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ORIGINAL ARTICLE

# DIGITAL IMAGES CLASSIFICATION IN AUTOMATIC LAPAROSCOPIC DIAGNOSTICS

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**ABSTRACT**

**The aim:** To evaluate the automatic computer diagnostic (ACD) systems, which were developed, based on two classifiers–HAAR features cascade and AdaBoost for the laparoscopic diagnostics of appendicitis and ovarian cysts in women with chronic pelvic pain.

**Materials and methods:** The training of HAAR features cascade, and AdaBoost classifiers were performed with images/ frames of laparoscopic diagnostics. Both gamma-corrected RGB and RGB converted into HSV frames were used for training. Descriptors were extracted from images with the method of Local Binary Pattern (LBP), which includes both data on color characteristics («modified color LBP»-MCLBP) and textural features.

**Results:** Classification of test video images revealed that the highest recall for appendicitis diagnostics was achieved after training of AdaBoost with MCLBP descriptors extracted from RGB images – 0.708, and in the case of ovarian cysts diagnostics – for MCLBP gained from RGB images – 0.886 ($P<0.05$). Developed AdaBoost-based ACD system achieved a 73.6% correct classification rate (accuracy) for appendicitis and 85.4% for ovarian cysts. The accuracy of the HAAR features classifier was highest in the case of ovarian cysts identification and achieved 0,653 (RGB) – 0,708 (HSV) values ($P<0.05$).

**Conclusions:** The HAAR feature-based cascade classifier turned out to be less effective when compared with the AdaBoost classifier trained with MCLBP descriptors. Ovarian cysts were better diagnosed when compared with appendicitis with the developed ACD

**KEY WORDS:** laparoscopic surgery, images analysis, HAAR features cascade, AdaBoost classifier

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## INTRODUCTION

Automatic computer diagnostic (ACD) / classification of video – images is actual for minimally invasive abdominal surgery and endoscopy [1 - 4]. ACD systems developed for tracking laparoscopic instrumentation [5], and identification of zones of pathology proved their effectiveness [3, 6, 7].

As far as HAAR features exclude analyzing each pixel of an image, the total time for analysis is shortened [5]. It makes the recognition of images congruent with the velocity of video-frames flowing and justifies the exploration of the classifier based on the HAAR-features cascade for video-data analysis. Meanwhile, the main disadvantage of that classifier exploration is confined to a prolonged period of training, which might be measured in months when tens of thousands of images are used. It is hard to avoid that inconvenience as far as increasing the number of images is proportional to the effectiveness of diagnostics [5].

To strengthen the effectiveness of the HAAR - feature-based classifier, we decided to use both color and texture features for training [6, 8]. Thus texture features such as the heightened mediana of greyscale and entropy and contrast might be treated as informative differential indices for normal tissue state identification [3, 9]. Besides, as an alternative to HAAR feature-based classifier, we have explored the AdaBoost classifier trained with a minimal number of descriptors gained from the Local Binary Pattern (LBP) method application [6]. The classical method of LBP manipulates with the greyscale of color and ignores other colors' information. Instead, the modified LBP method, which includes data on color characteristics (modified color LBP- MCLBP) [10], was used in the present investigation to gain color and texture descriptors [11 - 13].

## THE AIM

To compare the effectiveness of an ACD based on HAAR-based features cascade classifier with an AdaBoost-based ACD, which both were trained to distinguish between the normal and pathological state of the appendix and ovary in women with chronic pelvic pain syndrome. Besides, the comparison of diagnostic results between RGB and HSV color scales was performed.

### THE OBJECT OF THE INVESTIGATIONS

Data on true and false diagnosed appendicitis and ovarian cysts gained in the course of laparoscopic ACD were taken into consideration.

## MATERIALS AND METHODS

All observations were performed in accordance with Helsinki Declaration, international laws, and policies. Odesa National Medical University Bioethics Committee (UBC) approval (No17) dated 22/03/2018 was obtained before the start of the study.

The following steps were performed in the course of collecting data and their analysis:

- Calibration of a digital camera, which included white color balance and conversion of color scale into digital code;
- The object was located in the frontal position, which was under inspection. The deviation from the right angle was 15±5 degrees, and the distance to the visualized zone was from 3 to 5 cm [11]. Those images which got in a such a fashion were used for both ACD training and testing;
- Those zones of interest size were 60 x 60 pixels [6, 8]; in the course of the laparoscopic intervention, the speed of video frames was modified via using the low-frequency filter, and the size of the image was artificially modified from 30 x 30 up to 60 x 60 pixels, which was necessary for optimizing classificatory performance.
- Gamma-correction of the gained image performed with the recalculation of gamma-coefficient. The usage of gamma-correction in the preprocessing of primarily gathering information permits to identify relations between quantitative pixel characteristics and their actual brightness [7, 11, 12].
- Conversion of RGB scale into HSV one. Haar features' orientation justifies such a conversion on the estimation of the intensity of pixels.
- Training to HAAR features classifier, using both RGB and HSV images;
- Training AdaBoost classifier with MCLB templates [6, 8]; key features used were confined to mean, entropy, contrast, homogeneity, and excesses.
- Results of classification stored in the database, and additional analysis performed later on.

