PHOTOMOSAICS AND IMAGE SIMILARITY

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INTRODUCTION AND GENERAL OBSERVATIONS

The term photomosaic was coined to denote a special artistic method. In this method, the original, source image, for example a photograph, is divided along its width and height in a set of equally sized pieces. Each of these pieces is compared to every image in a library of possible replacements. When an appropriate replacement is found the given piece is replaced with it. The end result of this process is a new picture that looks in some way similar to original picture when viewed at a distance. Yet on such picture new details introduced by replacements from the library can be seen when viewed up close (Fig. 1.)

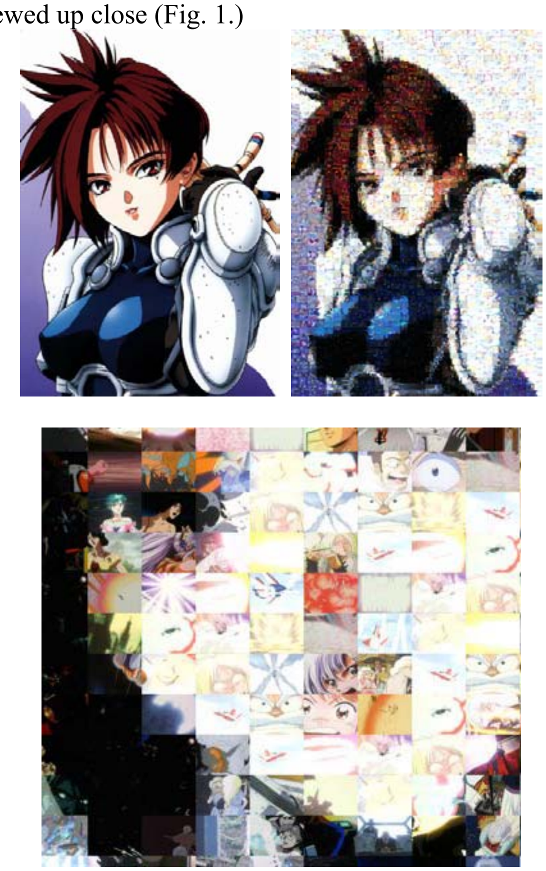

Fig. 1.

Although this method was developed first for classical artistic media, development of photomosaic generating software marked the start of its wider application.

Generating a photomosaic is a problem of finding the most similar replacement for each piece of original image. Various similarity measures have been defined for different particular purposes in image processing and related applications [1], [2], [3]. Image similarity is in general a very complex problem, but in this case it is greatly simplified by some general presumptions.

All pieces of the original image are of the equal dimensions. This applies also to the possible replacements in the library. Orientation of every piece and every replacement tile remains the same through the process.

Important issue that needs to be established is the definition of similarity of pieces and replacements. It is obvious that we do not seek to find two exactly the same images, but rather two images that share some common visual elements that enable the observer to recognize main features of original source image on newly generated image.

By observing source image and examples of photomosaics we can distinguish some common visual elements that must be taken into account. First, there are areas of mostly homogenous color. Second, there are border regions where areas of distinct color meet. These borders are of great importance because human visual system is very sensitive to transitions with great contrast difference. Edges define shapes, and shapes are crucial for our process of recognition. This information must be preserved in order to enable viewer to recognize main features of source image on a newly created photomosaic.

The texture is not a factor that needs to be taken into account because areas of mostly homogenous color without any distinguishable pattern can be replaced by images with distinct texture that on the average gives the same color impression to the viewer.

General goal can be achieved by a combination of two methods, one for parts of source image with homogenous colors and another for parts with distinct edges. In this paper, we propose a realization of these methods.

2. DESCRIPTION OF METHODS

2.1 Preparation of images

First task in comparison process is to categorize pieces of source images and tiles in library of replacements in two classes. Peaces with homogeneous color are in one class while peaces with distinct edges are in the other. An appropriate comparison method will be selected for each class.

The way human visual system perceives colors, determines the method for comparison of pieces with homogenous color. Human eye is many times more sensitive to wavelengths that correspond to the red and the green color then to the blue color. That is why RGB color model is not suitable for comparison such pieces. It can be proven that HSV (Hue, Saturation, Value) color model gives much better results in these cases [4].

A histogram is generated for every channel in the HSV color space of image. Each histogram is analyzed. Maximum value in the histogram is found and then the area around this value is observed. If more then a given percentage, for example 80% of image pixels, are in the observed area, we consider that the image has one dominant set of color component values in this channel. If this is not the case, the next greatest value is found and process is repeated for the area around it. When the picture has one dominant set of values in each of three channel histograms, we consider it to be of mostly homogenous color. Otherwise, we assume that the image has more than one area with different dominant color and edges separating them. Such image must be processed as an image with distinct edges.

