The Search and Identification of Underwater Object by Sonar and Vision systems of Underwater Vehicle

BOGDAN ŻAK
Department of Mechanical and Electrical Engineering
Naval University of Gdynia
81-103 Gdynia, Smidowicza 69
POLAND

Abstract: - In the paper the conception of identification of underwater like mines objects was presented basis on images of underwater area. Methods of preliminary processing of images acquired by underwater vehicle and a method of seeking chosen elements on these images and their identification at using the Hougha transform were described. Moreover the results of preliminary processing and the results of chosen elements identification on images obtained from cameras at the different level of noises were presented at work.

Keywords: image recognition, image identification, underwater vehicle.

1. Introduction

Recognizing mines barriers and their identification is one of main military tasks for unmanned underwater vehicles, so it will be seeking the different type of being in the sea depths or lying at the bottom objects. The searching and observing underwater area system is presented on the fig.1.

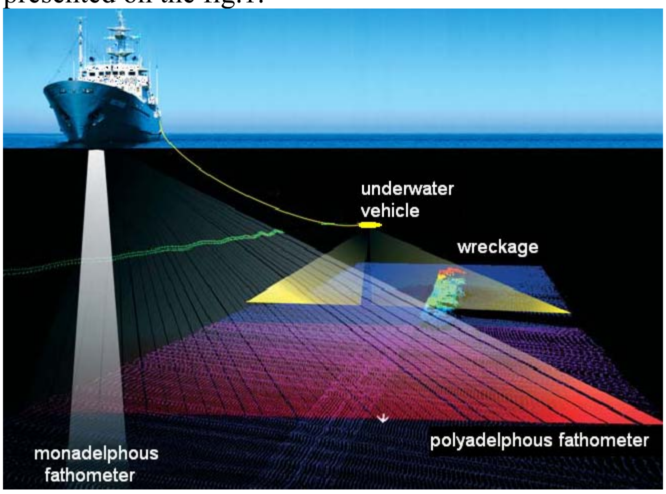

Fig.1. The system searching and observing underwater area

In this purpose the unmanned underwater vehicle should be equipped with the navigational system, TV cameras and sonars which permitting for searching and observing underwater area and analysis system which permit to process the obtained images [1]. On account of limited dimensions, and displacement of the unmanned underwater vehicle the systems for analysis the acquired images and systems for seeking objects on them not always can be assembled directly on vehicle. On that account the images from cameras and sonars should be transmitted through the umbilical cord or the acoustic channel on ship-base where the identification process can be carry out (fig.2) [2].

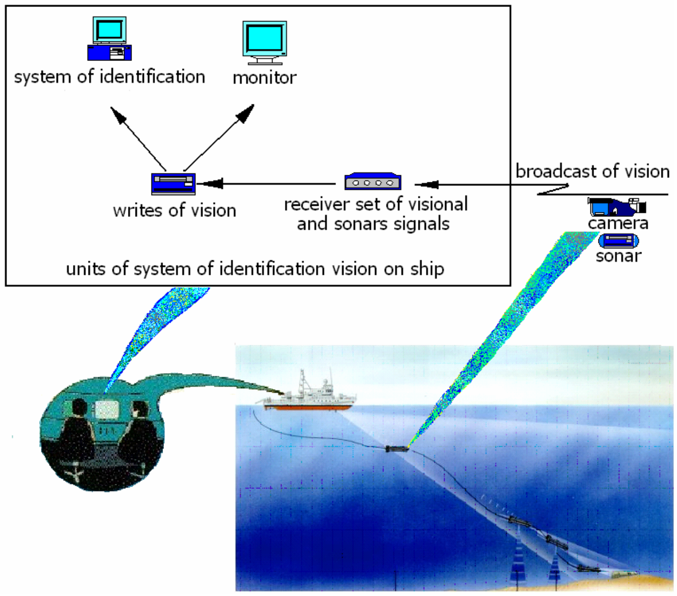

Fig.. The conception of system of mine like object seeking using underwater vehicle

The identification process consists of few steps. The first step is preliminary processing of acquired images which should improve the quality of images. The second step is the preparation the images for identification process. Next step is the identification process which in simply way can be described as comparison of images parts with that collected in data base. The last step is to pointed and named the finds objects.

