Hybrid Method For Image Segmentation And Recoloring Of The Original Grayscale Photographs

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Abstract – **In this paper we will present hybrid method for recoloring the original black and white photos. Main novelty we attempt to introduce is specific combination between human and machine capabilities in simultaneously image processing. Algorithm covers different manual and automatic techniques in colorization resulting in better achievements. Cross combined methods for image segmentation have a successful image for the result. In this paper combined process methods which are based on Gray scale algorithm, from one side, and analyses of the patent photos in color, from the other side will be also presented. This suggested method requires restoration and segmentation of the photo, as the result of colorization, will give maximum effects. Original colorization algorithm of 2D photo will also be presented here, and that algorithm reduces colorization to the minimum, under the condition that the user obtains enough information about the photo itself during the colorization process. The generality of the proposed method will be demonstrated on the series of original photographs from the Nikola Tesla Museum of Belgrade heritage.**

Keywords – **Image processing, Segmentation, Coloring, Image restoration**

I. Introduction

Digital image processing belongs to the multidiscipline engineers` sphere which covers different aspects of human life from photos, mathematics, electronic, optics and computer science. In last few decades the number of the applications and techniques for the process of digital images increased. Considering that increase, the demands in relation with developing of technology for the color image process increased, too.

The basic spheres of digital image processing are representing representative. Remodeling image, improving image quality, image restoration, image analysis, reconstruction of image from projection and compression of image in the sphere of image analysis are present in the coloring, as well as in the image segmentation.

The term itself - *segmentation of image* [1] - is related to the group of procedures for dividing an image into regions with similar attributes, in order to get more precise process of coloring [2]. Two basic ways of segmentation which are made from structures of data and transformation, are showed for making groups of pixels [3]. Hence, it is always recommended to start with the method of finding edges and separating regions [1],[3].

After the determination of the regions we use half - automatic techniques of segmentation: class Haf transformation and texture segmentation. Proposed methods of coloring process the monochrome image using appropriate colors so that image primarily shows its existence more closely. To achieve desired results, in the process of colorization, the user the most often uses one automatic technique. In that case application of colors is performed without the possibility of maneuvering nuances, which as the result has different final solutions using variable applications. Scientific contributions to this subject already exist. Welsh [4] widened the automatic system for color transfer from one image to another by changing middle variation of the color on the image. Dalmau [5] suggested the colorization method based on color application on gray scale image wherewith the probabilities of the gray pixel limit values are defined. Calculated probability is used for further utilization through the linear function where the color is channeled through α-channel. Levan [6] has perfomed colorization based on assumption of the neighboring pixels in time/space. He was guided by the probability that pixels with similar intensity should have the same colors. Kumar [7] performs colorization based on the color image which is of the similar texture as the gray one. Afterwards, similarity measures of the texture are calculated and compared. After that the transfer of the colors from the colored image to the gray image pixels is performed. Kumar [8] has also performed image colorization through standard deviations of the data.

However, independently of the technique that is used, object possesses two dimensional values which present the raster of image. Data on the image has different values independently from the image format itself. Grey tones on the image are generated through matrix and appropriate color from the palette of color spectrum is gotten that way. By the use of function for combining 2D vector graphics with the image of the object, extremely big manipulation on the image is not allowed. By using half - automatic coloring we achieve great effect , during which function canalling black and white patterns through RGB canal is performed. Processing of the photos will be achived through algorithm and the result of segmentation and coloring of image will be used on the original image of Nikola Tesla's Long Island Laboratory and the results will be shown in the conclusion of this work.

Thanks to the long cooperation with the "Nikola Tesla Museum" in Belgrade on a project supported by the Ministry of Science of the Republic of Serbia, authors had the opportunity to work with original photographs that were created as part of the Museum heritage. The idea to apply the general methods presented in this paper to the original photos that were obtained from the Museum proved to be very successful, so the Museum participated in the project.

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Nowadays, our recolored Tesla images that are in basic presentation setup of Museum in Belgrade. The results of our work were evaluated both through the basic setup of the Museum which has about visitors 40,000 per year, as well as the successful presentations in many international exhibitions that saw hundreds of thousands of people.