The width of area around maximum values that is being observed varies. We have used greater margin for Hue channel then for Saturation and Value channels because of importance it has in human visual system.

In our experience, values around 30% of complete range for Hue channel and about 10% for Brightness, and Saturation channels give good results.

Images categorized in the class with distinct edges by the previous method, must undergo another preparation process. Image is converted into grayscale mode and then an edge detection algorithm is applied to detect edges. As we need to detect only most noticeable edges in the image, we do not need a very sophisticated edge detection algorithm. The Sobel method [5] applied three times for vertical, horizontal, and diagonal edges gives good results with short calculation time.

To get better results in edge detection, we suggest application of a low pass filter to eliminate small details with sharp contrast that tend to be identified as parts of edges by edge detectors since they are of no interest for us. Edge maps developed as a result of this process are saved for later comparison.

2.2 Comparison Methods

For comparison of images with one dominant color, we suggest a method based on square root error. Each piece of source image is compared to every tile in library of replacements using previously generated histograms. Comparison is performed for each pair of corresponding channel histograms. Difference of histograms for each channel is calculated as

$$d_{channel}(h_1, h_2) = \sqrt{\sum_i \left(h_1(i) - h_2(i)\right)^2},$$

where $h_1(i)$, $h_2(i)$ are the *i*-th values of the histograms. Since there are three channels, three differences are calculated. Total difference is calculated as

$$D_c = \sqrt{d_h^{\,2} + d_s^2 + d_v^{\,2}},$$

where d_h, d_s, d_v are differences of H, S, and V channel, respectively. The tile with a minimal value of D_C is selected as the replacement for the given piece of source image.

Comparison method for images with distinct edges is more complex. We consider two parameters D_C and D_E. The parameter D_C is calculated as described above. Difference D_E between edge maps of a given piece of source image and every tile from library is calculated as a number of different pixels in these maps, expressed as a percentage. If $D_E \leq 10\%$, we take into consideration that particular tile from library of replacements and check the value of D_C parameter. Again, the tile with a minimal value of D_C is selected.

SOFTWARE IMPLEMENTATION

Software that we have developed as an example of implementation of these methods performs its task in three steps.

- Building of library of replacements. (preprocessing phase)
- Making of a photomosaic (image comparison phase)
- Rendering of finale image (generating of final output from data created in the previous step)

This organization of steps was selected to take advantage of opportunities for speeding up this time demanding calculation process.

Preprocessing phase

During this phase every image from source folders is scaled down to the appropriate dimensions specified by the user. Image is converted to HSV color mode, and histograms are calculated for each of the channels. Histograms are stored for further use. Analysis of each histogram is performed to distinguish images with single dominant color values from these with distinct edges. Classification of images is performed according to this criterion. Library is divided in two separate parts, one that stores images with single dominant color and the other for images with distinct edges.

Images with distinct edges are then converted to grayscale mode. Low pass filtering and edge detection is performed on them. Generated edge maps are stored for further use.

Image comparison phase

Actual image comparison is performed in this phase. Each piece of source image is processed in similar way as tiles from library of replacements. The process consists of scaling to appropriate dimensions, conversion to HSV mode, histogram calculation and analysis, classification by color and distinct edges. Again conversion to grayscale, low pass filtering, and edge detection is performed where needed.

If given piece is classified as an image with single dominant color, it is compared only to tiles with homogeneous color by using the first method.

For pieces with distinct edge second comparison method is performed and only tiles with distinct edges from are taken in to account. The best matching tiles are selected for each piece. The matrix with positions of selected tiles is generated and saved in output file.

Rendering of finale image

Rendering phase generates the final output image, a new bitmap that consists of tiles positioned according to matrix generated in previous the step. Rendering is separated from the previous processing so it could be done later.

CONCLUDING REMARKS AND FURTHER WORK

This paper presents a method for generation of photomosaics and its software implementation. Work flow is simplified as much as possible for convenience of users. Quality of end result varies significantly depending on number of images in library and their diversity. For good results a large library of replacements is needed e.g. several thousands of images. In the current version, our software supports only uncompressed Windows Bitmap format. Large hard drive space is needed for storing a huge number of images in this format. Further work will be devoted to implementing other image formats and developing methods for to prevent repeating of same tile more then once on one photomosaic.

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ABSTRACT

In this paper we explain possible methods for generating photomosaics out of one source image and a library of replacement images. Problem of photomosaic generation is approached from two directions, by comparing image histograms to determine the color features of images and by edge detection methods. We also give a software implementation of suggested methods with regard of calculation speed and needed resources.

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