Identification of spatial objects by their monochrome images of autonomous mobile robots

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Abstract- *The method of image recognition of spatial objects of autonomous mobile robots is presented in this paper. This method is based on equations system in which the changes of the inertia moments depend on the change in the size and rotation of the image of a plane figure. The results of computer simulations confirming the effectiveness of the proposed method are carried out.*

Keywords- identification of images, flat figure, monochrome images, affined transformation, inertia moments.

I. INTRODUCTION

Artificial intelligence technology has always been closely linked with robotics, whose main objective is the creation of robots that can act like a man. Besides they should have certain intelligence elements, mobility and ability of autonomous regime to perform the operations for the achievement of this goal. When they can be used in emergency situations during the rescue operations in the chemical, oil and gas and other industries in the fight against terrorism, protection of the most important objects and other extreme cases, in space researches, in the condition of strong radio interference, the radio shadow and away from the command post, then it is dangerous for a man to be near or inside the object. In addition, during high-risky situations people often make mistakes that reduce the effectiveness of the work. Robotics also allows to eliminate human error [1, 2].

II. STATEMENT OF THE RESEARCH TASK

At the moment the recognition of objects in three-dimensional space is performed by means of the analysis of two-dimensional images. In this case there are certain standard images (SI), which in most cases they are in a front view with two kinds of sides, a back view and a top view. SI are matched directly with the obtained recognizable images (RI). As a result, this is determined by their compliance, as well as the location of RI regarding SI [2].

However, an object appears in the field of autonomous mobile robot (AMR) which is not exactly perpendicular to the plane of its projection, and under a certain angle. In addition, the view body of the AMR is not at the level of the mass center of the object sides. These factors cause the curvature of the object side in the resulting RI, i.e., the image is subjected to affined transformation. For reliable object recognition AMR should have a special tripping system of the body to move the object circling each organ of the level of the center of his hand, or have a large base of SI every possible position of the object. This requires the expenditure of considerable time, and during the presence of dynamic objects it greatly reduces the effectiveness of AMR.

Based on the foregoing problem according to their two-dimensional images the development of the methods of spatial objects recognition is an urgent task.

III. SOLUTION METHOD OF THE PROBLEM

The proposed method based on the assumption that the image segmentation of the object that carried out and monochrome image of its sides was obtained, and in its turn the most recognizable image presents flat, closed single-loop or multi-loop figure. As affined transformation rotation is considered in the paper, image plane figure is around the y axis or the z [3] with the rotation around the horizontal axis passing through the center of the image plane figure, and zooming about the center.

In [4], the equations (1) ÷ (3) showing appropriate affined transformation according to changing the inertia moments of the object side during changing its size relatively to the center along the axis ordinates in M times and along the axis applicate in N times to turn these axes image around the axis abscissa by angle φ were obtained:

$$J_{U2} = J_{Y1} \cdot M^2 \cdot N^4 \cdot \cos^2 \varphi + J_{Z1} \cdot M^4 \cdot N^2 \cdot \sin^2 \varphi - J_{YZ1} \cdot M^3 \cdot N^3 \cdot \sin 2\varphi \quad (1)$$

$$J_{V2} = J_{Y1} \cdot M^2 \cdot N^4 \cdot \sin^2 \varphi + J_{Z1} \cdot M^4 \cdot N^2 \cdot \cos^2 \varphi + J_{YZ1} \cdot M^3 \cdot N^3 \cdot \sin 2\varphi \quad (2)$$

$$J_{UV2} = J_{YZ1} \cdot M^3 \cdot N^3 \cdot \cos 2\varphi + \frac{J_{Y1} \cdot M^2 \cdot N^4 - J_{Z1} \cdot M^4 \cdot N^2}{2} \cdot \sin 2\varphi \quad (3)$$

where J_{Y1}, J_{Z1}, J_{YZ1} are inertia moments of the image side of the object that relative to the standard axes of ordinates and applicate, as well as the centrifugal inertia moment is relative to these axes; J_{U2}, J_{V2}, J_{UV2} are accordingly the inertia moment and the change in size of the rotated image that relative to the object-side of the ordinate axis and rotated on the angle φ as well as centrifugal inertia moment is relative to these axes; angle φ of the rotation of the ordinates and applicate around the axis of abscissa.