The project of the Museum was also the default at the World Exhibition in China 2010 at the stand of the Republic of Serbia. Precise data about these details may be obtained directly from the Nikola Tesla Museum [9].

II. SEGMENTATION

Segmentation is closely related to the process of coloring [1]. The term „segmentation" of the image is related to the group of actions for dividing image into regions with similar attributes. The attribute which is the most often used is lightness with monochrome images or colors with color images. Segmentation of image comes from the theory of Gestalt psychology which studied the making of the groups of pixels according to their shape, similar to the properties of human observing. The outcomes of this theory are two basic aspects of image segmentation:

Data structure - which is needed for studying the qualities of homogenous groups

Transformations - needed for calculating the quality which means two basic kinds of segments are boundaries and regions. This way of segmentation is presented graphically by the knots, where the pixels are the key and present borders (Fig. 1) [3].

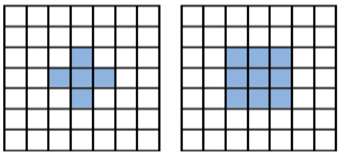

Fig. 1. Classifying regions by boundary pixels.

From here the mathematical definition can be extracted:

Segmentation on of image R is formally defined as separating into not overlapping regions R_i , where are i=1,2,3,....,N. is metrical, not empty, sets.

If P(Ri) is the indicator of uniform of all elements in set R_i, end Ø empty set, then it means:

$U_{Ri} = R_{ni}=1$

For each i and j, for which means $i \neq j$, valves $R_i \cap R_j = \emptyset$

For each i=1,2,..N, must be $P(R_i)=1$

For all pairs $i \neq j$, means $(R_i \cup R_j)=0$. For each i=1,2,..N, R_i is connected region.

This definition is of great importance because according to it the division of image at regions according to the similar attributes is done, as well as combining of the same (in monochrome image: color, lightness, edges, measures for textures, etc.) pixels.

Although the segmentation represents the most important phase in the image analysis, there was only theoretical base for segmentation until nowadays. Most actions of segmentation which are accepted in practice have neuron character. Apart from this, there is no way for quantitative estimation of how good the action of segmentation is. Hence, starting points are the basic techniques of segmentation for separating (Fig. 2):

Finding the edges- separating the pixels which belong to the rims of the objects,

Separating the regions – separating the whole region is object from the background of the joining pixels which lightness is below the border of background, and the rest to the object and reverse.

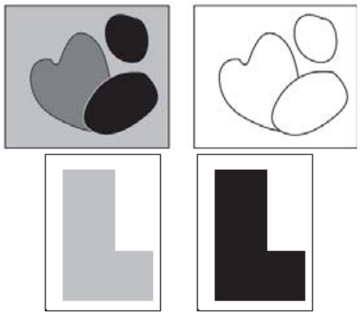

Fig. 2. a) Separating edges; b) Separating object from background.

This kind of use of general techniques is simply not enough, because it would lead to imprecise process of segmentation. Therefore, more precise technique is needed to provide more serious results. The process of combining is specific and very complex. It is needed to coordinate techniques for combining with basic foundation where it is applied. Considering that manual colorization process can take a long time, and automatically can have unwanted results in tuning of colors and impossibility of precise segmentation as a result of the damaged photo – the most precise way of colorization is semi-automatic colorization.

III. THE ALGORITHM FOR SEMI-AUTOMATIC COLORIZATION

Figure shows data-flow diagram of our new algorithm with complete colorization phases (Fig. 3):

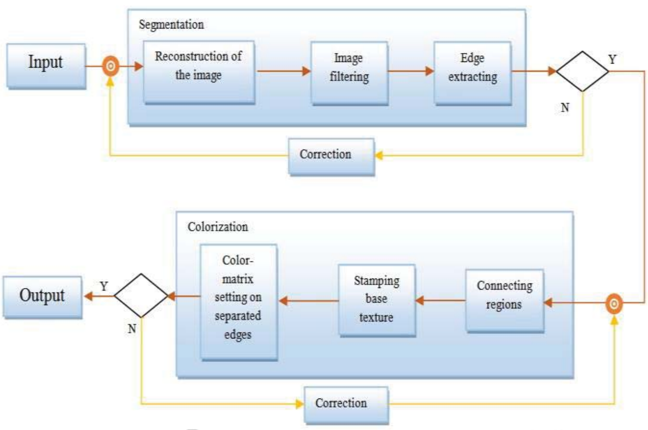

Fig. 3. The algorithm for semi-automatic colorization.