All laparoscopic videos got a 5 mm aperture diameter Carl Storz Tricam Camera (Carl Storz, Germany) during the 2015-2021 years. That camera had the analogous input (PAL 475 horizontal lines), and the incoming signal was digitalized with the pixel density of 720 x 576 and capture was made with video capture card "AVerMedia HD capture Studio 203" (Avermedia, France) and presented at ACD interface (Fig 1).

### FEATURES EXTRACTION AND CLASSIFIER TRAINING

MCLBP calculates LBP for R and G channels of normalized RGB color space [10]. It served to get a more stable RGB – MCLBP under different conditions of illumination intensity.

The texture characteristics calculation using HSV - MCLBP was performed via recalculations on the Hue channel, which was invariant concerning illumination and saturation variability. For LBP calculation, the radius of 1,5 and 12 pixels was applied [10]. The pertinent pattern created for each scale vector, as a result, and the characteristic vector for templates of MCLBP, which included mean, entropy, contrast, homogeneity, and excesses, was determined [10, 11].

For the training of classifiers, 45 laparoscopic video images of patients with appendicitis and 43 with ovarian cysts were used as "positive" ones (Figure 2). Also, 40 videos gained from the normal appendix and 35 from the ovarian surface for the classifier training were used as a control – "negative" images. Each video contained 2500 – 3000 frames, among which manually, those for teaching and testing collections were verified, cropped out, and stored.

**Table I.** Comparative effectiveness of HAAR features-based and Ada-Boost classifiers trained with RGB and HSV images

| Classifier | Frames type used for training | True positive | True negative | False positive | False negative | Precision | Recall | F1 Score | Accuracy |
|---|---|---|---|---|---|---|---|---|---|
| **Appendicitis** | | | | | | | | | |
| Haar-features cascade | RGB | 107 | 113 | 83 | 136 | 0.563 | 0.440 | 0.494 | 0.501 |
| | HSV | 116 | 125 | 71 | 127 | 0.601 | 0.477 | 0.527 | 0.549 |
| AdaBoost | MCLBP (RGB) | 172 | 151 | 45 | 71 | 0.793*# | 0.708*# | 0.748*# | 0.736*# |
| | MCLBP (HSV) | 145 | 137 | 59 | 98 | 0.711* | 0.597* | 0.649* | 0.642* |
| **Ovarian cysts** | | | | | | | | | |
| Haar-features cascade | RGB | 83 | 105 | 45 | 49 | 0.654 | 0.629 | 0.641 | 0.653 |
| | HSV | 94 | 110 | 40 | 38 | 0.701 | 0.712 | 0.706 | 0.708 |
| AdaBoost | MCLBP (RGB) | 117 | 129 | 21 | 15 | 0.848*# | 0.886*# | 0.867*# | 0.854*# |
| | MCLBP (HSV) | 106 | 116 | 34 | 26 | 0.757 | 0.803* | 0.779* | 0.771* |

Note: Fisher's exact test used for statistical comparison *-P<0.05 when compared with the corresponded group diagnosed with Haar–features cascade; #-P<0.05 when results between RGB and HSV data compared in corresponded groups.

