Преглед НЦД 11 (2007), 12–20

Maja Jovanović, Aleksandar Perović,
Nenad Andonovski, Aleksandar Jovanović
(Matematički fakultet, Beograd)

A METHOD AND TOOLS FOR DIGITAL DOCUMENT AND IMAGE RECONSTRUCTION

Abstract. We were exposed to the demands and wishes to see invisible, to see better and analyze preparation details in microscopic images, to integrate astronomic data and images from all variety of sensors, to clean of arte facts fingerprint images. We propose similar methods and tools that would provide a way to make readable damaged and partly destroyed ancient documents and pictures in archive and museum collections, as well as their digital presentation preparation. Our solutions are presented, showing their effects on the input materials. Our implementations with instructions are available on our web site *www.gisss.matf.bg.ac.yu* or by demand.

Overture

Our fantasy, guided by some of our earlier and recent experience in image processing in a variety of distant contexts extracted a selection of problems for whose solutions there might be a considerable desires in a broader society of cultural experts. We will list some for us intriguing questions, some with the simpler and some with harder potential solutions, using examples provided by National library. The white angel image in our monastery Milesheva is clearly painted over a previous picture of an angel or a saint. How the former could become visible again? What technologies could be applied in order to penetrate to the deeper layer image and open it to our curiosity without harming the eight hundred years old fascinating fresco that we can see now?

Figure 1

Maybe we have much more often situations with transparent or less obscuring coverings as in the first example. Definitely totally obscuring layers in visual light are candidates to remain such in other possible wavelengths, but still there might be ways for alternative nondestructive penetrations that could partly solve these sort of problems. On the figures 2. to 7. we have often and usual damages to old and precious materials, poured various liquids, or inscriptions of diverse nature over these objects.

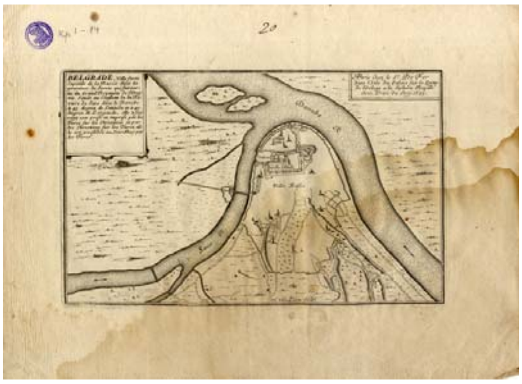

Figure 2

Figure 3

Figure 4

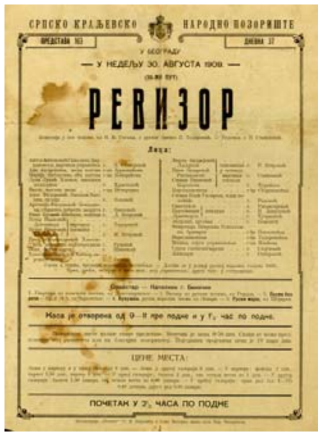

Figure 5

Figure 6

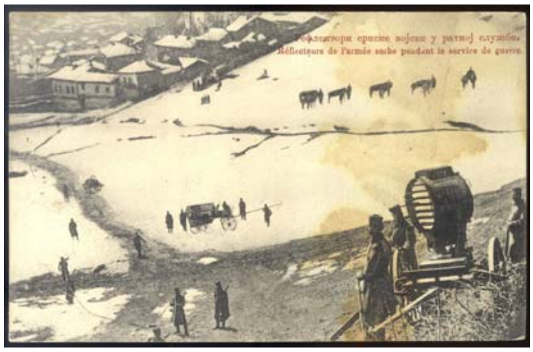

Figure 7

In the examples shown on the Figures 8 to 13 the damages and the deterioration of the ancient books include above mentioned problems with some extras: page material brake, cut offs, with text deformations and some missing parts, a sort of echo of the writing, partly vanishing words due to watering, burnt segments with partial word remnants, crumpled parchment, etc.

