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APPLICATION OF MACHINE VISION FOR THE ORGANIZATION OF ROBOTIC VEHICLE MOVEMENT ON THE TRACK

Vasily Aleksandrovich Porkhalo, Vasilij Grigor'evich Rubanov, Aleksand Sergeevich Knish,
Belgorod State Technological University named after V. G. Shukhov,
Russia, 308012, Belgorod, Kostyukova Street, 46.
Belgorod State Technological University named after V. G. Shukhov,
Russia, 308012, Belgorod, Kostyukova Street, 46.
Belgorod State Technological University named after V. G. Shukhov,
Russia, 308012, Belgorod, Kostyukova Street, 46.

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Abstract:

This paper describes methods for image processing used in the building control systems of the motion robotics vehicle on track which can be used as part of warehouse management systems Automatic Guided Vehicle, and also as robots of service sphere and may be part of the safe city system. The controlalgorithms consists of the following steps: Image capture, Image enhancement, Image characteristics calculation, Contours detection, Classification. Trace detection has been tested using mobile robot on the track.The stage of the image capture is image digitizing with the further presentation in the matrix form. The improving of image quality is removing noise, sharpening, operation with the contrast, brightness, application of threshold transformations. To determine various objects at the images we calculate characteristics of the image: computing various characteristics, such as gradient, operators Laplace, Sobel, Canny. Using these characteristics the contour is determined and the found contours are classified. Weused Hough transform for the classification of simple geometric objects.

Keywords: mobile robot, machine vision, control, robotics, track.

Introduction.

Mobile robots can be "autonomous" (AMR – autonomous mobile robot) which means they are capable of navigating an uncontrolled environment without the need for physical or electro-mechanical guidance devices. Alternatively, mobile robots can rely on guidance devices that allow them to travel a pre-defined navigation route in relatively controlled space (AGV – autonomous guided vehicle).

Today, machine vision systems play an important role for the robotic systems. Currently intensively developed areas such as face recognition, motion control systems of the motion robotics vehicle, cars, trucks. A large variety of system with machine vision are being realized such areas as face recognition are currently developed.

Control of mobile vehicles in the transport and warehousing operations is widely used in automation systems of technological processes [1].Mathematical modeling and computer simulation allows to analysis of control systems, as well as the synthesis of control devices without the needing of expensive physical model experiments [2, 3]. There are a large number of vehicle models, which are based on certain assumptions and, accordingly, have its advantages and disadvantages [4].

There are various designs of mobile vehicles intended for the transportation of load at intrashop operations, and wheeled vehicles are most frequently used. The use of automation allows to create automatic guided vehicles (AGV) [5]. Machine vision(MV) methods are defined as both the process of defining and creating an MV solution, and as the technical process , the first step in the MV sequence of operation is acquisition of an image, typically using cameras, lenses, and lighting that has been designed to provide the differentiation required by subsequent processing. MV software packages then employ various digital image processing techniques to extract the required information, and often make decisions (such as pass/fail) based on the extracted information.

Main part. Any recognition algorithms can be represented as the following image processing algorithm [6], which is represented in Fig. 1.

Figure 1.Image processing steps

The stage of the image capture is image digitizing with the further presentation in the matrix form. The result is a matrix, with levels of intensity in the nodes:

$$f(x,y)=\begin{pmatrix} I_{11} & I_{12} & I_{13} & \cdots & I_{1n} \\ I_{21} & I_{22} & I_{23} & \cdots & I_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ I_{m1} & I_{m2} & I_{m31} & \cdots & I_{mn} \end{pmatrix},$$

I_{11} – the level of intensity.

The next step in the scheme considered is improving the image quality by removing noise (Fig. 2, a), sharpening (Fig. 2, b), operation with the contrast, brightness, application of threshold transformations (Fig. 2, c).

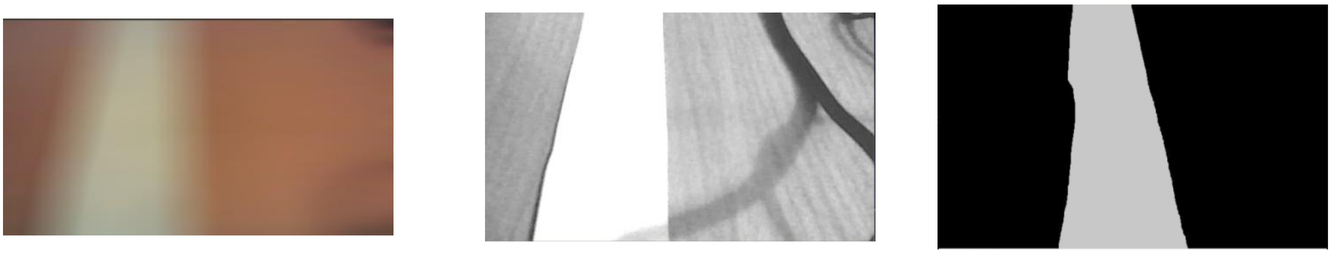

Figure 2. Improved image quality: a – Gaussian filter application; b –bundle use; c – threshold conversion