2. Image's preliminary processing

Having the recorded image a need of improving it or making different operations which assure the success of identification of its elements on it will exist. A whole range of the operation and methods of transformations of images is being using in the aim of improving the quality during preliminary processing. The main aim of preliminary image processing is to prepare data for the last step of identification and assure the correct results of analysis of the picture elements.

2.1 Unplait operation

The images of the underwater area are marked by a weak quality because of the aqueous environment and the very faint light in depths. Therefore the images acquired from the vision system of underwater vehicle should be corrected by compensation and reduction for noises and reconstruction its shapes. A method which is being practiced in this purpose is the unpalit operation which task is to reconstructing the genuine or planned appearance of the image [6]. It is possible to treat the observed image $f(x,y)$ which was deteriorated as the plait of original picture $g(x,y)$ with the impulse reply function $h(x,y)$ which described how the point of picture is looking in ideal conditions. It is possible to write that:

$$f(x,y) = g(x,y) * h(x,y) \tag{1}$$

Applying the Fourier transform the above equation will take form:

$$F(u,v) = G(u,v) \cdot H(u,v) \tag{2}$$

From here, if there is a known function of the impulse reply it is possible to perform the image using the equation:

$$G(u,v) = F(u,v) / H(u,v) \tag{3}$$

In practice it is necessary to add the additive noise which is present on the image. Above equation will take form as:

$$G(u,v) = (F(u,v) - N(u,v)) / H(u,v) \tag{4}$$

It should be noticed that if $H(u,v)$ is small both expressions in the equation (4) can become big and the noises can be increased. One of methods of avoiding this occurrence is to apply the Wiener filter which consists in recording the image in his reconstructed figure as:

$$G(u,v) = [F(u,v) \cdot \hat{H}(u,v)] / [N(u,v) \cdot \hat{H}(u,v) + n_u] \tag{5}$$

where: $\hat{H}(u,v)$ - is the conjugate complex value of $H(u,v)$;

n_u - is the noise to signal ratio and it is the heuristic value which is selected in experimental way.

The result of a unplait operation was introduced on fig.3 and fig.4. The picture was taken by camera which was mounted on the underwater vehicle.

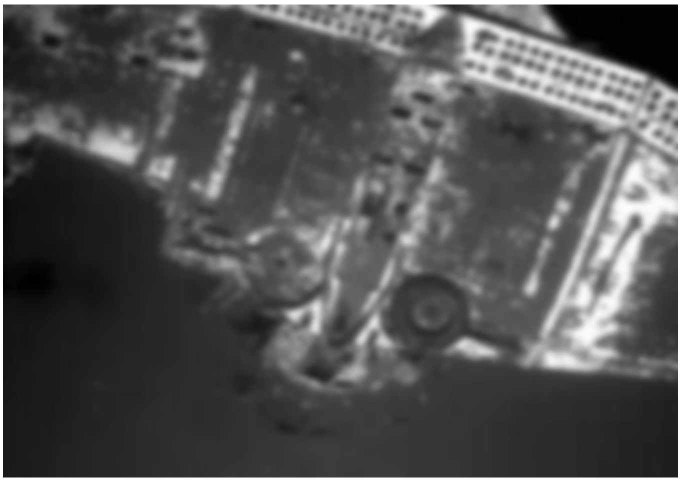

Fig.3. The image of the plane laying on the see bottom acquired from vision system of underwater vehicle

Fig.4. The results of unplait operation applied to the image obtained by vision system of underwater vehicle

2.1 Finding edges

The filters which permit to finding edges are commonly used during classification of object shapes. The basic method of finding edges consist of sum of product of first order but such approach not always is giving the proper results. Therefore the best results are taken by using the first derivative like in Sobel's filter [7]. It works as the gradient method, which means it described the points on picture where the luminosity is changed in highest way. In practice to find edges on picture it is calculated the plait of the picture with horizontal Sobel's filter and next plait of the picture with vertical Sobel's filter what can be written as:

$$I_1 = picture * S_{po}$$
$$I_2 = picture * S_{pi} \quad (6)$$

where: S_{po} – horizontal Sobel's filter with coefficients:

$$S_{po} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix},$$

S_{pi} – vertical Sobel's filter with coefficients:

$$S_{po} = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

The luminous of the new pixel is calculated as follow:

$$I = \sqrt{I_1^2 + I_2^2} \quad (7)$$

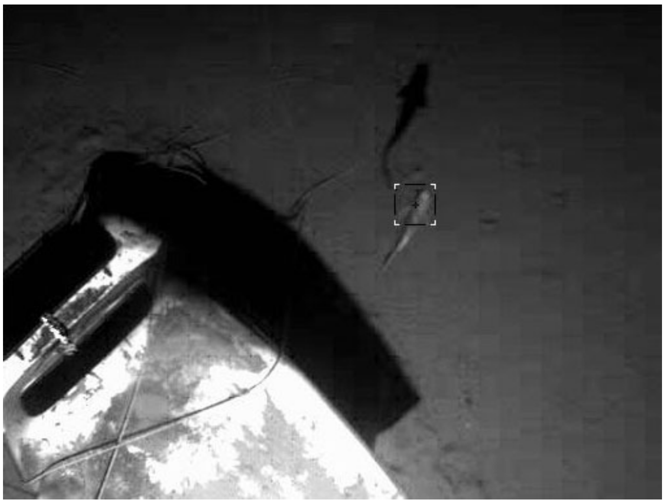

Fig.5. The image of sinked object

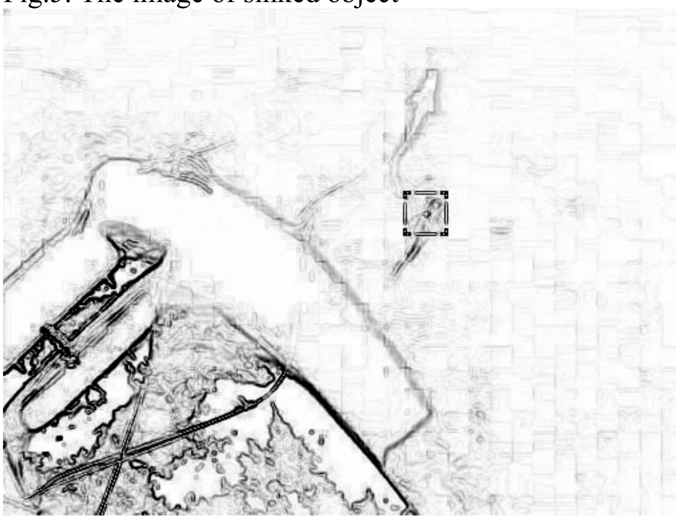

Fig.6. The image of sinked object after finding edges using the Sobel filter

Applying the finding edges function allow in a way to eliminate the noises origin from the changed conditions of underwater vision which influence on quality of image processing. On the fig.6 the results of Sobels filter operation where presented for picture taken from vision system of underwater vehicle. On the fig.7 is presented picture wreckage taken from sonar system of underwater vehicle and on the fig.8 is presented the results of Sobels filter operation.

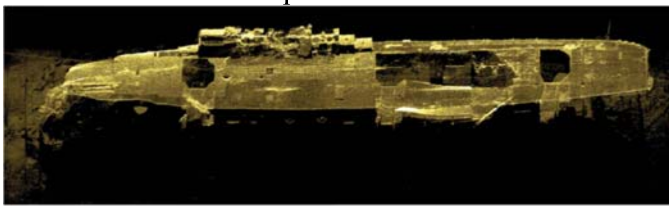

Fig.7 Picture wreckage taken from sonar system of underwater vehicle

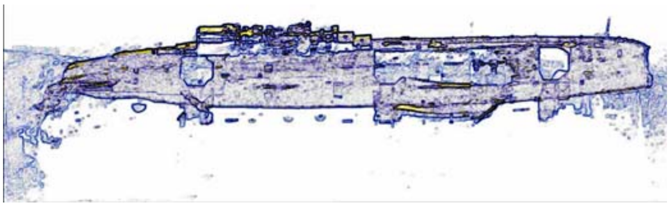

Fig.8 Picture wreckage after finding edges using the Sobels filter

3. Identification of mine-like objects on images

As an identification method of chosen elements on images acquired from camera can be used the Hough's transform.

The set of collinear points (x, y) can be described as follow [3][4][5]:

$$\lambda_0 = \{(x, y) \in R^2 : y - \hat{a}x - \hat{b} = 0\} \quad (8)$$

where: $\hat{a}$ and $\hat{b}$ are the constant parameters which described the straight line.