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

Introduction

We have developed image fusion methods for integration of composite images starting with microscopic images obtained in different wavelengths – monochromes, which were subsequently preprocessed and further processed into composites with one major aim, to provide better insight into the investigated materials and complex properties and relations which were either invisible or unobservable or hardly perceptible. Our software main use was in UV digital microscopic imaging, specifically enhancement of image processing in conjunction with modern FISH techniques, which enabled addressing of individual genes on chromosomes, separation of multiple FISH gene signals, together with metric tool box, chromosome and nuclei relation to gene signals, especially useful for detection of genetic defects, etc.

The procedures and tools that we have developed for image processing of genetic material, especially the algorithms for chromosomal transformations towards normalization prior to comparisons and similarity investigations, included contour definitions, object reconstruction – unbending, while maintaining all relevant topologic invariants of the photo morphic representations, necessary in automatic cario typing [3], suggest that in similar fashion the mentioned topology defects curing tools could be developed successfully with reasonable efforts, that would include gluing the broken pages, removal of phantom – echo text, enhancement of watered text parts, some letter and text reconstructions. Variants of spectroscopic filtering could remove or reduce some of artifacts.

We will shortly describe our color fusions method in two fields, CCD-microscopy and astronomy. In the former, it enabled user to combine CCD images obtained in all standard and nonstandard wavelengths in visual and UV – microscopy, combining disjoint techniques into easy and comfortable fusions, that allowed clinic and research to see invisible relations in the examined preparations, with user controls of all segments in production of final composites. Color fusions are formed by integration of a selection of monochromes as their linear combinations. Input monochromes could be linear combinations of monochromes as well – when needing recombination of inputs which are close to collinear, thus leading towards better input separation or orthogonalization. When monochrome images in different wavelengths are made – under different optical filters, microscope is slightly moved, changing the positions of objects. These errors are to be compensated, allowing recentering of inputs in formations of color composites.

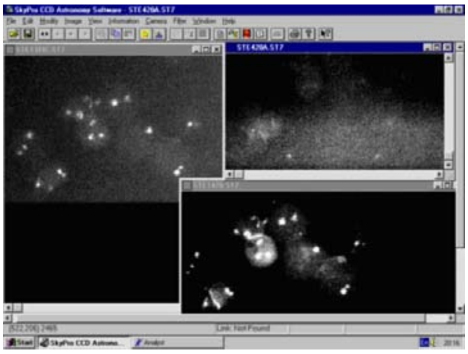

Figure 14

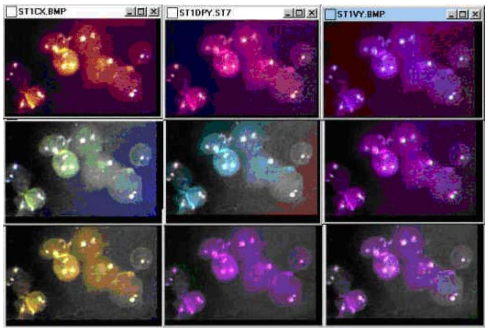

Figure 15

In the Figure 14 we obtained monochrome images of nuclei with gene signals, in the three different wavelengths in fluorescent microscopy with poor detail resolution. Our color fusions, shown on Figure 15 with user free component selection, and color combining – balancing, opened insight into hardly perceptible predicates, like relations between gene signals and their numbers and nucleic contours, extremely important in the detection of genetic malfunctions.

Method

Monochrome image fusions into functional coloring in microscopy was further generalized in our astronomy application. Our desire was to produce an efficient and comfortable work environment that would provide for “false color fusions” of all astronomic sources, with ease and necessary input preprocessing. Existing software on the market did not support all needs average researcher would demand, which was sufficient motivation. The method and software provide for fusions of data obtained with visual, IR, all radio, X and gamma recordings prepared as standard monochrome image inputs. Here described software is still under development, expected to expand the number of features and to incorporate in future other specifics, especially virtual optical components – spectroscopic lensing, based on our method of image spectroscopy, applied in the corrections of defects present in the microscopy at high magnifications.

