Method for Colorization of the Original Photographs of Nikola Tesla

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Abstract – **This paper presents in detail the basic methods for colorization of the original photographs of Nikola Tesla. This research is done in cooperation with the Nikola Tesla Museum in Belgrade on a project entitled "Computer Simulation and Modeling of the Original Patents of Nikola Tesla" approved by the Ministry of Education and Science of the Republic of Serbia [1]. The colorization of the old, original photographs from the Museum of Nikola Tesla gives the another dimension of them. The authors show in detail the procedure that was used in the realization of this segment of the project.**

Keywords – **Nikola Tesla original photographs, colorization techniques.**

I. Introduction

Project Computer Simulation and 3-D Modeling of the Original Patents of Nikola Tesla has begun in April 2009, carried out at the Faculty of Electronics in Nis, in the laboratory CiitLab [1]. The team of engineers and students from the Faculty of Electronic Engineering has accomplished a great success and results, which are implemented in presentation systems at the Nikola Tesla Museum, so that museum visitors have the opportunity to see modern animation of Tesla's inventions. In this way, through the project, the two institutions, Nikola Tesla Museum in Belgrade as an institution of national importance, that heritage Tesla's legacy and Faculty of Electronic Engineering in Niš as a development institution, were linked in a common project. The aim of the project is multiple. Basically, it is digital and detailed 3-D modeling of the original patents of Nikola Tesla, which are the part of the Museum's archives. Using 3-D models, further objectives are rendering, animation, simulation and visualization in real time and space shaded by wire (3-D stereo) model [2],[3],[4],[5]. Beginning with the late 2013, the another research direction of the project has opened. The idea is to colorize the series of white/black photographs of Nikola Tesla heritage from the Museum of Nikola Tesla. Color is a form of human perception. Eyes and the brain as well receive the spectral information used as the basis for a sense of color. Colors such as red, green or blue, for example, are just words that do not describe the spectral components of the light that is reflected from the object. The picture color makes it much easier for us to understand the essential characteristics of an object or human figure.

Whether the image is in color (RGB) or grayscale (Grayscale) it makes a certain impression on us. Considering the fact that there are a large number of images in Grayscale mode, it is good to perform a colorization and thus contribute to the image revival. The combination of grays and colorization can make very effective results.

In this paper a method of accurate segmentation of the image is presented, it is one of the most famous images of Nikola Tesla and its colorization. This method is based on the colorization process at the level of the pixels in space, on additional heuristic knowledge as well, and historical period and the conditions in which the image is created.

II. Image Enhancements

In order to perform colorization method successfully, it is essentially to prepare basic background image. The process of colorisation is carried out according to the gray image source color. The technique of this colorization staining by reference. It is based on the fact that each pixel of the gray Ig (x, y) is transformed into a color pixel U (Ri) wherein the starting point is the fact that the distance is the same for all of a color tint. The process of colorisation is best to start with the process of segmentation, which is a critical and essential component in the systems of image analysis and pattern recognition. Therefore, image segmentation can be formally defined as the process where someone shares a picture to the many non-overlapping regions, where i = 1,2,3, ..., n, where is the number of non-empty sets. If the P (Ri) denote a basis related to the generality (uniformity) of all elements within the region Ri, these conditions are to be met:

1. $U_{i=1}^{n} R_i = R$
2. $R_i \bigcap R_j = \emptyset$, for every i and j, wherein i<> j
3. $P(R_i)$ =TRUE , for every i=1,2,3,...,n
4. $R_i \bigcup R_j =$ *FALSE* , for every i<> j
5. R_i is connected region, for every i=1,2,3,...,n

This is a necessary condition for colorization method and generate good results in the treatment process. However, in addition to these conditions, it is very important to perform some improvements of the basic image. An improvement to the base is done using a method whose main goal is to change some features of the image so that it is suitable for further analysis and processing. In general, the improvement is not improving the information content of the image, but facilitates the use of existing information. Methods for image

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enhancement are numerous, and many depend on the conditions under which the image is obtained, as well as the implementation of an enhanced image. Therefore, many methods for image enhancement are interactive or adaptive. The most common methods for improving the image are contrast enhancement, noise elimination, image sharpening, coloring pictures... Some methods:

• each image pixel is treated independently of the other,
• the pixels are treated depending on their environment.