The solution of equation $y - \hat{a}x - \hat{b} = 0$ for constant $(\hat{a}, \hat{b})$ is the set of points on surface. The feature of such calculated map $(\hat{a}, \hat{b}) \rightarrow \lambda_0$ is that, for one point in parameters space we receive the set of collinear point on picture. In order to calculate the values of parameters (a, b) of straight line which go through the given point $(\hat{x}, \hat{y})$ it should be solved the equation $\hat{y} - a\hat{x} - b = 0$ relative to (a, b). It is the same as calculation the bunch of straight lines which go through the given point $(\hat{x}, \hat{y})$.

As the results of identification are taken the straight lines (a, b), which collect from the all active pixels of image the biggest numbers of vote. The expansion of this method to the detection of curved lines parametrically defined is enough simple. Points of picture (x, y) which are laying on curved line which is described by n-th parameters $(a_1,...,a_n)$ can be presented in form as:

$$\lambda_0 = \{(x, y) \in R^2 : g((\hat{a}_1,...,\hat{a}_n),(x, y)) = 0\} \quad (9)$$

where: $g((\hat{a}_1,...,\hat{a}_n),(x, y)) = 0$ is the equation described the curved line.

To calculate which curved line $(a_1,...,a_n)$ is taking the biggest vote from the active points of picture *B* the Hough transform $H(a_1,\ldots,a_n)$ is defined as follow:

$$H(a_1,...,a_n) = \sum_{(x_i, y_i) \in B} h(\hat{x}_i, \hat{y}_i, a_1,...,a_n) \quad (10)$$

where:

$$h(\hat{x}_i, \hat{y}_i, a_1,...,a_n) = \begin{cases} 1 \; if \;\; g((\hat{x}_i, \hat{y}_i),(a_1,...,a_n)) = 0 \\ 0 \; otherwise \end{cases} \quad (11)$$

As the result of such calculation the matrix is received in which every element is described by values of parameters $(a_1,...,a_n)$. The cello f the matrix is increased by one if the curved line described by cell coordinate $(a_1,...,a_n)$ is going through the point $(\hat{x}, \hat{y})$ of object on picture *B*. It can be accepted that Hough transform consist in to mapping the picture *B* onto matrix *A*.

Presented above method can be generalized on to irregular patterns [8]. Lets make an assumption that pattern *W* can be rotated about angle α and shifted about vector $[x_T,y_T]$. In such way the given point of pattern (x_i,y_i) is transformed onto point (x_i',y_i'). So in such case the Hough transform $H(x_T,y_T,\alpha)$ for picture $B(x,y)$ can be defined as follow:

$$H(x_T, y_T, \alpha) = \sum_{(x_i, y_i) \in M_W} h(x_i, y_i, x_T, y_T, \alpha) \quad (12)$$

where:

$$h(x_i, y_i, x_T, y_T, \alpha) = \begin{cases} 1 \; if \;\; (x_i', y_i') \in b(B) \\ 0 \; otherwise \end{cases} \quad (13)$$

Generalized this method it can be written as:

$$h(x_i, y_i, x_T, y_T, \alpha) = 255 - |B(x_i', y_i') - W(x_i, y_i)| \quad (14)$$

Often to avoid the loss of some information about picture during its conversion onto monochromatic the Hough transform can be generalized on pictures with TrueColor type palette of colors [9]. It is made by calculating the distance between colors. The problems can be solved by calculating the distance between two points (r_B, b_B, g_B) and (r_W, b_W, g_W) which are placed in RGB cube. This distance can be defined as follow:

$$|B(x_i', y_i') - W(x_i, y_i)| = \\ = \sqrt{(r_B - r_W)^2 + (g_B - g_W)^2 + (b_B - b_W)^2} \quad (15)$$

