# Modern Methods and Algorithms in Digital Processing of Endoscopic Images

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*Abstract*—**The paper is devoted to new methods and algorithms applied in various fields of digital image processing in endoscopy. The paper is separated on several parts dedicated to different groups of methods clustered by their function. The paper covers such topics of medical image processing as: contrast and brightness enhancement, color correction, highlights removing, image mosaic synthesis and the combination of images obtained in different spectral bands. For each described task of medical image processing the new algorithms or approaches are presented.**

## I. INTRODUCTION

The ability to take pictures during endoscopy created a new and rapidly developing field of research: endoscopic image processing. The main goal of this paper is to describe new and effective methods of endoscopic image processing providing image enhancement, comfortable visualization, image segmentation and analysis for automated decision support system.

The first part of investigations, is to develop new methods of brightness and contrast enhancement, edge sharpening, highlights detection and inpainting, color correction. These tasks are actual because the endoscopic images suffer from various degradation [1]. The second part of investigations - methods of visualization. The result of these advanced methods - image with wide viewing angle of organ under supervision, which is comfortable for the analysis and navigation during the physician's inspection and increasing diagnostic values of images.

The feature of proposed enhancement methods is nonlinear processing of main image characteristic (brightness, contrast and so on), nowadays the traditional image enhancement base on linear transformation [2]. The linear enhancement is not effective for medicine images, because due to complete conditions of their obtaining medicine image has nonlinear contrast and brightness changes. So there are very dark and very bright areas in one image, it demands special methods of correction. One section of the paper is devoted to non-linear method of brightness and contrast enhancement and its adaptation to medicine images.

The special attention in endoscopic images must be given to custom color correction [3]. The monitor and video processor can be adjusted to match the user's own color preferences. The important point for endoscopic color imaging is to provide the specific image that the user wants to see. For this task we offered special method based on recalculating color space of the sensor according to customer preferences given in the form of customer color space by the using a linear transformation matrix.

The third part is devoted to highlights detecting and repainting. The presence of highlights (non-uniform illumination regions) in most acquired images badly affects as for image classification as for visual analysis. White areas on the image are not suitable for image observing by physician. Moreover, the highlights can confuse the classifier and significantly decrease the precision of the diagnostic. Therefore, it is important to build the highlights map for the image and realize highlights inpainting.

The main problem of endoscopic information is the narrow field of view [4]. For overcoming this problem, we propose «mosaic» panoramic representation of organs having wide cavity. The methods of panoramas synthesis from endoscopic images is new scientific solutions by the reason of low quantity of detail in initial data. This new method is described in fourth part of the paper.

Also the paper includes method aimed on improving diagnostic properties of endoscopic images – method of combined image synthesis including information obtained in white light and the IR light. This method includes image segmentation and analysis and can be foundation for future automated decision support system. The specificity of IR images demands solutions for their segmentation and analysis based on the data mining technologies. This method is described in fifth part of report.

All methods and algorithms proposed in this paper were realized in special software "EndoscopicToolbox". This software gave possibility to realize and thoroughly test non-linear contrast and brightness enhancement, edge sharpening, noise removing, custom color correction and other described procedures.

## II. METHODS AND ALGORITHMS IN DIGITAL PROCESSING OF ENDOSCOPIC IMAGES

### A. *Contrast and brightness enhancement*

Contrast is one of the key characteristics of an image. Images with low contrast usually display little visual information, whereas high-contrast images maximize the available visual information. The conditions under which an image is captured greatly affect its contrast. In medical images improved contrast is crucial for a correct diagnosis, and from another hand the conditions of medical images obtaining are very difficult. So the medical images suffer from degradation it is necessary to eliminate this degradation before images will be demonstrated to physician.

Numerous contrast and brightness enhancement techniques exist in literature. Among them there are two main groups: linear enhancement and non-linear enhancement. Non-linear algorithms can be categorized to global and local.

Global contrast enhancement algorithms apply the same transformation to all image pixels. This category comprises the logarithm transformation, power-law transformation and Histogram Equalization.

Although global contrast enhancement methods are simple, they cannot be used successfully to all images, since they tend to exhibit degraded appearance, amplified noise or other annoying artifacts. The main reason for this is that the global methods cannot adapt to local features because they use the same transformation over the whole image.

Local enhancement techniques take into account the local features of the image and apply different transformations to every pixel or region.