In our case we preferable method in which each pixel is treated independently of the other wherein the method includes a simple approach: take the sample of adjacent pixels in space and time, which have similar intensities, and which should have a similar color. To achieve this, we multiply the quadratic cost function and thus obtain an optimization problem that can be efficiently solved using standard techniques. A characteristic of image enhancement methods is that it's usually very simple, so it can be executed in real time. In order to present image colorization better and more faithfully, we take as an example, one of the most famous images of Nikola Tesla in front of his high-frequency transformer. The first step in colorization is of course introduction to Tesla's habits, details from his life from that time, including the manner and style dressing. Image we will process is the original from in 1896. Materials of that time, and above all we are considering electrical materials, are very different from the present, modern materials, and therefore it was more of a challenge to colorize this original photo in Grayscale technique. Figure 1 shows the original black and white photograph of Nikola Tesla in front of his transformer. At first glance, the image seems very easy to handle, however, a more detailed analysis shows that the image has a lot of flaws and imperfections that must be removed before the colorization. First of all, deficiencies are related to "blotch" skin and clothing, as well as stains that appear on clothes and the floor. A major problem is a blurring of the chair, clothes and the background, while the transformer itself with its windings is very complex - individual coils can be seen in termination. Due to the focus and shooting angle, the coils have different thicknesses so their shadows should be taken into account.

Fig. 1. Nikola Tesla - Bases of colorisation

Because of the image specificity and complexity, in the pre-processing, we have used both methods. Arranging basic background begins by filtering the image using the method where the pixels are treated depending on their environment

A. Filter image

One of the best solutions is filtering software image. Image filtering allows you to apply different effects to digital photos. Here we apply the Dust & Stretches filtering images using 2D filters similar to those that are an integral part of the commercial packages for image processing. In this way, the image defects will be reduced and skin freckles removed. The advantage of this tool is having a 2D matrix and 2D images.

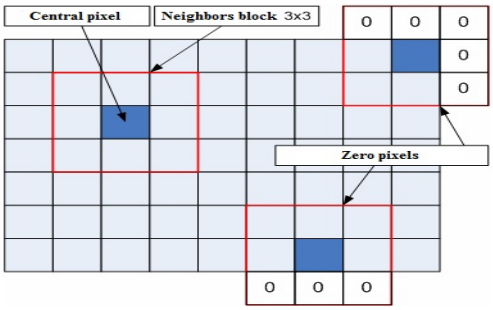

Fig. 2. Filter image

The essence is that each pixel of the image is summarized and thus provides the product that represents the pixel color component values of the pixel and its neighbors. This method constructs a matrix which is further multiplied by the current pixels and their neighbors, while other elements of the filter matrix corresponding to adjacent pixels (Fig. 2).

The operation in which the summation of the elements product of two 2D functions, which allows you moving one of the two functions over elements of the other functions is called convolution. The difference between the convolution and correlation is that reflexive projection of filtering matrix is essential for convolution (mirror method), but usually it is all symmetrical so that there is no difference.

As shown in Figure 3, selecting the desired radius and type of matrix multiplication, the picture gets a completely different look – face 'blotch' is lost (Fig.3).

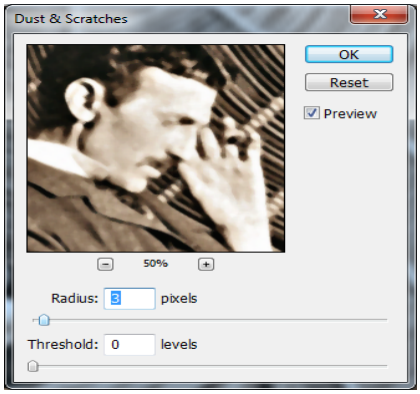

Fig. 3. Dust & Streatches filter

However, despite image filtering, certain other irregularities and picture stains are necessary to remove by manual image reconstruction. This process is necessary because filtering includes only three pixels in order to preserve the authenticity of the images. Increasing the value of the radius the picture quality would be reduced.