The proposed algorithm consists of the following steps:

Step 1. Upload an image.
Step 2. If damages exist, reconstruct damaged regions of the image. The reconstruction is performed directly. In that case, artificial “cloned” pixels must be generated. The pixel is copied from the closest neighboring, healthy pixel, where the region’s borders are very helpful in order not to step out from the mentioned regions.
Step 3. *Image filtering* of scab in the picture, haziness, turbidity. Filters such as: *Dust&Scratches*, *Fibers* and *Sharpe*, must be applied. This way the damage of the photo is minimized. With the help of this tool, 2D matrix which is formed from the basics of the photo is obtained. The product of every damaged pixel with the good pixel on the photo is summarized, and that way resulting pixels which perceive color value of the basic pixel are obtained.
Step 4. *Edge detection* - extracting contours of the image. The edges very often detect important information such as the location of a discontinuity among the shades, color and texture [10]. Moreover, the edge of the figure represents the boundary or contour, where significant changes in some of the physical aspects of the image occur, such as surface reflections, lighting, or distance to the visible surface of the observers. Changes in the physical aspect of the image are manifested in the form of changes in the intensity, color and structure of the image. These edges enrich information that refers to the importance of the object recognition and detection of the edges themselves and refers itself to the process of identification of sharp discontinuities in the analysis.
Step 5. *Finding and connecting regions* with the same basic statistical attributes and *marking the region* by tagging pixels after achieving binary files. The simplest method in this case is to join each pixel tags or index segment. There is one more effective method, which is found in the fact that the closed contour that limits a region is specified, but after that each pixel within the contour must be marked.
Step 6. The choice of texture as a basis for the matrix colorization of individual objects is done by comparing the segmentation method with a threshold. Textures RGB measures and color histogram are calculated for any pixel in a region automatically with following procedures (C++ code):

```
private void panelRed_Paint(object sender, PaintEventArgs e)
    {
base.OnPaint(e);
using (Graphics g = e.Graphics)
        {
int[] hist = this.texture.GetRedHistogram();
int maxHistValue = this.texture.GetMaxHistValue();
this.drawHistogram(g,                  ((Panel)sender).ClientRectangle,
Color.FromArgb(255, 0, 0), hist, maxHistValue);
        }
    }
privatevoid panelGreen_Paint(object sender, PaintEventArgs e)
    {
base.OnPaint(e);
using (Graphics g = e.Graphics)
        {
int[] hist = this.texture.GetGreenHistogram();
int maxHistValue = this.texture.GetMaxHistValue();
this.drawHistogram(g,                  ((Panel)sender).ClientRectangle,
Color.FromArgb(0, 255, 0), hist, maxHistValue);
        }
    }
privatevoid panelBlue_Paint(object sender, PaintEventArgs e)
    {
base.OnPaint(e);
using (Graphics g = e.Graphics)
        {
int[] hist = this.texture.GetBlueHistogram();
int maxHistValue = this.texture.GetMaxHistValue();
this.drawHistogram(g,                  ((Panel)sender).ClientRectangle,
Color.FromArgb(0, 0, 255), hist, maxHistValue);
        }
    }
privatevoid drawHistogram(Graphics g, Rectangle bounds, Color
color, int[] histogram)
    {
for (int i = 0; i < histogram.Length; i++)
        {
int height = (int)(0.95f * (float)bounds.Height * histogram[i] /
this.maxHistValue + 0.5f);
int width = 3;
int x = i * (width + 1);
int y = bounds.Height - height;
g.FillRectangle(newSolidBrush(color), x, y, width, height);
```

Part of the function belonging to this code calculates and shows color histogram for the starting texture (separating RGB component processing). This algorithm automatically tunes the color components of the manually segmented image. For the purposes of color pre-tuning for these procedures, we use original photo of Tesla’s Long Island Laboratory, front view (Fig. 4). This complex, high resolution, original grayscale image has all color components that could be use further on, for automatic colorization.