In our investigation we used only non-linear enhancement techniques. It is connected with main feature of images: there are very dark and very bright areas in the same image. The main methods for non-linear contrast enhancement under investigation were:

- Multi Scale Image Contrast Enhancement [5].
- Adaptive and Integrated Neighborhood Dependent Approach for Nonlinear Enhancement (the so called AINDANE) [6].
- Locally Tuned Nonlinear Technique for Color Image Enhancement (LTSNE) [7].

The key feature of first method is three spatial scales by employing different region sizes. As a result, contrast enhancement is performed in different spatial frequencies of the original image.

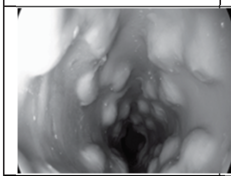
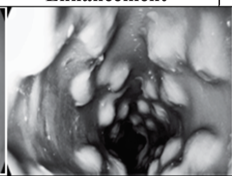
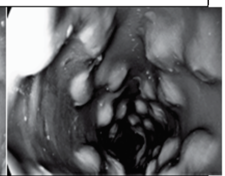
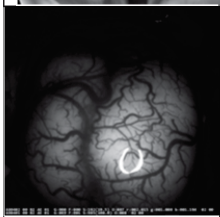
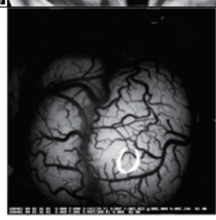
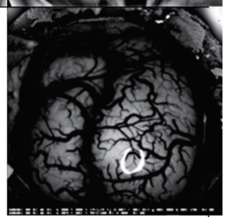
The key feature of last two methods are intensity enhancement, contrast enhancement and color enhancement. The difference between AINDANE and LTSNE takes place on the step of intensity enhancement. In AINDANE this step is based on global information about image, in LTSNE on local information, so it makes adaptive intensity enhancement. On steps of contrast and color enhancement both methods use local information and give possibility to apply different transformations to every region.

For effectiveness investigation we realized all three algorithms. According to our tests the results of AINDANE and LTSNE are quite similar, but in most cases the quality of images after LSTNE is slightly higher than after AINDANE enhancement.

The reason of this situation is clear, because LSTNE is advanced modification of AINDANE, so for further investigation we selected the LSTNE. The Multi Scale Image Contrast Enhancement is not effective for difficult cases on images with big very dark fields, but in the case of image with moderate degradations it is very useful.

The quality of it correction for images with moderate degradations is very high and comfortable for visual analysis. The illustration of this conclusion is given in Table I.

TABLE I. THE RESULTS OF VARIOUS ENHANCEMENT ALGORITHMS

| **Initial Image** | **Multi Scale Image Contrast Enhancement** | **LSTNE** |
|---|---|---|
|  |  |  |
|  |  |  |

In this table for image in top row the result of Multi Scale Image Contrast Enhancement has good quality, but this method didn’t give satisfactory result for image in bottom row. Here the enhancement was achieved only with LSTNE. The Multi Scale Image Contrast Enhancement is not effective for difficult cases (with big very dark fields). So for difficult cases we can advise LSTNE, otherwise Multi Scale Image Contrast Enhancement.

On the stage of contrast enhancement LSTNE applies the transformation function to every pixel.

$$S(x,y) = 255 \cdot Ien(x,y)^{E(x,y)} \quad (1)$$

$$E(x,y) = r(x,y)^P = (\frac{Im(x,y)}{I(x,y)})^p \quad (2)$$

where S(x,y) – pixel brightness after correction, Ien(x,y) – normalized brightness, I(x,y) – initial pixel brightness, Im (x,y) – the brightness of a local fragment of an image after Gaussian filtering, p - parameter for correction “strength”.

The described methods have common drawback. Simultaneously with the increase of the contrast, the methods significantly emphasize the noise, especially in areas of the image with low detail.

To solve this problem, we propose to consider the local features of the image on the base of the found functional relationship between the correction “strength” $p$ and the normalized variance of brightness in the image fragment [8].

It is important to stress that the method uses information about contrast in local part of image and on this base realize non-linear enhancement, so additionally to contrast and brightness enhancement it realizes edge sharpening.

### *B. Custom color correction*

The special attention in endoscopic video processing should be given to custom color correction. The picture for physician must be adjusted to match the user's own color preferences. The important point for endoscopic color imaging is to provide the specific image that the user wants to see. It makes necessary to develop new method of color correction.