Similar approach to ours must have been applied in the Hubble Space Telescope image processing, report of which was published in the August, 2002, issue of Sky and Telescope magazine, though all interesting details on the software were not shown, nor that software is publicly available.

Shortly the method comprises the following. Suppose the recordings of astronomic data, originating in all perceptible windows, are prepared in the form of .bmp inputs, i.e. made available in some sort of standard visual form. Designate the mentioned windows as

$$W=\{w_{s1,1};\ldots w_{s1,n1};\ w_{s2,1};\ldots;w_{s2,n2};\ \ldots\ w_{sk,1};\ldots w_{sk,nk}\},$$

with source type domains $\{s_1, s_2,\ldots,s_k\}$. Allow the preprocessing operations on the separate domains that would provide for filtering, noise reduction, sharpening, some feature enhancing, centering consisting of the reshaping of involved coordinate systems, so that the contained objects are positioned at the same coordinates, aiming finally to the linear combinations that will integrate one output for each source type

$$o_i = \Sigma\lambda_j w_{si,j} \text{ for } i\ \varepsilon\ \{1,2,\ldots,k\}.$$

So obtained type representatives are further individually and combined processed and centered before they are entered into final pre color monochrome fusion:

$$m_i = P_j(o_{i1},\ldots,o_{il}),\ i\ \varepsilon\ \{1,2,3\}.$$

Both initial and final centering consist of combined translations, rotations and zooming. The coordinate system transformations are not fully integrated yet but are experimented with, to provide for unification of diverse prevailing standards. In such a way, efficiently, a gallery of color composites $cc_j = (\rho_j m_1,\gamma_j m_2,\beta_j m_3)$, $j\ \varepsilon\ \{1,2,\ldots,v\}$,
is generated in real time, supplying researchers with potentially reach insight into the investigated phenomena and physics.

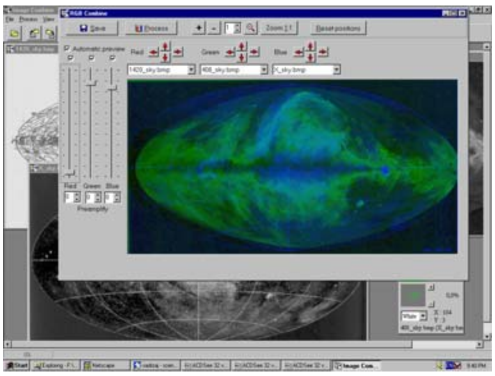
Figure 16

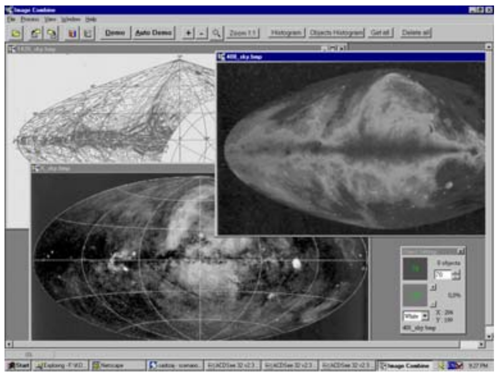
Figure 17

The Figure 16 depicts opening program frame with two radio and one X ray source images of the same area of the sky. The next image shows the final monochrome centering and integration operation for this example of fusion of radio 1420Hz and 408Hz, together with X ray source. The color composite fusion module on top of the initial program frame, shows selection, centering and weighing features of the software, which in the real time action generates the whole color composite gallery in minutes, with color balance selection suiting diversity of visualizations, some of which can be seen on Figures 18 to 21.