Taking J_{Y1}, J_{Z1}, J_{YZ1} for inertia moments of the standard images of the object sides and J_{U2}, J_{V2}, J_{UV2} for a recognizable image of the object side of the inertia moments, the identification can be produced. To do this, trigonometric equations (1) and (3) are substituted into a relative uniform and are solved relatively as φ. As a result, the followings are obtained:

$$\varphi_1 = f(M, N, J_{Y1}, J_{Z1}, J_{YZ1}, J_{U2}, J_{V2}) \quad (4)$$

$$\varphi_2 = f(M, N, J_{Y1}, J_{Z1}, J_{YZ1}, J_{UV2}) \quad (5)$$

By adding the equations (1) and (2) the followings are obtained:

$$M = f(N, J_{Y1}, J_{Z1}, J_{U1}, J_{V1}) \quad (6)$$

Substituting (6) into the equation (4) ÷ (5), we obtain two expressions depending on changes φ and N:

$$\varphi_1 = f_1(J_{Y1}, J_{Z1}, J_{YZ1}, J_{U2}, J_{V2}, J_{UV2}, N) \quad (7)$$

$$\varphi_2 = f_2(J_{Y1}, J_{Z1}, J_{YZ1}, J_{U2}, J_{V2}, J_{UV2}, N) \quad (8)$$

Substituting the calculated numerical values of the inertia moments for the identified and the standard image side of the object ($J_{X1}, J_{Y1}, J_{XY1}, J_{U2}, J_{V2}, J_{UV2}$) into equation (7) and (8), and setting the variable N values in the range (0 ÷ t), where t represents the maximum scale of the recognizable images, graphics of these equations are built. Considering the graphics image as independent curves, their intersection point and the coordinates which are the values of the roots are defined. Substituting the obtained value N into the equation (6) the value of the variable M is obtained.

Thus, a set of roots φ, N, M of the equation system (1) ÷ (3) is obtained.

The recognition process of the object images will be achieved by substituting an identifiable image of a plane figure into the angle φ, adjusting the size according to the values of M and N, and direct comparisons of images obtained by standard. That is, after the preliminary calculations of various provisions the bust is limited to several provisions. If the identifying image corresponds to the standard, after the transformation it will coincide with the standard. In this case a complete coincidence is not due to its presence in the transformed image of a plane figure distorted by the sampling of the image. These distorted images appear on its contour in the form of the changes of individual pixel values. As a numerical evaluation of the similarity of the standard and recognizable image side of the object the length of Manhattan [3] can be used:

$$Z = \sum_{i=1}^{m} \left| A(x, y)_i - B(x, y)_i \right| \le \varepsilon = P_э \quad (9)$$

where: $A(x, y)_i$ and $B(x, y)_i$ are respectively the values of pixels belonging to the standard and recognizable image side of the object; x, y are the coordinates of a pixel on the image side of the object; i is the number of pixels in the image side of the object; ε is the confidence of the threshold depending on the size and the perimeter of the image side of the object, as well as computing error analysis; Pε is the standard perimeter.

This proximity measure shows the difference of the images, i.e., the number of distinct pixels in direct comparisons.

If one of the provisions identified by the object side image of the specified condition is satisfied, it means that it is an analogue standard.

IV. COMPUTER MODELLING

Computer modeling of the proposed identification method was carried out in order to confirm the obtained theoretical results.

Experiments were carried out on four images representing a single-loop closed flat figure that given as standard. Standard images were changed in different scales in the horizontal and vertical axes, as well as they were rotated in the image plane in order to obtain recognizable images using Photoshop program.

Standard and recognizable one-circuit plane images are presented in Fig. 1.a – 1.d and Fig. 2.a – 2.d, respectively after their monocromization.