*1) Color correction matrix:* There is a possibility to implement the custom color correction by recalculating color space of the sensor according to customer preferences given in the form of customer color space by the using a linear transformation matrix.

There are two possibilities to realize this transformation by using 9 coefficients matrix and by 12 coefficients matrix [9].

This color correction matrix allows each color component in the corrected image (e.g., red) to be calculated as a linear combination of the color components in the calibrated image (e.g., red, green, and blue).

This approach assumes that the image **O** is taken as a reference and the coordinates of colors from the image **P** obtained by sensor are recalculated, so that they differ from reference colors of the image **O** is minimal. Let us assume:

$$\mathbf{O} = (O_{Ri}, O_{Gi}, O_{Bi}) \tag{3}$$

$$\mathbf{P} = (P_{Ri}, P_{Gi}, P_{Bi}) \tag{4}$$

are the RGB-coordinate vectors of *i* color in the images **O** and the **P**, the reference image and the image generated by calibrated sensor, respectively. Then recalculation one color space to another can be implemented by using a linear transformation matrix consisting of 9 coefficients.

$$\mathbf{O}_i \approx \widehat{\mathbf{O}_i} = \mathbf{P}_i \mathbf{A}_9 \tag{5}$$

$$\mathbf{A}_9 = \begin{bmatrix} \alpha_1 & \alpha_2 & \alpha_3 \\ \beta_1 & \beta_2 & \beta_3 \\ \gamma_1 & \gamma_2 & \gamma_3 \end{bmatrix} \tag{6}$$

$$\begin{cases} \alpha_1 + \beta_1 + \gamma_1 = 1 \\ \alpha_2 + \beta_2 + \gamma_2 = 1 \\ \alpha_3 + \beta_3 + \gamma_3 = 1 \end{cases} \tag{7}$$

To determine the coefficients ($\alpha_i$, $\beta_i$, $\gamma_i$), it is necessary to minimize the error function based on the distance between the colors of reference and calibrated image. Minimizing the error function allows to determine the coefficients ($\alpha_i$, $\beta_i$, $\gamma_i$), then coefficients can be found from condition (7) which realized the white balance preservation (taking into account brightness shifts between the reference and calibrated images).

Accounting brightness offsets between the reference and calibrated images can be realized by the expansion of the coefficients number in the linear transformation matrix up to 12 and by the introduction in the RGB-color coordinates vector additional fourth coordinate with value equal 1. In this case, the color space recalculation can be represented in matrix

$$\mathbf{O} \approx \widehat{\mathbf{O}} = [\mathbf{1P}]\mathbf{A}_{12} \tag{8}$$

form:

where $\widehat{\mathbf{O}}$ - matrix of RGB-coordinates for colors from image P after the recalculation; $\mathbf{A}_{12}$ - the matrix of linear transformation; **O** - matrix of RGB-coordinates for colors from reference image O; **P** - matrix of RGB-coordinates for color from calibrated image P. In the equation (8), 1 - column vector needs to account shifts in brightness between images P and O.

Thus, each transformed pixel color is a linear combination of a DC offset and the processed red, green, and blue samples.

If the number of independent color coordinates in the reference image exceeds twelve, for the matrix A12 coefficients identification it is possible to use the method of

$$\mathbf{A}_{12} = ([\mathbf{1P}]^{\mathbf{T}}[\mathbf{1P}])^{-\mathbf{1}}[\mathbf{1P}]^{\mathbf{T}}\mathbf{O} \tag{9}$$

least squares.

Equation (9) is the basic equation for estimating calibration matrix coefficients in the second approach.

*2) Custom Color Checker:* Both approaches with 12 or 9 coefficients in matrix of color correction use special test set of references colors, and the coefficients of correction are determined on the base of difference between RGB – coordinate of original colors from the etalon test set (reference image) and the real colors from the test set obtained by particular sensor. So to determine the special test of reference color is important part for correction.

Usually for color correction in common purpose the test, so called Color Checker, is used. There are several implementation of Color Checker, the most often used test includes 18 colors –Fig.1 – Standard Color Checker. If we use in color correction Standard Color Checker, we realize precise color.

