Regular Shapes Detection for Analysis of Biomedical Image Sequences

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***Abstract* –Segmentation of moving areas in high-speed biomedical video sequences captured by light microscope often contains some false-positive results which are generated by artifacts present in the image, e.g. air bubbles or red blood cells moving across the video. Such artifacts are common part of tissue samples under microscope. Moreover, if they closely interact with the objects of interest or they are crossing the scene, they might distort the segmentation results. In many cases these particles are of regular shape, usually circular or elliptic. This is in contrast with linear character of observed objects. There are many ways how to detect regular shapes in an image. In this paper some of them will be discussed and the results compared.**

Keywords-Hough transformation, shape detection, virtual instrumentation, cilia, high-speed cinematography

I. Introduction

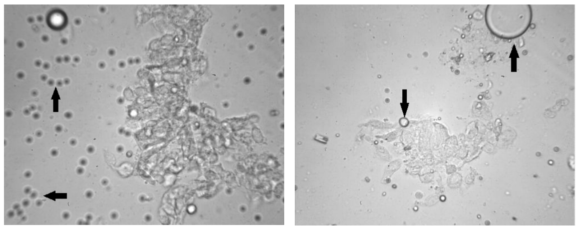
The necessary task when dealing with analysis of any image sequence, is the segmentation of captured scene and recognition of the objects of interest [1]. In our research such objects are cilia of respiratory epithelium, so that we are dealing with biomedical image analysis. Cilia are microscopic hair-like organelles which are responsible for cleaning mechanism in human airways. As long as they are moving, the main segmentation criterion is the movement within desired frequency range.

However, the video sequences with living and moving microscopic cilia in many cases comprises also certain artifacts typical for biological preparates – blood cells, especially the red ones (erythrocytes), and air bubbles (Figure 1). In case of that such artifacts are situated close to the objects of interest, their movement influences the evaluation and causes mistakes in final results. The same might happen when the artifacts are floating the scene throughout the whole video sequence, too.

Although the presence of artifacts in the images means a complication in analysis process, this problem cloud be solved. Due to their regular (mostly circular) shape they can be easily identified and detected by certain methods of computer vision analysis [2], [3]. Once they are reliably detected and marked, they can be easily excluded from the image sequences and not to influence the segmentation any more.

This artifacts detection aims to more objective diagnostics, i.e. the elimination of naked eye errors. The proper results of segmentation can be used to set some useful indexes for classification of degree of ciliary pathological changes in airways. The essential part of this research lies in implementation of novel machine vision approaches into medical imaging.

Figure 1 Epithelial cell surrounded by circular objects: a) red blood cells and b) air bubbles



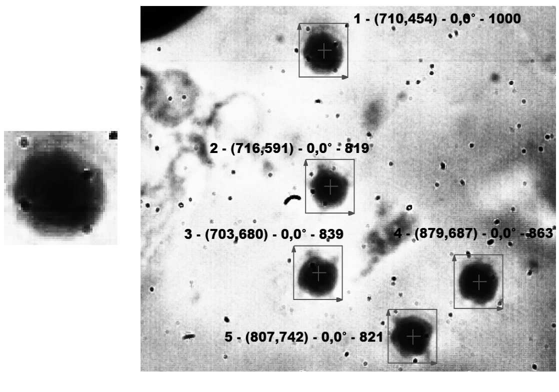
a) b)

II. Shape Detection Methods

The object of interest can be recognized by its typical texture features, shape features or both. Most popular methods for object recognition in machine vision applications are pattern matching, geometrical matching and Hough transformation.

Pattern matching is based on normalized cross correlation between template image and inspected image (object is recognized by its texture) [4]. Primary it is not invariant to object's scaling and rotation. If the object in inspected image is rotated or scaled, pattern matching requires iterative correlation process with scaled and rotated templates. The results include coordinates of the object's center, rotation angle in degrees and matching score, respectively (Figure 2).

