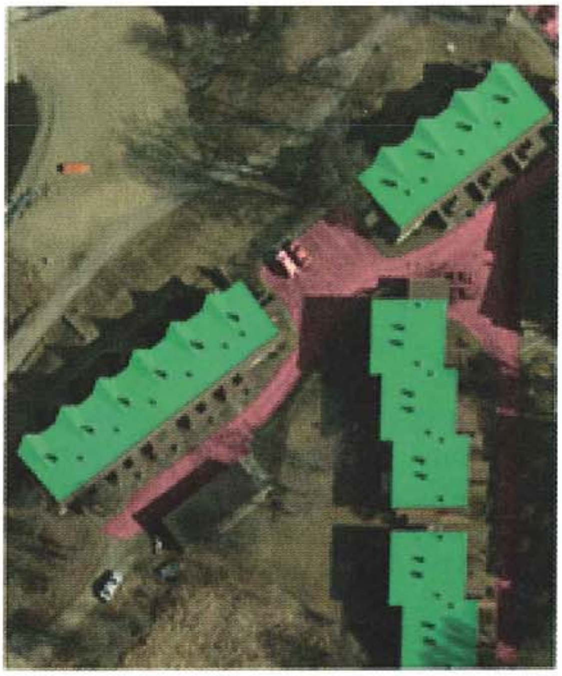
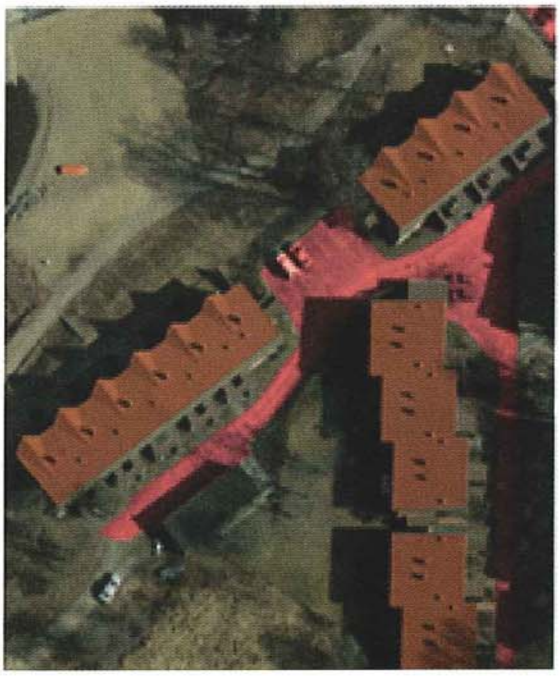
a) Original image.



b) Buildings(140°, 0.6), Road(5°, 0.2).



c) Buildings(30°, 0.6), Road(5°, 0.3).

d) Buildings(60°, 0.7), Road(5°, 0.4).

Plate 1. Examples of transparent superimposition of graphics.