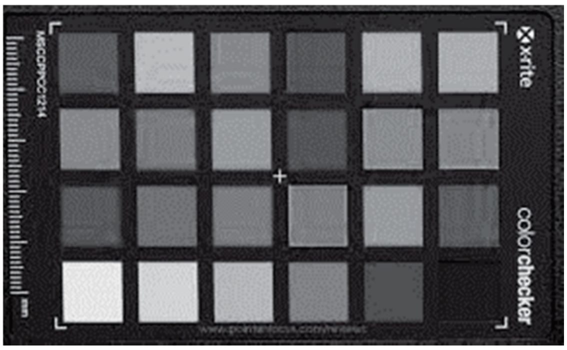



Fig. 1. Standard Color Checker

The custom color correction means, for example, that in the resulting images red color must not be pure red. It must be with some yellow tone (shade). According to "Olympus" determination one should show specialist not reddish, but yellowish color. To realize this, it is necessary to change in Standard Color Checker such colors as red, dark red and so on in yellow, red-yellow, orange and so on according to physician preference. So it is necessary to prepare the Special Color Checker with some changes in red and dark red colors.

In our research we designed a special software with the implementation of described approaches (12 and 9 coefficients of color correction). The investigation of both approaches effectiveness was realized.

Estimation of the proposed procedure effectiveness was carried out according to the next criterion - the values of average and maximum errors of color reproduction by calibrated sensor

$$E = \sum_{i}^{N} E_i \tag{10}$$

in relation to the reference Color Checker:

where $E_i$ is equal to the Euclidean distance between the RGB-coordinates of color from image O and the RGB-coordinates of

$$E_i = \sqrt{\left(O_{Ri} - \widehat{O_{Ri}}\right)^2 + \left(O_{Gi} - \widehat{O_{Gi}}\right)^2 + \left(O_{Bi} - \widehat{O_{Bi}}\right)^2} \tag{11}$$

fitted processed color:

Our investigation shows that more effective is approach based on 12 coefficients correction. The average and maximum errors in this case are smaller.

### C. *The highlights removing and inpainting*

*1) Building the map of high reflectance points:* The presence of specular highlights (non-uniform illumination regions) in most acquired images badly affects as for image classification as for visual analysis. White areas on the image are not suitable for image observing by doctor.

Moreover, the highlights can confuse the classifier and significantly decrease the precision of the diagnostic.

Therefore, it is important to build the specular highlights map for the image. The highlights map is the base for inpainting algorithm which gives possibility to synthesize image without highlights for visual analysis. The map contains important information for correction of automatic classification.

We propose the algorithm for map building, that consists of next steps.

First, the original image should be transformed to gray level image – Fig.2.

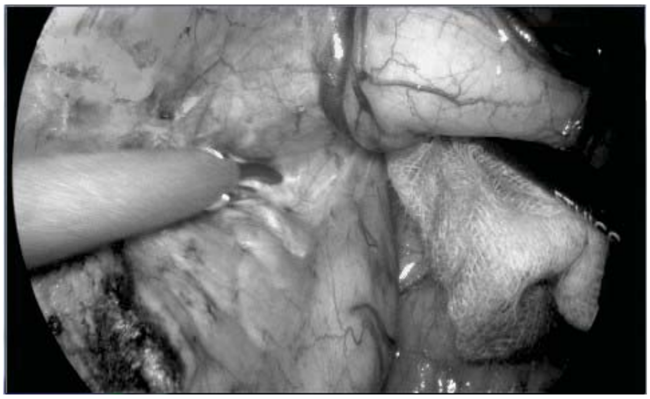


Fig. 2. Grayscale initial image

Second, the morphological operation "opening" [10] is applied to estimate the background. The result of this step is displayed on Fig.3

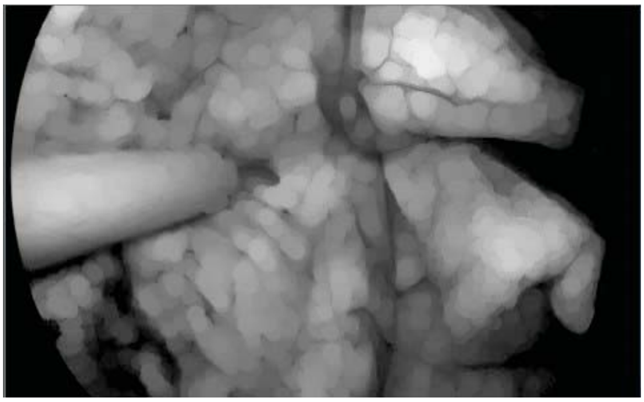


Fig. 3. Image after morphological "opening" operation

The important parameter for «opening» operation is the size of morphological structuring element. The structuring element size should be larger than the high reflectance points. The larger the element is, the smoother the background will be. For wide ranged foreground objects, it is better to increase the size of the structure elements. But the choice depends on the region of interest and on specific sensor. After testing on large set of images from popular sensors, we choose the size of 40 pixels for structure element as the experienced value.