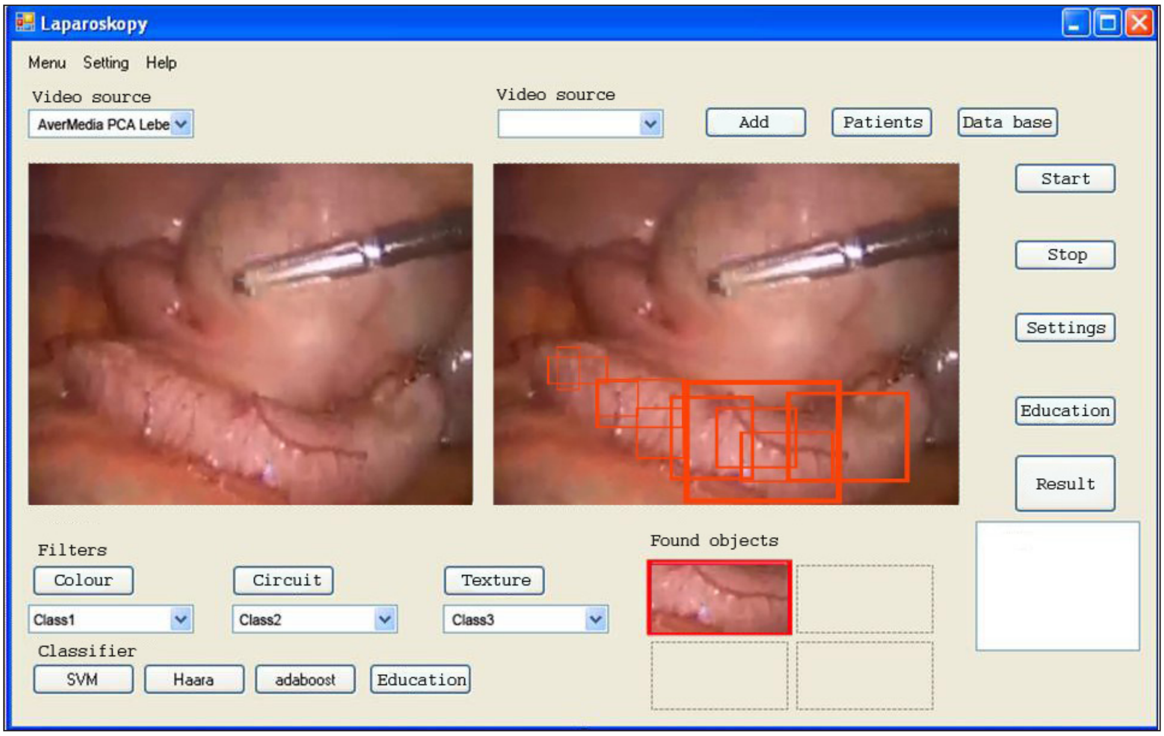


**Fig. 1.** The interface of the software illustrates zones of appendix inflammation (frames)

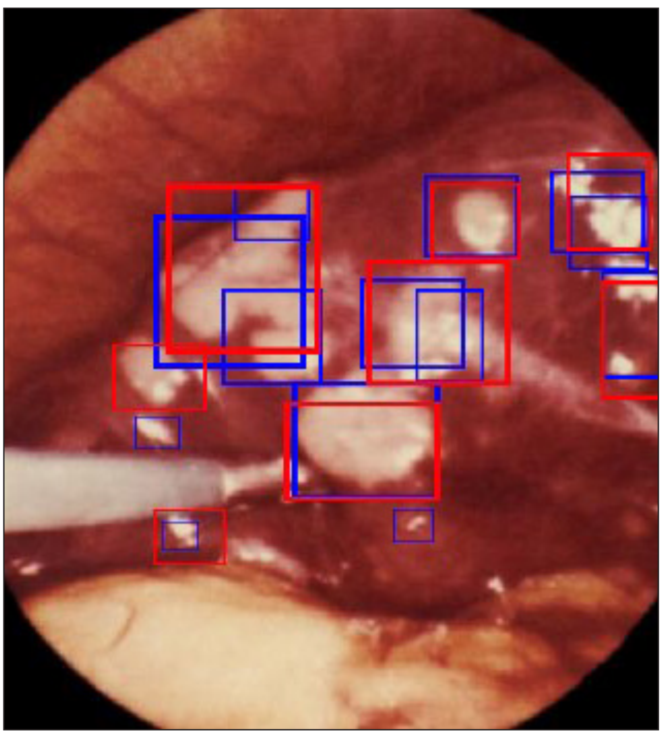

**Fig. 2.** The general scheme on the ACD work. With the squares, «zones of interest» are automatically defined and tracked

For classifiers training, the next parameters were explored [6]:
- False-positive rate f = 0,3;
- Windows with the size of the frame as 60x60 pixels;
- Number of positive images - n=1000 for each pathology;
- Number of negative images - n=500;

After cessation of training, the tests were performed to estimate the effectiveness of recognition.

Test session images were different from those which have been used for the training of the classifier. Test control sessions were performed with 243 frames containing appendicitis and 132 frames with ovarian cysts. Three 346 frames with the absence of mentioned pathology were used as a control group – normal appendix (196) and ovarium (150).

## STATISTICAL PROCEDURES

To assess the performance of our classifiers, we use the measures precision, recall, and F-score [1, 5]. Precision measures the fraction of the detected-positive instances, which are true-positive (TP):
Precision = TP/ (TP + FP),
where FP – false positive instances.

A recall (TP/ P - number of positive instances) is the fraction of all true-positive instances, which are also detected positively.