Figure 2 Searching for defined objects using pattern matching technique: a) template and b) results detail



a) b)

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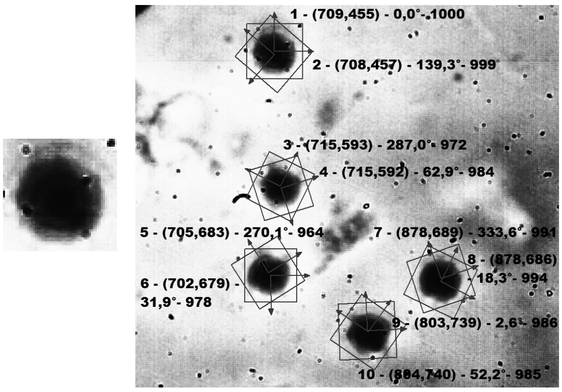
In the first step, geometrical matching algorithm learns the chosen template: it describes basic shapes and their relations which create the object [5]. These shape descriptors are stored in feature vector and sorted by their importance. This phase is very sensitive to edge detector and boundary tracking algorithm. In the other step, geometrical matching searches for edges in inspected image and tries to find the regions containing shape descriptors very similar to those ones from template feature vector. Method is scale and rotation invariant. Recognized object is described by its matching score (similarity), position in image and rotation angle compared to the template. Disadvantage of this algorithm is the fact that the same circular object can be found more than once – as the original one which matches with the template and then again when searching under different angles of rotation (Figure 3). However such multiplicity of one object can be easily excluded based on its coordinates.

Figure 3 Detection of defined objects using geometrical matching technique: a) template and b) multiple results



a) b)

Hough transformation is a method which transforms certain image features into the probability of particular shapes occurrence [6], [7]. When searching for circle objects, the parametric expression of a circle is needed:

$$(x-a)^2+(y-b)^2=c^2 \quad (1)$$

Objects are searched as local maxima in parametric space – accumulator, whose dimension is given by the number of unknown parameters (Figure 4 and Figure 5) [8]. In order to simplify the task, it is often searched for two unknown parameters (coordinates of circle's center *a, b*) with known radius (one value or narrow range of values). This method is also able to detect circular objects even if they are defective or incomplete [9], [10] and [11].

Figure 4 Principle of Hough transformation for circles

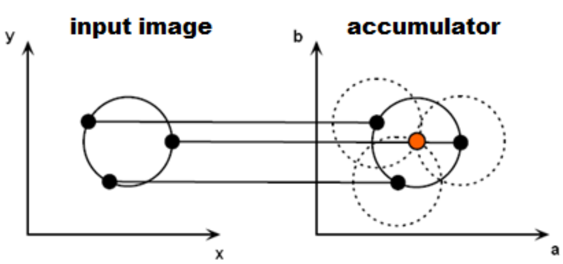
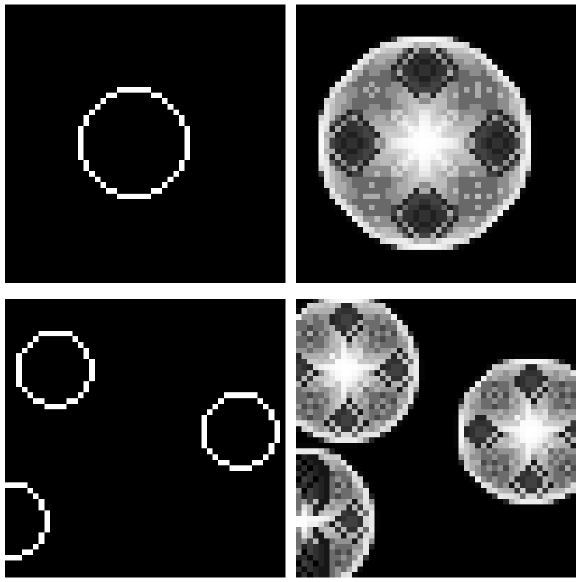


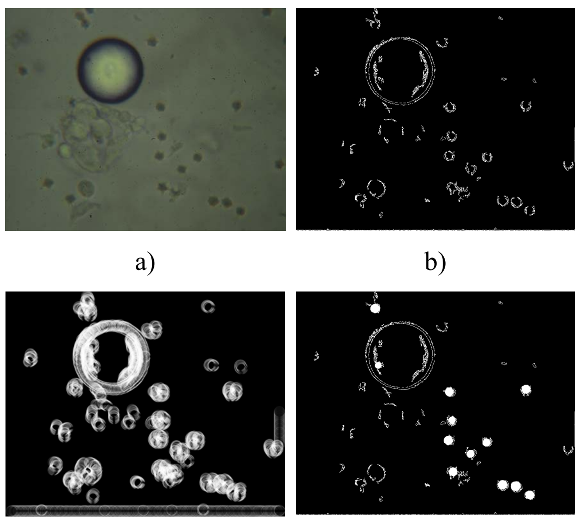
Figure 5 Example of Hough accumulator for some circular shapes