Third, the subtraction of the "background" from the gray

$$Ifg = Iinp - Ibg \tag{12}$$

image is used to prominent the "foreground" objects – Fig.4.

where *Ifg* - is the foreground image, *Ibg*- is the result of "opening" operation, *Iinp* - is the initial image.

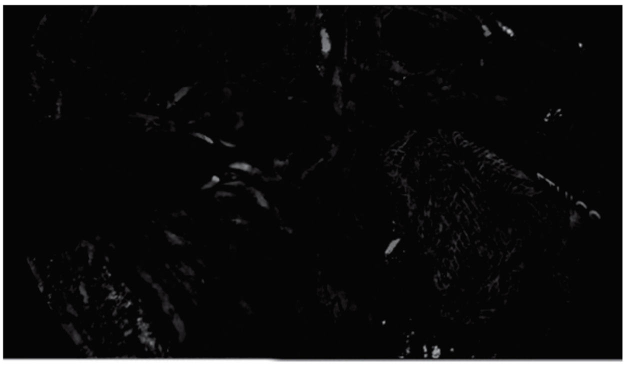


Fig. 4. Foreground extracted

The threshold is used to get the binary image – Fig.5.

$$I(p) = \frac{\sum_{q \in B_\varepsilon(p)} w(p,q)[I(q) + \nabla I(q)(p-q)]}{\sum_{q \in B_\varepsilon(p)} w(p,q)} \quad (13)$$

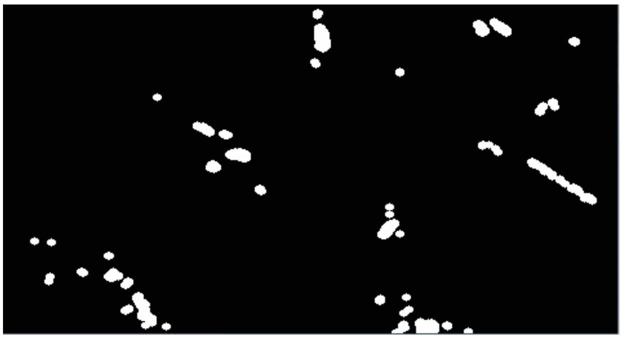


Fig. 5. Binarized foreground image

In order to show the results – Fig.6, the boundaries of the high reflectance regions were found and then superimposed on the original image. As it is shown, the algorithm can locate the high reflectance points very accurately.

The obtained map of highlights will be used in inpainting algorithm – the map shows what points should be painted.

*2) The inpainting algorithm:* Digital inpainting is the technique of reconstructing small damaged portions of an image, which has received considerable attention in recent years. Digital inpainting serves a wide range of applications, such as removing text and logos from still images or videos, reconstructing scans of deteriorated images by removing scratches or stains, or creating artistic effects. In current work we propose and implement this technique for highlights removing.

The very useful algorithm for inpainting is based on Fast Marching Method (FMM) [11]. The map of high reflectance points, which was obtained on previous step, is used for marking the regions on the image to be inpainted. The example is shown in the Fig.6 – the "dots" should be inpainted.

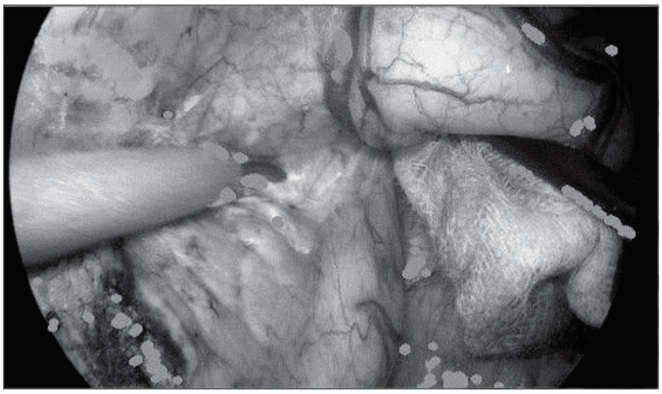


Fig. 6. Specular highlights on the initial image

Algorithm [11] starts from the boundary of the region (the area of the highlights in our case) and goes inside the region gradually filling everything in the boundary first. It analyses a small neighborhood around the pixel. This pixel is replaced by normalized weighted sum of all the known pixels in the neighborhood.

