A TECHNOLOGY FOR DETECTING AND COMPENSATING LOCAL DEFECTS IN TRIPLE NEGATIVES: SOFTWARE IMPLEMENTATION AND EXPERIMENTAL STUDY[1]

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A software system supporting information technology for detecting and compensating local defects in images created in the technique of triple color photography is developed. The developed algorithms meet the requirements of preserving historical authenticity of the image content. Testing has shown the efficiency of implemented methods and algorithms.

Introduction

This paper presents the software system "Triple Image Tool" for supporting information technology previously developed by the authors [3, 4] for detecting and compensating local defects in images obtained using the technique of triple color photography. The results of computing experiments aimed on evaluation of the efficiency of implemented techniques and algorithms are given. The system is used for reconstruction of "The Collection of the Splendors of Russia in Natural Colors", created by S.M. Prokudin-Gorsky during 1905-1916 years [7].

Several commercial programs equipped with toolboxes for image registration, correction, and retouching are available now (for example, Adobe Photoshop, Correl Draw, Paintshop Pro, and some others). However, retouching triple images from the particular collection by standard tools meets some difficulties conditioned by: (1) the great number of images; (2) the variety of defect appearance; (3) standard tools cannot use the peculiarities of the triple color images. Techniques and algorithms included in the developed system are based on rather strong correlation of image content in different frames of the triplet [3, 4].

For compensating defect regions in one of the triple frames, the only information taken from the other frames of the same triplet is used in order to provide historical authenticity of image content. Standard algorithms for image processing and analysis, and the specialized tools oriented on triple images are integrated in the system. Techniques and algorithms are tested using test images, fragments and full-size images of the Prokudin-Gorsky collection. In the following sections the description of the software system and the results of the computing experiments for evaluating the efficiency of the available tools are given.

"Triple Image Tool" Software System

The system is aimed on detection, verification, and compensation of local defects in images obtained using technique of the triple color photography. The system is designed as Windows application. It is developed using Microsoft Visual C++ (Visual Studio 2005) environment. The system includes the following components: (1) multiple document user interface with main menu, toolbar and status bar; (2) libraries of image processing,

[1] The work is supported in part by the Russian Foundation for Basic Research, Grant N 06-07-89282.

analysis, and graphic functions; (3) database for registering objects in defect regions masks. Standard Visual C++ graphic libraries and image operating functions are used as well as the specific functions oriented on triple images processing and analysis.

The input files of the system are 8 and 24 bits per pixel images of formats supported by GDI+ library. The main operating formats are TIFF, JPEG, and Bitmap. The output information is represented by defect region 8-bits per pixel mask files and reconstructed color image files.

Image processing library includes the following functions: (1) mathematical morphology functions based on fast Van Herk erosion-dilation algorithm [6]; (2) morphological functions with non-flat structuring element; (3) functions for computing gradient maps; (4) thresholding functions with automatically calculated threshold value after Otsu [5], Kittler-Illingworth [2], thresholding algorithm using statistical characteristics calculated in sliding window; (5) functions for segmenting grayscale and color images; (6) functions for calculating and visualizing image features (histogram, mean, minimal, and maximal pixel values, dispersion, number of objects in binary images, object area and size values); (7) filters.

Library of triple image processing functions includes: (1) functions for detecting local defects in triple glass negative images; (2) functions for obtaining binary defect region masks; (3) functions for binary masks logical processing; (4) functions for binary masks editing; (5) functions for compensating local defects in triple negative images.

Functions for managing database of stored objects in the defect region masks are available in the “Triple Image Tool” system. The database is used for verification of detected defect regions.

Different level of automation can be chosen for local defects detecting and compensating tasks. Available different automation levels provide feasibility and increase the quality of image restoration process. Verification of detected defect regions is performed by the operator interactively.

Computing Experiments

For evaluation the efficiency of implemented in the system techniques and algorithms, a set of computing experiments are carried out. We used a color image of size 988 by 1631 pixels containing rather uniform region (sky) and regions with texture (forest and field). In different image color components, the defects of different type representative for the collection [3] are modeled: emulsion degrading and losses, pollution, scratches and cracks of the base. Pollution, emulsion degrading and losses are modeled as white and black circles of radii 7, 11, and 15 pixels blurred by Gaussian filter of radius 2 pixels. In total, 320 objects (272 bright and 48 dark) are embedded in the image (see Fig.1 (a)). Scratches and cracks are modeled as blurred curves of width 1, 4, and 7 pixels (see Fig. 1(b)). In total, 92 objects are embedded in the mage.