III. EXPERIMENTAL RESULTS

In the first step of automatic segmentation of acquired video sequences, all regions with motion are detected. ROI window (e.g. 10x10 pixels) shifts across the image and intensity changes are evaluated for each position (Figure 6a). This time profiles of intensity changes are then analyzed by FFT [12], [13] and [14]. After that, each ROI is replaced by the dominant frequency. Such frequency map is the basis for highlighting and quantification of moving regions [15], [16]. After that, false positive regions (artifacts) are removed: circular objects are detected and in case of that their position coincides with highlighted region, such regions are no longer considered as regions of interest (cilia) and are simply excluded from resulting images. Detection of circular objects is done by all three methods mentioned above (pattern matching, geometrical matching and Hough transformation) and obtained results are compared in the discussion.

Figure 6 a) Input image, b) Binarized image for Hough transformation, c) Hough parametric space (accumulator), d) Result after Hough transformation with labeled (white ovals) regular shaped objects



a) b)

c) d)

Pattern and geometrical matching do not require any special image preprocessing, only smoothing, blurring and intensity corrections of the input images might be made. Before applying the Hough transformation for circle detection, it is necessary to extract only the important edge information. Canny edge detector or Moravec operator can be used for such purpose. Image is then binarized by thresholding. In order to fasten the Hough transformation it is suitable to search for only narrow range of diameters. It is also appropriate if the object's boundary width is only 1 pixel.

Moravec operator follows the equation:

$$f(i,j)=\sum_{k=i-1}^{i+1}\sum_{k=i-1}^{i+1}\left|g(k,e)-g(i,j)\right| \qquad (2)$$

where *i, j* are coordinates of certain pixel and *k, e* are coordinates of its surrounding.

The following image series demonstrate the analysis and rejection of false-positive segmentations of ciliary areas. Figure 6b shows binarized image created using Moravec operator 3x3 and manual threshold (T=10). Figure 7, Figure 8, Figure 9 represent detection of regular shaped objects by presented three methods on selected one frame of a video sequence. Non-filtered segmented areas are shown in Figure 10 and the result after removing false-positives (based on all three methods) is in Figure 11.

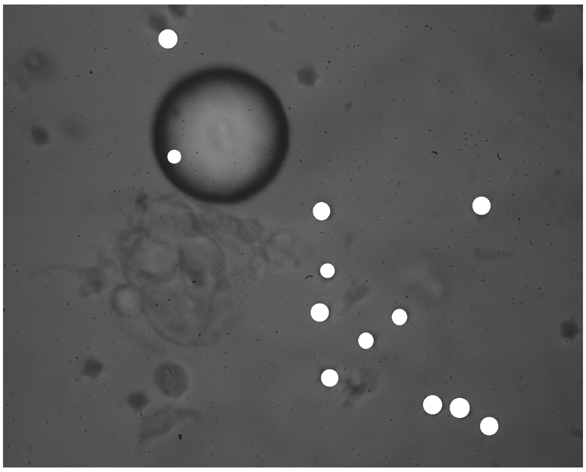


Figure 7 Result after Hough transformation applied to the origanal image

The experiment of reliability of each method for regular shape detection was tested in four selected images from four different video sequences. The real number of moving artifacts, which could possibly cause false-positive detection of cilia, is determined subjectively. Our experiment was focused on red blood cells which occur more often. The results are shown in Table I as detected percentage of real amount of artifacts.