The algorithm inpaints a point p as a function of all points q in $B\varepsilon(p)$ weighted by a normalized weighting function w(p,q):

Selection of the weights is an important matter. Larger weights are given to pixels lying near to the point, near to the normal of the boundary and those lying on the boundary contours. Once a pixel is inpainted, it moves to next nearest pixel. FMM ensures those pixels near the known pixels are inpainted first, so that it just works like a manual heuristic operation.

The result of inpainting procedure is shown on the Fig.7. In comparison with figure Fig.2 all marked regions are filled.

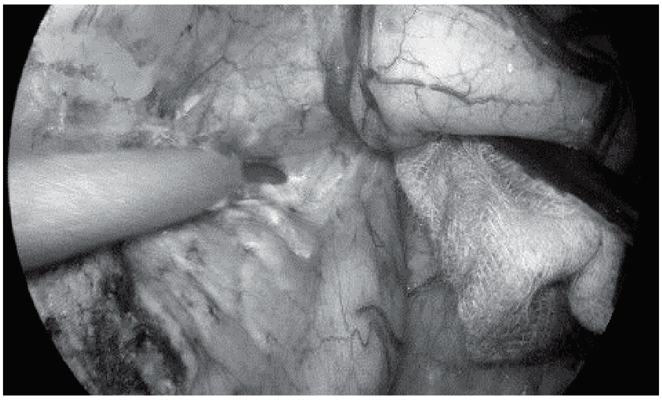


Fig. 7. The inpainted image

### D. *Synthesis of mosaic images for wide angle observation (panoramic images).*

One of the main problem of endoscopic images is the narrow field of view due to the size of most endoscopic imaging systems. As a result, individual images are often not very intuitive for evaluation. Automated mosaicking offers the opportunity to create an integrated picture or an environment map of a scene from a video sequence of endoscopic images.

In general, the problem of image mosaicking is well studied. The main steps of image stitching are:

- Key points detection.
- Key points matching and selection.
- The coefficient of transformation matrix identification.
- Bundle adjustment.
- Images stitching.

The first and very important step in panoramic synthesis approach is key point detection. Usually this step is realized by some "feature detector", like SURF, of SIFT [12].

At the second step the correlation matching of blocks formed with key points as center is carried out. Each block of the first image is compared with all the blocks of the second image. This allows to find for each key point from the first image matching key point from the second image and to obtain matched pairs of key points.

The presence of noise, the difference in the angles of images leads to the formation erroneously matched pairs. Typically, to reduce their amount threshold is used. If the images have low amount of detail, this leads to a small number of matched pairs of key points. Insufficient amount of matched pairs leads to incorrect identification of the transformation parameters.

In the case of medical images mosaicking which are often homogeneous the initial quantity of detail the quantity of key points is very low. We propose the special procedure for video panorama construction from the images with small quantity of key points. The main features (and differences in comparison with the classical approach) of proposed procedure are:

- The reliability degree for key points matched pairs is introduced. It gives possibility to eliminate threshold
- for matched pairs filtering and using the maximum quantity of key points pairs.
- The special modifications of RANSAC method are proposed. It supports the using of all found matched points with taking in advance their reliability degree for the source images transformation parameters identification.

The estimation of reliability degree for matched pairs is realized on the base of the so called suppression measure. For each pair of matching key points (*pi, pq*) the measure of suppression is calculated:

$$\xi_i = \frac{1}{N-1}\sum_{j=1}^{N}\frac{min\left(\frac{\Delta x_i}{\Delta x_j},\frac{\Delta x_j}{\Delta x_i}\right)+min\left(\frac{\Delta y_i}{\Delta y_j},\frac{\Delta y_j}{\Delta y_i}\right)}{2} \quad (14)$$

where $j \neq i$, $(x_{qi}, y_{qi})$ – coordinates of the point *i* from set *Q* (key points from first image), $(x_{qj}, y_{qj})$ – coordinates of the point *j* from set *Q*, $(x_{pi}, y_{pi})$ – coordinates of the point *i* from set *P* (key points from second image), $(x_{pj}, y_{pj})$ – coordinates of the point *j* from set *P*.