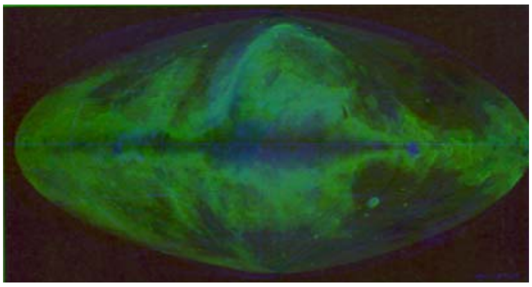

Figure 18

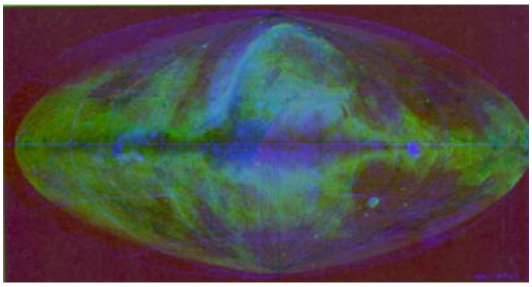

Figure 19

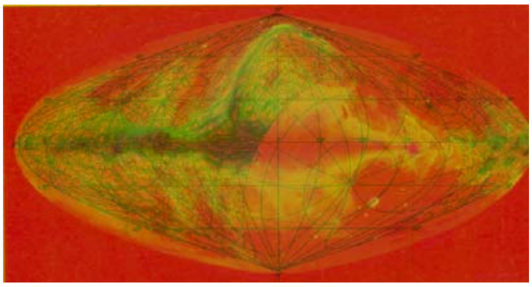

Figure 20

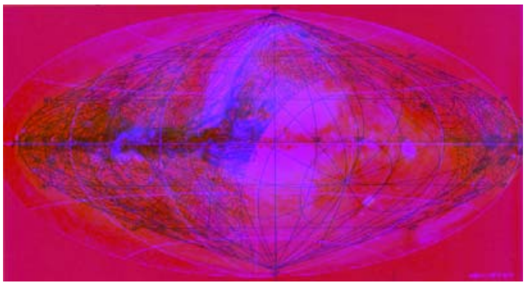

Figure 21.

For the solution of some problems listed at the beginning we would rather apply inverse transformations, image color fragmentations, rather than the described color fusions. Some problems in forensics - fingerprints, in which we are involved, are very similar to some of the problems we are facing here. This class of problems was enriched with the recent demand of one agency working for one EU country police on the problem of finger prints that should be captured from bullets and materials with overlapping artifacts. The demand is to clean as well as possible the inputs collected in the field work, so that those could be submitted to the automatic recognition which is highly sensitive to all sorts of noise. The examples of their inputs are shown on the following pictures.

Figure 22

Figure 23

A sequence of images as shown on Figures 22, 23 should be corrected against cylindrical deformation, then merged together to form the complete fingerprint. The cleaning needing examples are presented on Figures 24 and 25.

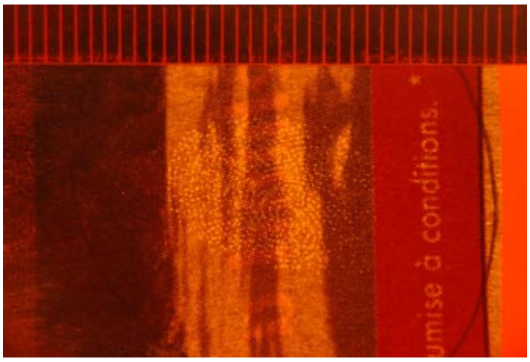

Figure 24

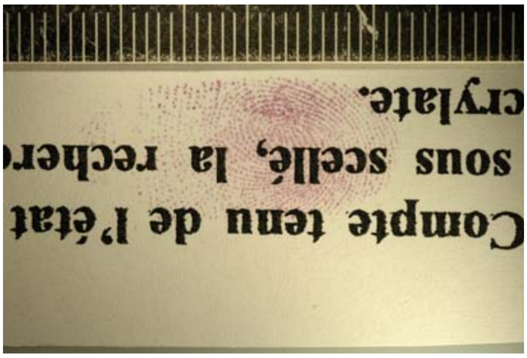

Figure 25

Various sources should support image recomposition towards the desired cleaner images. Here the aims are somewhat different and opposite to the earlier situations, so that the transforms needed are inverses of those discussed above. We need to collect enough of essentially different material, that we could preprocess and obtain reasonably non colinear, better close to orthogonal components that will serve this time not to fuse different features, rather to kill undesirable ones, with all zooming, rotation and recentering needed before the counter fusions. The way it works: suppose we have different wavelengths artifacts recorded separately, as on Figures 26 to 28.