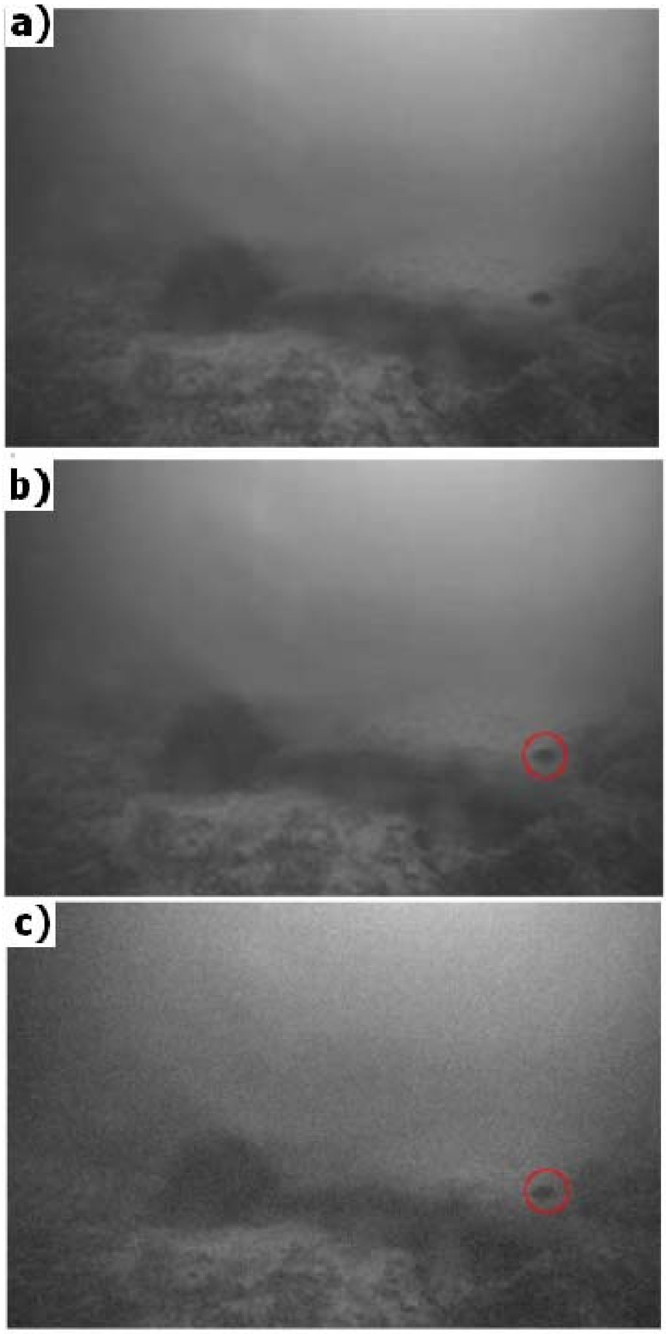

Fig. 9 The image of underwater area acquired from monochrome camera: a) image without noises; b) results of identification on image without noises; c) results of identification on image with noises