Then from the set of all matched pairs *PQ* the set with good matches *PQopt* with the measure of suppression $\xi i$ = [0,9..1] and the reliability degree *Rd*=1 is formed. For each element of the set (*PQ – PQopt*) the measure of suppression $\xi i$ = [0..0,9] from the pairs of the set *PQopt* and the reliability degree *Rd* = [0..0,9] is calculated via iterative procedure.

The introduction of the reliability degree gives possibility to produce transformation parameters identification with all found matched pairs of key points. This position is ensured by using special proposed modification of RANSAC algorithm.

The main idea of RANSAC modification is using two criteria for selecting the best estimates of the transformation parameters instead one criteria in the base version of RANSAC [13]. In addition to the generally accepted criteria of the matched pair's total quantity the criterion of pair's reliability is introduced. It calculated as sum of reliability degree of matched pairs used on the current RANSAC iteration.

The algorithm is described below.

The goal of RANSAC algorithm to identify the coefficients of transformation matrix. In our task we use matrix corresponding homography transformation.

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \quad (15)$$

where (*x'*, *y'*, *1*) and (*x*, *y*, *1*) – coordinates of corresponding points in the images (the first image is reference, the second - under transformation); $\{h_{11},\ldots,h_{33}\}$ – coefficients of transformation matrix.

The main steps of RANSAC algorithm with modification are:

- To choose randomly 5 points from the matched pairs set. Then to calculate the transformation parameters (set the initial hypothesis *T*) and the transformation error *E*.

$$E = \begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} - \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \quad (16)$$

- To compute the number of inliers *P* for current *T* (the inlier means the pair with transformation error *E* smaller then 2-3 pixels) and to calculate the mean reliability degree *D* for current *T*.

$$D = 1/P \sum_{P} d_j \quad (17)$$

- To repeat the stages 1 and 2 *K* times (*K > 1000*). If new hypothesis with more inliers then current *T* is found, then the new parameters are memorized and the current hypothesis *T* is updated.

- To rank all the hypotheses in two lists according to the inliers number and according to the mean reliability degree value.
- To choose the hypothesis with the minimal sum of places in both lists.
- To calculate the transformation parameters on the base of all inliers for chosen hypothesis.
- To remove the outliers and to recalculate parameters until all outliers will be eliminated.

The offered method gives possibility to obtain panoramic images in condition of medical images with low detail – Fig.8.

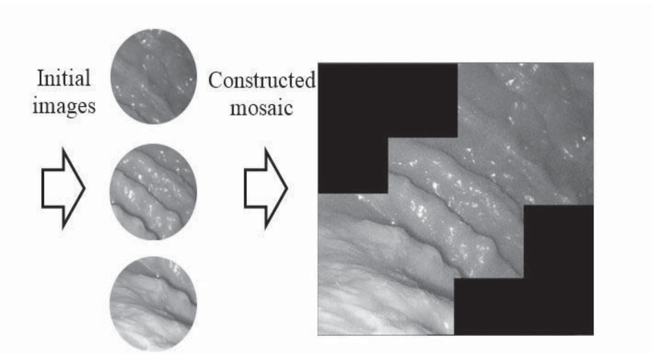



Fig. 8. Mosaic image obtained with proposed method

### *E. The combination of images obtained in different spectral bands*

For better representation and automatic image analysis it is important to take in attention and use combination of images, obtained in different spectral bands. Most promising is a combination of IR and fluorescent or visible bands.

The main feature of infrared channel in conditions of diagnosis and therapy of different cancer diseases is the ability of special injected reagents to glow in IR spectrum – Fig. 9.

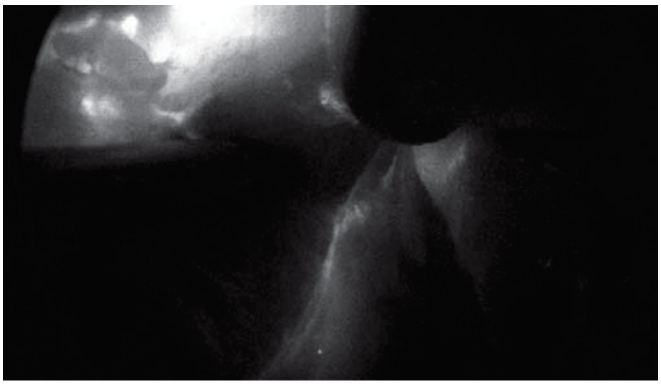


Fig. 9. Glowing in IR channel

The drawbacks of IR representation are high presence of noise and weak ergonomics of visualization.