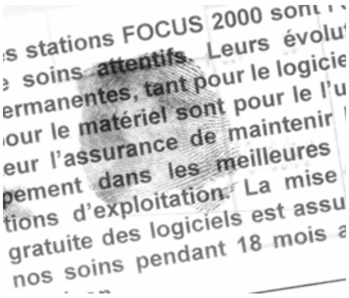

Figure 26

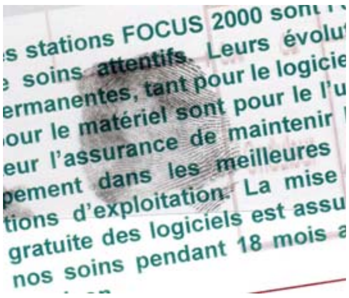

Figure 27

Figure 28

As demonstrating below, the color gallery offers the opportunity to accomplish the desired aim. Leading are the separated obstacles, the fusions provide for dimming of each of the obstacles, certain combinations are close to the optimum, with completely removed artifacts on the Figures 33 and 34.


Figure 29


Figure 30

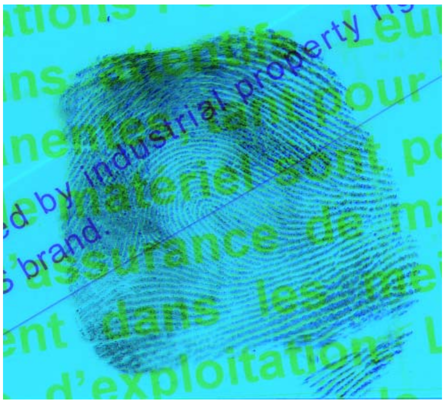
Figure 31


Figure 32


Figure 33

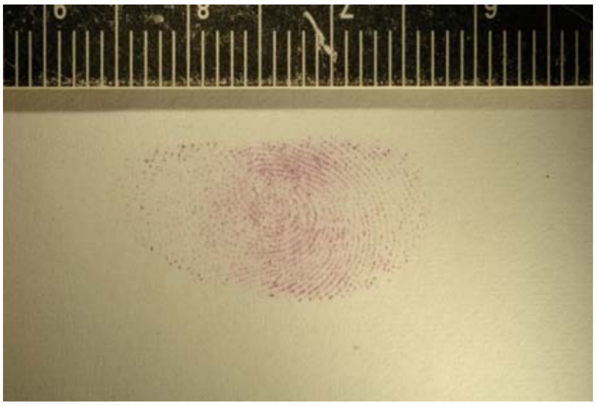
Figure 34

The diversity of inputs is necessary for the successful removal of artifacts with this method. The hard cases that we faced are when the absorption is total, or when the original acquisition of image is of insufficient resolution. If possible, the reasonable actions could include pictures in different wavelengths and change of image acquisition conditions, using IR, UV, special light effects, etc. Thus, first fusing diversity, so that we can obtain suitable fragmentations leading to the desired separation/extraction of undesirable image additions. Clearly the described procedures would help in the treatment of some of the originally described problems. Herein described image processing method is well applicable in fusions of diverse diagnostic sensors, that could lead to the integration of X-ray, NMR, sonar and whatever other diagnostic system. Obviously someone would have to do all necessary math in order to adjust – normalize the diverse inputs so that the fusions could make sense.

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[5] www.gisss.matf.bg.ac.yu

aljosha@lycos.com
www.gisss.matf.bg.ac.yu