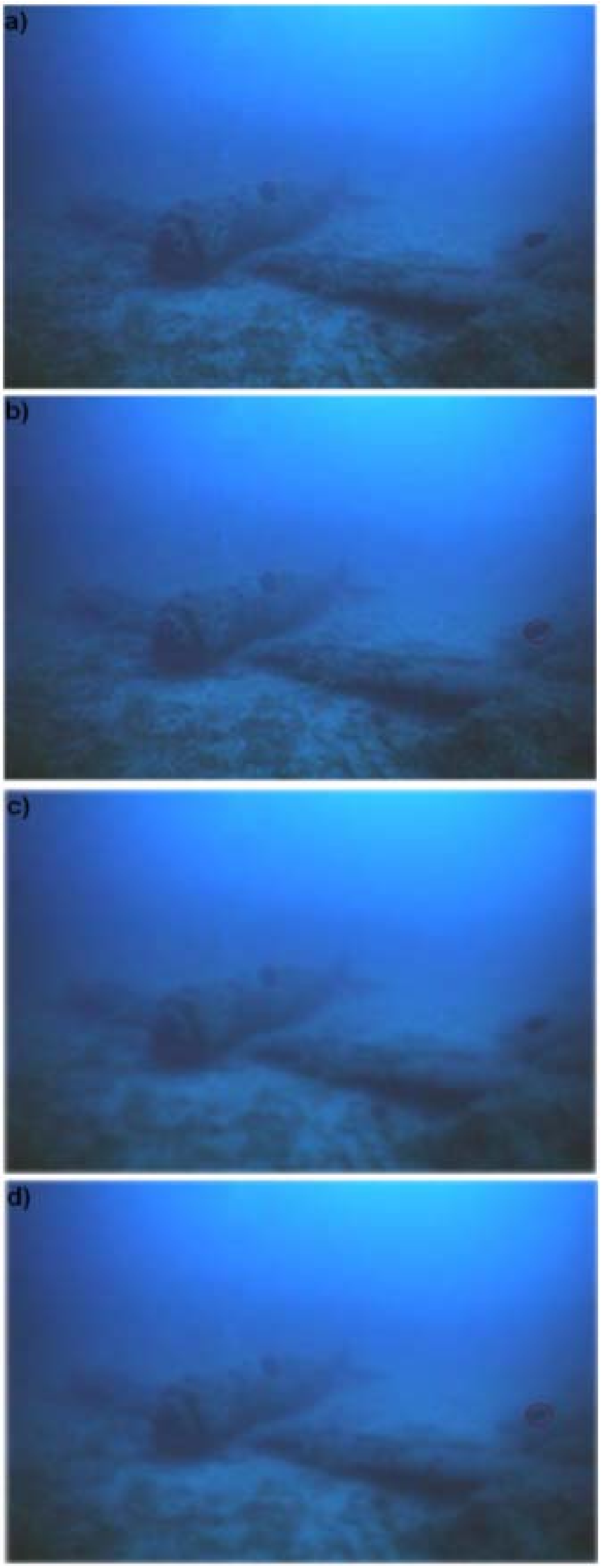

Fig.10. The image of sinked object acquired from color camera: a) image without noises; b) the results of identification for image without noises; c) image with noises; d) the results of identification on image with noises.

The described above methods was calculated on the pictures acquired from the vision system of underwater vehicle. On this picture the pattern of bottom sea mine was searched. The identification was processed for picture acquired from underwater camera and for the picture with noises such as luminance change and camera focus change. The results of research for monochromatic camera where presented on fig 6. The same research where made for picture acquired from color underwater camera. The results were presented on fig.10.

4. Conclusion

Observation of the underwater area using technical system of observation isn't an easy thing. Noises caused by environment, which are first of all the illumination, pollutants of the organic and inorganic origin and are making up above all to sharpness and the sharpness of seeing the camera are influencing into the meaning way on quality of registered images. Therefore a strong need of the preliminary processing of acquired images which will let to leading further operations such as elements searching and determining its position. The presented results of research shows that even applying straight methods of preliminary processing influencing for improvement the quality of images and the same for making bulge the important information for recognizing and the identification of images. The carried out examination confirmed usefulness of the Hough transform for the identification of underwater objects. This method permitted for correct recognition of objects on images of the underwater area in spite of the change in conditions. In the present implementation this method lets work at stationary, recorded by the visional system of the underwater vehicle on account of long time of leading calculations.
Wanting to use it for the identification of underwater objects in the real time this method should be implemented in hardware. At present the works at adapting this technique for working in the real time are carry out.

References

[1] Ballard D. H., Brown C. M.: *Computer Vision.* Prentice-Hall, Englewood Cliffs, New York 1982
[2] Garus J., Kitowski Z.: Sliding control of motion of underwater vehicle. Proc. of the 4th Int. Conference on Marine Technology III ODRA'99, Computational Mechanics Publications, Southampton, 1999, pp. 603-611

[3] Hough P. V. C.: *Method and means for recognizing complex patterns.* U.S. Patent 3,069,654, Dec. 18, 1962
[4] Gonzales R.C., Woods R.E.: *Digital Image Processing*, 2nd edition, Prentice Hall 2002
[5] Leavers V. F.: *Shape Detection in Computer Vision Using the Hough Transform*, Springer, London 1992
[6] Tadeusiewicz R., Korochoda P.: *Computer analysis and image processing*. Publication Foundation of Progress of Telecommunication, Cracow, 1997
[7] Jahne B.: *Digital Image Processing*, 5th edition, Springer-Verlag 2002
[8] Żorski W., Foxon B., Blackledge J., Turner M.: *Irregular Pattern Recognition Using the Hough Transform*. Machine Graphics & Vision, 5, 1996, pp. 111-121
[9] Żorski W., Foxon B., Blackledge J., Turner M.: *Irregular Colour Pattern Recognition Using the Hough Transform.* Bulletin on Institute of Automation an Robotics MUT, 15, 2001, pp. 27-42.