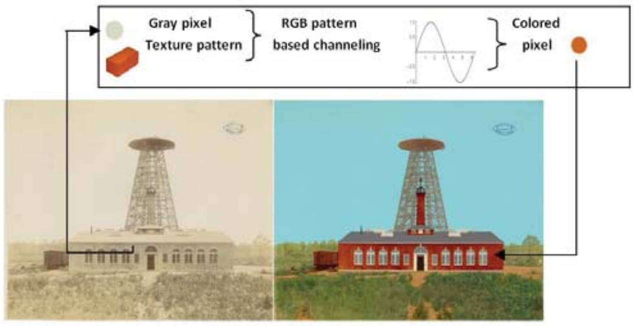

Fig. 4. The algorithm for semi-automatic colorization.

Step 7. Arranging the basic photo, the borders of the photo are separated and that is the base from which we obtain separate regions. After that the color is applied, based on the patent texture which we chose for that region. After the infliction of the colors, the effects (Multiply, Soft Light, Color) are applied because of the authenticity of the image.
Step 8. Upon completion of the question: Are we satisfied with image colorization? *The process is repeated starting with the connecting regions.*

All phases in our proposed algorithm, from original grayscale to colored version are shown on standard test image (pepper_test) (Fig.5):

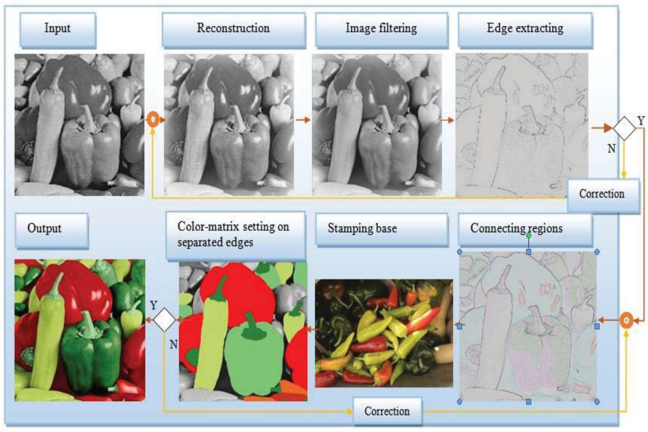

Fig. 5. Standard test image processed by the algorithm for semi-automatic colorization.

Also, there is the deviation using different color environments. Mathematical differences (PSNR values) are negligible, but in visual form that differences are becoming highly visible and that is shown in the Fig. 6 (pepper_test):

a) b) c)

Fig. 6. Comparing of the experimental results of the colored images through PSNR values: a) colored image in RGB environment; b) colored image in YCbCr environment; c) colored image with pattern channeling in RGB environment.

Different experiments show that our method highly depends on manual (human) side. Nevertheless, if the operator is experienced, algorithm clearly improves technique of the colorization, as well as shorter time interval for the image processing itself in comparison to other colorization techniques.

IV. Conclusion

In this paper we presented hybrid procedure for recoloring the original black and white photos. We used original procedures and recursive algorithms for segmentation of the grayscale 2D images as well as half-manual colorization. First we performed the photo analysis and did necessary reconstruction of the photo based on copied pixels addition. After that, in the process of the segmentation, the regions were separated and by incorporating procedures the photo was prepared for colorization. Then, we chose original patents and textures, and with the help of the algorithm shown by pseudo-code, we implemented those modifications in the colorization process. In this way we showed method of coloring in very successful way, where the risk of making mistakes is decreased, because it decreases modifying between the classes of withdrawal. It defines preciseness and exactness which should be appropriate to time it dates from. This direction of research can further be improved in direction of coloring SBS stereo images creating the 3D animation. Based on our insights, an automatic animation algorithm can be developed, giving life to basic original Tesla's images. These methods contribute preserving legacy which can be used as basic foundation for further research.

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