F-score (also F-measure or F1-score) is the harmonic mean of precision and recall:

F = 2 ∗ Precision ∗ Recall/ Precision + Recall.

Accuracy is the proportion of correctly classified items out of all the items classified:

Accuracy = (TP + TN)/ (TP + TN + FP + FN),

where TN – the number of true-negative, FN – the number of false-negative instances.

Statistical comparisons of gained data were performed using Fisher's exact test. The value of $P<0.05$ was taken as significant.

## RESULTS

Presented data showed that appendicitis diagnostics in women with chronic pelvic pain were less effective than diagnostics of ovarian cysts (Table I). Such difference in effectiveness was observed in both training with RGB and HSV types of images. Meanwhile, the highest value of recall was observed for appendicitis diagnostics after training with RGB images for MCLBP – 0.886 and exceeded such one for training with HSV images for MCLBP, which occupied second place - 0.803 ($P<0.05$). The lowest recall was registered for appendicitis diagnostics with HAAR features trained with RGB images (0.440). It should be stressed that in the course of diagnostics of appendicitis as well as diagnostics of cysts MCLBP- based methods revealed better diagnostics results when compared with the based RGB and HSV images training of the classifiers.

It is worth noting that training MCLBP with RGB images raised the number of true positive diagnoses pertained to that gained with HAAR-features cascade classifier in case of appendicitis diagnostics by 1.61 times ($P<0.05$) and in case of ovarian cysts diagnostics – by 1.41 times ($P<0.05$). The corresponded reduction of false-negative diagnoses was 1.92 ($P<0.05$) and 3.27 times ($P<0.05$). A less pronounced increase in the number of true positive diagnoses with MCLBP – HSV training was 1.25 times for appendicitis and 1.13 times for ovarian cysts. The reduction of false-negative diagnoses was 1.18 and 1.08 times correspondently.

## DISCUSSION

Hence, gained data favor the relatively high effectiveness of laparoscopic diagnostics of the diseases that cause chronic pelvic pain in women using developed ACD systems. It should stress that such a result corresponds with early gained data in the course of liver pathology diagnostics [6]. Altogether our data prove that only the HAAR-like feature-based classifier is insufficient for reliable object classification [5].

One of the reasons for such a difference is that HAAR feature-based cascade classifier needs more time for the stream of image recalculation, even though better diagnostic results followed training with HSV images. The massive number of variants of pathological manifestations (shape, color, texture) and the role of different orientations are also crucial for correct HAAR feature-based cascade classifier application [14, 15].

Also, our data showed that diagnostics of appendicitis results were weaker than cysts diagnostics independently of image type, which was used for training. Such result points to less potential of HAAR features based classifier for correct video laparoscopic diagnostics when compared with AdaBoost results of diagnostics.

Hence, developing a diagnostic system based on training with modified templates of both RGB and HSV images and minimal MCLBP-derived descriptors substantially improved the results of classification performed with the AdaBoost classifier. Our data showed that MCLBP descriptors from RGB images drastically reduced false-negative diagnoses - by 1.92 for appendicitis and 3.27 times for ovarian cysts compared with the corresponding data gained with Haar feature-based classifier exploration. The number of true positive diagnoses rose by 1.61 times and by 1.41 correspondently. Similar tendencies but less pronounced were registered for training with HSV images.

It should be noted that results on RGB image usage were better than such ones based on HSV image exploration. This fact is in favor of a better description of tissue properties in the RGB color scale [7, 16]. Although the net advantage of HAAR features based classification – shortened number of data for the machine learning as well as preventing overfitting of trained classifier [15, 17], the exploration of MCLBP-based training of AdaBoost proved to be more effective for laparoscopic ACD of diseases which caused chronic pelvic pain in women. It is also possible that a cascade classifier trained with MCLBP descriptors could demonstrate better diagnostics performance, and AdaBoost trained with HAAR descriptors.

Altogether, our data point to a positive perspective with the usage of MCLBP descriptors for AdaBoost classifier training to resolve automatic diagnostics problems in laparoscopic surgery.

## CONCLUSIONS

1. The ACD of laparoscopic images based on the AdaBoost classifier permitted effectively classifying appendicitis and ovarian cysts in women who suffered from chronic pelvic pain with the highest recall gained with MCLBP from HSV images used for training – up to 0.803, and for MCLBP RGB – up to 0.886 correspondently.
2. MCLBP used descriptors for training the AdaBoost classifier proved to increase the precision, recall, F1 score, and the accuracy of automatic diagnostics of appendicitis and ovarian cysts.

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**Conflict of interest:**

*The Authors declare no conflict of interest.*

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