(a) (b)

Fig. 1. Images for testing defects detectors: (a) pollution, emulsion degrading and losses; (b) scratches and cracks of the negative base.

Five detectors (see Tables 1, 2) are tested. False defects are removed by applying morphological filters to defect mask images.

The results of the computing experiments are presented in Tables 1, 2.

The results of test detection have shown the following: (1) none of the tested detectors provides localization of 100% of defects; (2) applying a set of detectors provides localization of 90% of objects emulating emulsion losses, degrading, and pollution, and

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94% of objects emulating scratches and cracks; (3) the objects of size less than 4 pixels that cannot be distinguished by experts (in the region containing field in the red component of the tested image) are not detected.

Table 1. The results of detecting pollution, emulsion degrading and losses

Algorithm	Amount of detected defects
Thresholding gradient image using Otsu technique	203
Thresholding using statistical characteristics calculated in sliding window	235
Detecting regions with dominating color by calculating color differences	163
Thresholding detector of bright regions	136
Thresholding detector of dark regions	48
Detector using morphological operations with non-flat structuring element [1]	153

Table 2. The results of detecting scratches and cracks of the negative base

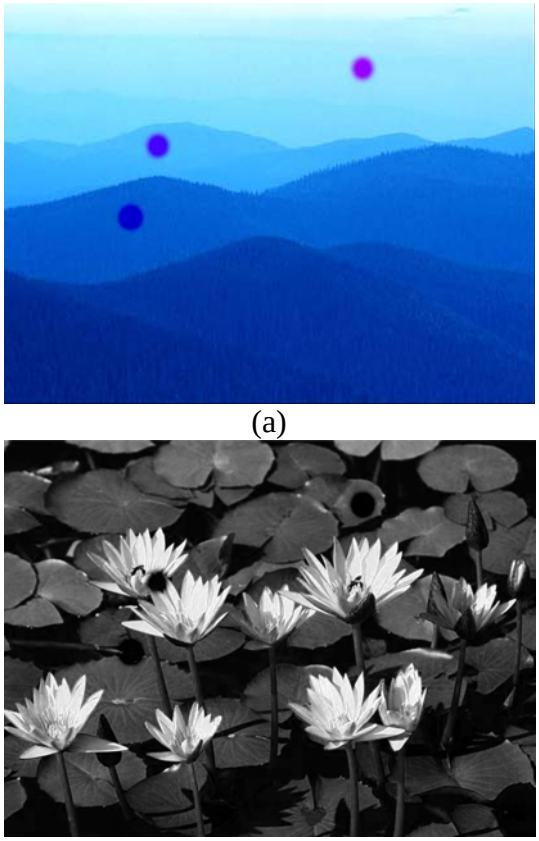
Algorithm	Amount of detected defects
Thresholding gradient image using Kittler-Illingworth technique	69
Thresholding using statistical characteristics calculated in sliding window	57
Detecting regions with dominating color by calculating color differences	49
Thresholding detector of bright regions	55
Detector using morphological operations with non-flat structuring element	45

For obtaining quantitative ratings of the quality of local defects compensation, the color images of size 800 by 600 pixels with embedded defects are used (see Fig.2 (a), (b). The image given in Fig. 2 (a) has textured regions (one can see the forest on the hills). The image shown in Fig 2 (b) is characterized by strong intensity edges in the defect regions.

The tuning of the inpainting algorithms is performed by minimizing the criterion value:

$$J = \sum_{x \in D} \sum_{y \in D} \left| u_0(x, y) - u_r(x, y) \right|,$$

where D – is the defect region; x, y - are the coordinates in the image plain; u_0 and u_r - are the intensity values at points (x, y) in the defect color component of the initial and restored images. The restored images are shown in Fig. 3.



(a)

(b)

Fig. 2. Images for testing algorithms for compensating local defects

The final examination of detection and inpainting algorithms was carried out using full-size image taken from Prokudin-Gorsky collection (see Fig. 4). 3271 defects are detected: 899 in the red image component, 956 in green, and 1416 in blue. The restored image is shown in Fig. 5.

Conclusion

The software system “Triple Image Tool” for supporting information technology for detecting and compensating local defects in images created in the technique of triple color photography has been developed. The results

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of the research have shown the efficiency of combining local defects detectors. The developed algorithms for defects compensating meet the requirements of preserving historical authenticity of the processed image content. The computing experiments have shown the efficiency of implemented methods and algorithms.

(a)

(b)

Fig. 3. The images shown in Fig. 2 (a), (b) after compensating local defects

Fig. 4. Image of size 3365x2973 pixels after color matching.

Fig.. 5. Reconstructed image from Fig.4.

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