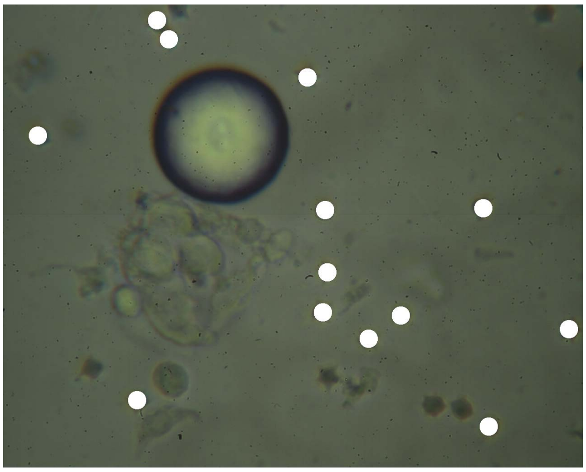


Figure 8 Resulting image after geometrical matching

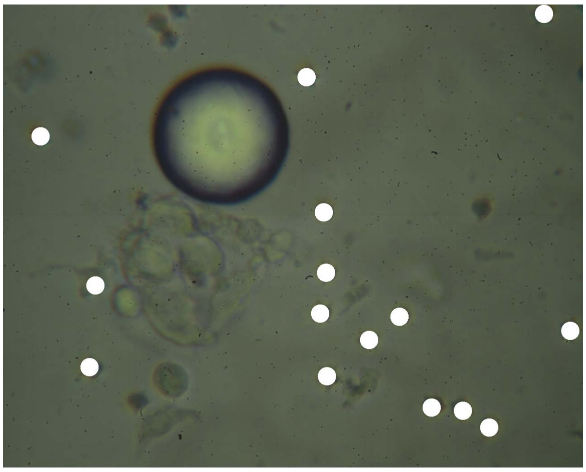


Figure 9 Resulting image after pattern matching

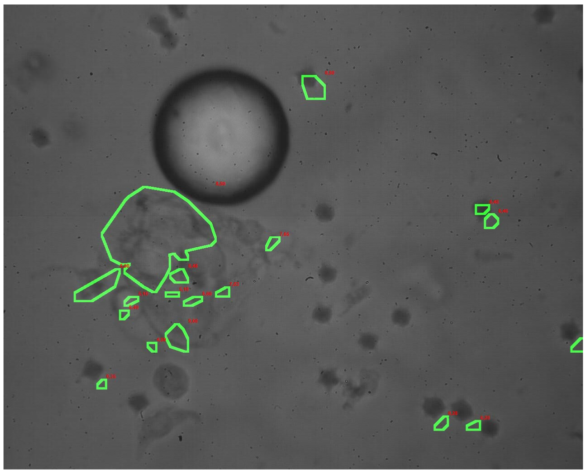


Figure 10 Image sequence analysed via FFT of local intensity changes (time profiles)

Figure 11 Removed regions based on result from pattern matching (1,3,4,5,6), geometrical matching (1,2,3,6) and Hough transformation (2,5,6)

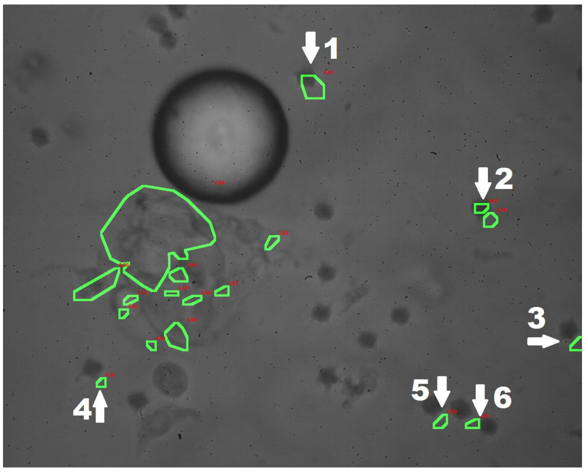


TABLE I. THE RESULTS OF REGULAR OBJECT DETECTION

	Real number of artifacts	Pattern matching	Geometric matching	Hough transformation
		Detected / False detected	*Detected / False detected*	*Detected / False detected*
Video 1	20	15 / 0 75%	13 / 0 65%	11 / 1 55%
Video 2	6	4 66,6%	4 66,6%	2 / 10 33,3%
Video 3	14	14 / 0 100%	10 / 6 71,42%	12 / 2 85,71%
Video 4	5	4 / 5 80%	3 60%	3 / 3 60%

IV. CONCLUSION AND DISCUSSION

Red blood cells in acquired video sequences always appear more-less of the same size and shape and that is the reason why pattern and geometric matching methods (based on template searching) are much more suitable for their detection than Hough transformation. This transformation is more suitable for air bubble detection whose diameter is changeable in various video sequences.

All three methods are able to detect most regular objects in an image quite reliably. Geometrical and pattern matching can be used when searching for structures which occur in different images with the same size and shape, e.g. red blood cells. Hough transformation is suitable when detecting circular objects with different diameter through any sequence, e.g. air bubbles.

This research deals with interdisciplinary problematic which is solved in order to improve modern approaches in medical diagnostics of respiratory epithelium diseases.

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