B. Reconstruction of the image

Because of optical electronic systems imperfections to scan black-and-white photographs, filtering images in such systems inevitably leads to smaller or larger image degradations, which in this case are rounded yellow (Fig. 4.). This imperfection arises often reducing image quality and creating a certain geometric distortion. Due to the limited duration of exposure when shooting, the obtained image is blurred. Similar degradation is obtained if the optical system of the camera does not focus the image on the image sensor surface.

Also, noises and distortions must be manually removed when image restoration is done. Using the image restoration procedures we compensate for the mentioned image degradation that is introduced during the formation and acquisition of images, which is another method of image enhancement.

Image restoration techniques are numerous, because they largely depend on the problem that is to be solved. Image restoration techniques can be divided into three groups:

- direct technique
- an iterative technique and
- numerical technique.

The most commonly used direct restoration technique that reduce the restoration process to processing images signals applying the appropriate filter on degraded image. Transfer function of such a filter is obtained on prior modeling of the process of degradation or on the basis of estimation of the parameters of degradation of the picture. The effect of degradation was determined using samples and its application to the appropriate location using the tools Brush Tool and for surface equalization and colors harmonization Blur Tool was used set to 50% in order to avoid too much loss of originals quality.Applying these procedures on basic image it is fully set in Grayscale mode and ready for the next stage of processing – colorization itself**.**

III. IMAGE COLORIZATION

Photos colorization using computer is a process of adding color to monochrome images. Colorizing the image includes hand-coloring pictures including any method of manual adding color to Grayscale mode, i.e. increasing the realism of photography. In the process of colorization is not just enough to add color but it is very important to harmonize the texture, set the edge and do the segmentation of the image if there is a need. Accordingly, colorization requires significant user intervention and a sense of color harmony. However, the problem may arise when adding color because photos can lose system details that characterize it. Therefore, the focus during the colorization is very important and the use of proper colorization techniques. In our case we preferable method in which each pixel is treated independently of the other wherein the method includes a simple approach: take the sample of adjacent pixels in space and time, which have similar intensities, and which should have a similar color. To achieve this, we multiply the quadratic cost function and thus obtain an optimization problem that can be efficiently solved using standard techniques. In this approach, optimization is solved through three layers: input, output, and an invisible layer. The essence of this method lies in the invisible layer neural network that is result of tangent function while the outputs reproduce linear functions (Fig.4.).

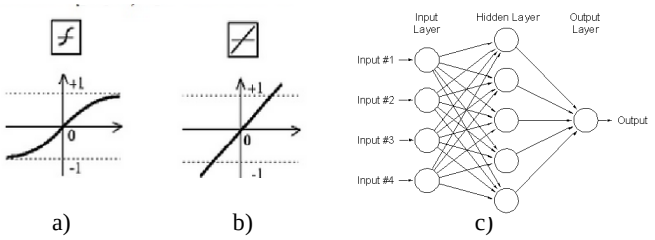

Fig.4. Tangent function of invisible layer, b) linear function of output layer, c) neural network for colorisation

A. Edge extracting

Edges extracting is one of the most important and most commonly used methods to analyze images. The edges are local discontinuities of brightness (or color) of the image and give a good indication of the boundaries of objects in the scene. Therefore, in the analysis of image edges are used for segmentation, registration and identification of objects in the scene. Figure 5a clearly indicates edges that should be carefully processed (indicated by yellow arrows), especially the edges of the transformer windings, which must be strictly defined, while the edges of face parts must blend in with the surrounding elements. All elements should be separated by levels in order to specifically assign the properties of the individual parts of the image and not to lose the detail quality. At the edge, which shadings should be milder, the tool Blur Tool is used – these are transitions between the skin and the hair, eyebrows and skin, hair and skin, etc... However, that image cannot be final since the quality of the details that describe and animate it has been lost. It is therefore very important that the next step is processing texture.

B. Description of textures

On object surfaces made of natural or man-made materials such as wood, fabric, leather, sand and the like, usually there are no expressed edges. What clearly characterizes appearance of such surfaces is their structure and texture.