The common approach to enhance the visualization quality is a combination of IR image with image in visible spectrum. The known algorithm to do it is based on channel mixing. The IR channel is merged with B channel of RGB image in visible spectral band.

Main problem of this algorithm is unavoidable errors in visualization. It represents well the areas with reagent glowing in IR, but due to the presence of noise and various distribution of initial RGB and IR channels there are some highlighted areas on combined image, that don't have any glowing in IR.

These errors can confuse the physician and are not suitable for observation.

To cope with these drawbacks a new algorithm for image combination is proposed. It has the following steps:

- First step is the estimation of noise level in IR image. The initial image is convolved with Gaussian kernel with relative high dispersion. The minimum of the convolution result is assumed as the mean noise level. The dispersion of noise is also estimated to give the possibility to estimate max value of noise level according to "three-sigma" rule.
- By the subtracting the noise from initial image the algorithm noticeably reduces the amount of noise pixels. And it produces the mask for pixels, that are generated not by noise.
- The morphological operation "opening" is applied on the image.
- The mask is applied on initial image.
- The resulting image is combined with image in visible spectrum as weighted sum. The weight could be adjusted to reveal more or less glowing of the reagent in IR channel on combined image.

On the Fig.10 left to right there are initial IR image, processed mask and the result of the mask application.

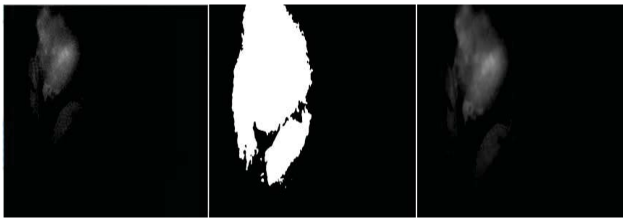


Fig. 10. The initial IR image, the mask, the result of application

The scheme below (Algorithm 1) represents the idea.

| **Algorithm 1** Combination of images from IR and visible spectral bands |
|---|
| 0: **Convolve** the *IR image* with Gaussian kernel to get noise *mean* and *dispersion*. |
| 1: **Subtract** the noise from initial *IR image* and get the *mask* |
| 2: **Morphological opening** for the *IR image* |
| 3: **Bitwise AND** for *IR image* and *mask* |
| 4: **Weighted sum** of *IR image* and *image in visible spectral band* |

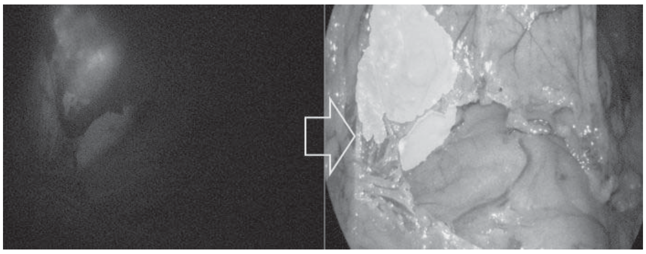


Fig. 11. The example of image combination by proposed algorithm

On the Fig.11 the results of the proposed algorithm are shown. It is clear that there aren't any visualization errors in comparison with the algorithm on the base of color mixing.

## III. CONCLUSION

It is important to note, that all the proposed methods can be used not only in endoscopy device, but also in clinical decision support system based on endoscopy images. The proposed methods have software realization and were successfully tested on real endoscopic images. The most interesting results, which were got during our research are:

- The methods of endoscopic images preprocessing for physicians analyze based on the nonlinear contrast, allows to save the contrast of the vessels relative to the background and the special process of color correction matrix, taking into account the characteristics of endoscopic images.
- The method of "mosaic" synthesis in conditional of low detail in the original video data. The method involves a new solution in the procedure for key points detection, procedure for detected key points selection, as well as in modification of the procedures for identifying the transformation equation coefficients.
- The method of combined image synthesis including information obtained in white light and the IR light. The method involves the development of new procedure for images segmentation obtained in IR light based on the technology of machine learning.

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