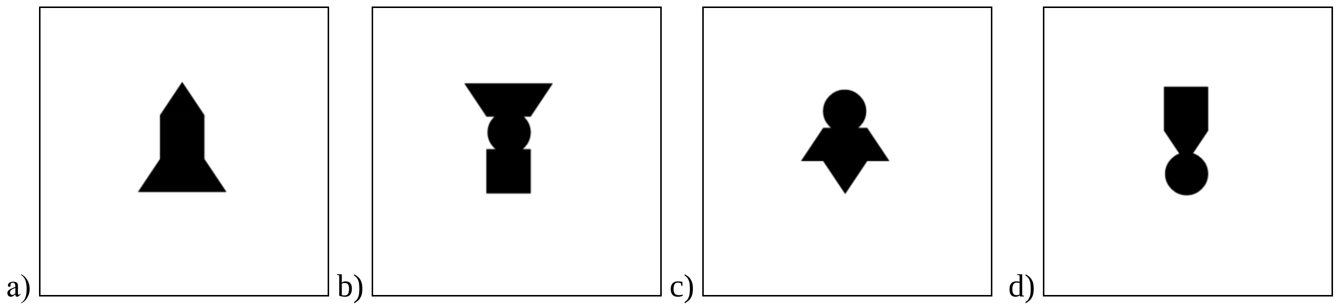

FIGURE 1. STANDARD BINARY IMAGES OF THE OBJECTS

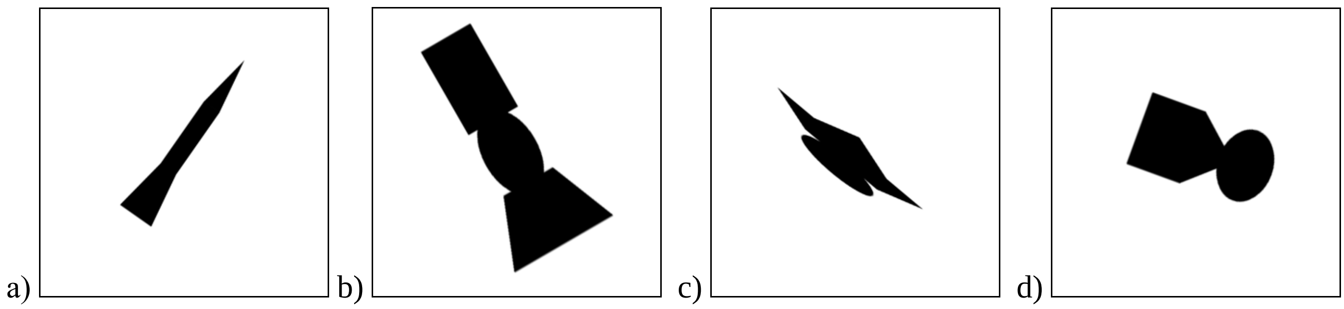

FIG.2. RECOGNIZED BINARY IMAGES OF THE OBJECTS

The calculated value of the standard images perimeters is summarized in Table 1.

TABLE 1
PERIMETER OF THE STANDARD IMAGES

Standard images	Fig. 1a	Fig. 1b	Fig. 1c	Fig. 1d
Perimeter, Pixels.	322	389	292	296

Using the formula (9) the calculated and the minimum value of Z is summarized in Table 2 for each recognizable image of a plane figure.

TABLE 2
THE SMALLEST DIFFERENCES BETWEEN THE STANDARD AND RECOGNIZABLE IMAGES.

Standard images	Recognized images			
	Fig. 2a	Fig. 2b	Fig. 2c	Fig. 2d
Fig. 1a	**179**	731	2100	1676
Fig. 1b	879	**99**	2758	1639
Fig. 1c	1852	2102	**156**	1752
Fig. 1d	1341	1105	1655	**129**

V. CONCLUSION

As it is seen from the table, only the corresponding standard images identified by the smallest difference do not exceed permissible threshold. In other cases, it greatly exceeds the permissible threshold. Besides, there may be some cases of non-intersection graphs constructed by the formulas (7) and (8). This indicates that the recognizable images do not match the standard ones.

Thus, two conclusions can be drawn. First, a method for identifying monochrome images of the single and multi-piece plane figure subjected to affined transformation (which consists of a non-uniform scale and image rotation in the projection plane) considered in the paper, allows us to make the identification process on the model retaining sufficient certainty. Second, considering in the paper the method for carrying out the identification process does not require multi-processor systems, or special software.

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