Using methods based on operator, first step is image processing application by an operator, and then from the obtained results suitable features for description of textures are extracted. Applied operators can be very different: the

operators to extract edges, linear and non-linear filters, histogram, various statistical operators of the first and second row, and so on. The basic element of texture, or primitive, is a collection of pixels that is characterized by the list of attributes. In our case, the primary attributes are the coils, clothes, plates, while the secondary are a wall, a chair, base moldings on transformator carrying coils etc...The simplest primitive is pixel with gray level attribute. However, the most common primitive is maximum connected set of pixels having a particular property (e.g., the same level of gray or the same direction of the edge). Properties that may be assigned after application of paint are: Soft Light, Darken, Hard Light, etc.., where the percentage adjustment of presence of color and shadow is performed (Fig. 5b).

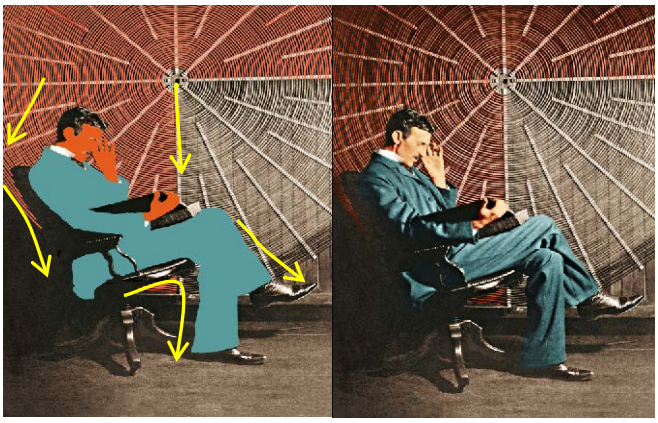

Fig. 5a. Edge extracting. Fig. 5b. Description of textures

IV. Colorization Analyses

After image colorization completion it is necessary to analyze the image. Thus using visualization the qualitative and quantitative characteristics of image objects and their relationships are determined. Image analysis has a number of procedures that to some extent imitate the process of human perception (perception), and the image was successfully colorized as far as it managed to preserve all details and avoid distortion (Figure 6).

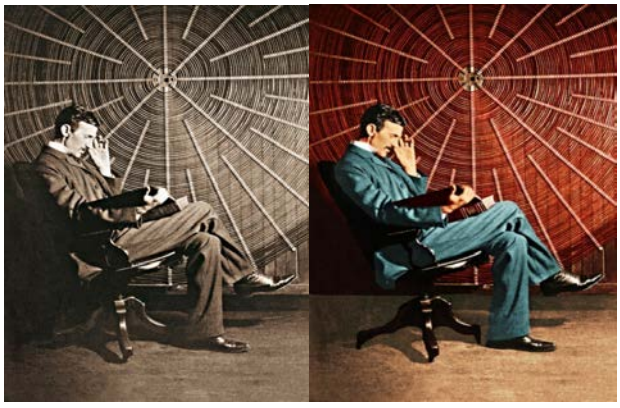

Fig. 6. Analyses Grayscale - RGB

V. Conclusion

This paper presents details about the colorization methods for the one of the famous Nikola Tesla photograph. This photograph was taken in 1896. and nowadays is presented in White-Black technology. We presented the method and a software infrastructure from the original photograph to the colorized version. There are many steps in this procedure, main ones are described. Finally, the colorized picture of Nikola Tesla is presented. This work is a part of an a interdisciplinary project III44006 realized at Faculty of Electronic Engineering in cooperation with a Ministry of Science and Technology and the Nikola Tesla Museum from Belgrade.

We believe that the realization of the project is very important for both institutions, especially the Nikola Tesla Museum in Belgrade, that has a special status of the institution of national importance, so that the results of the project were implemented immediately in direct support the work on this major institution. The project had a number of promotions, seminars, and media attention. To crown the success is a joint appearance with the Museum of Nikola Tesla at the World Exhibition in China in 2010 at the central stand of the Republic of Serbia. 3-D movie for the occasion was made especially seen by some 200,000 visitors.

Acknowledgement

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