The Fig. 2, b shows the use of a convolution of the following form:

$$S = \begin{bmatrix} [-0.1] & [-0.1] & [-0.1] \\ [-0.1] & [3.0] & [-0.1] \\ [-0.1] & [-0.1] & [-0.1] \end{bmatrix}.$$

To determine various objects at the images we calculate characteristics of the image [7]. This operation consists in computing various characteristics, such as gradient, Laplace operator, Sobel operator for each image point as well as calculating textural characteristics, brightness values. For example, the calculation of the Laplacian consists in calculating the second derivative by the coordinates XandY:

$$I''(x,y) = \left|\frac{\partial^2 I(x,y)}{\partial x^2}\right| + \left|\frac{\partial^2 I(x,y)}{\partial y^2}\right|.$$

x, y – indexmatrix the intensities of the (image sizes), $I''(x,y)$ – the second derivative of the intensity matrix.

For the calculation of the Sobel operator, the first derivative must be determined i.e. the gradient vector length, that indicates the direction of growth function is calculated. In this case it shows the direction of increasing the intensity of the image by Sobel operator. This is determined by the following formula:

$$I'(x,y) = \left|\frac{\partial I(x,y)}{\partial x}\right| + \left|\frac{\partial I(x,y)}{\partial y}\right|.$$

Also at this stage, Kenni operator can be calculated. It requires calculating the Sobel operator with the further refinements of the gradient direction.

The algorithm for calculating the gradient direction for image processing is as follows:

1. The gradient is calculated. The derivatives of x and y are calculated:

$$grad(I) = \left(\frac{\partial I(x,y)}{\partial x}, \frac{\partial I(x,y)}{\partial y}\right).$$

2. The angle between the projections x and y is calculated:

$$\alpha = arcg\left(\frac{I_y}{I_x}\right),$$

where I_x, I_y –the projection of vectors of the x and y.

3. The normalization of the angle is produced, so that it is multiple of 45^o (Fig. 3, a). In the cells of the matrix values that characterize the direction of the gradient vector (Fig. 3, b) are stored.

a b

Figure 3. The normalization of the gradient vector directions for the Canny edge detector: a – scale of the normalization of the gradient angle; b – matrix which characterizes the direction of the gradient vector

The example of calculation characteristics of Laplace, Sobel and Canny is shown in Fig. 4. Using these characteristics the contour is determined and the found contours are classified.

a b c

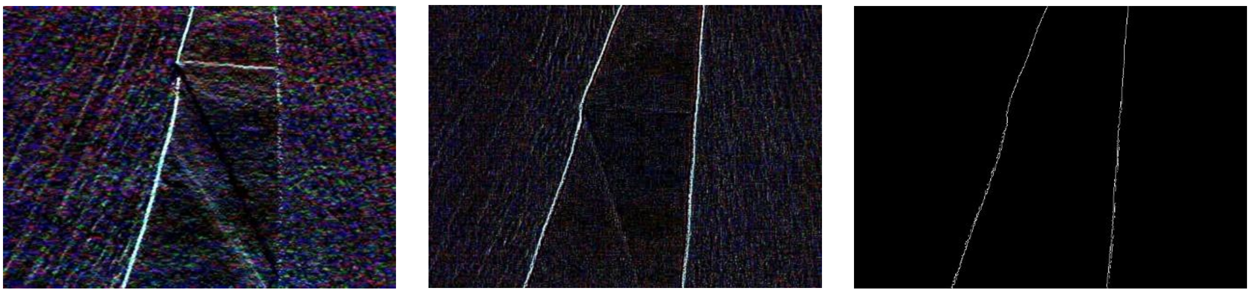

Figure 4.Theexample of calculating the characteristics of the image: a – Laplace operator; b – Sobel operator; c – Canny edge detector

We can encode contours in different ways: using complex coordinates, as well as using Freeman lattices. The length of eachcontour is determined by the lattice resolution, and the segment direction is determined by the selected code[8]. Direction is encoded by two bits of the four connected grid, and three bits for eight connected grid. The example of Freeman chain code is shown in Fig. 5.

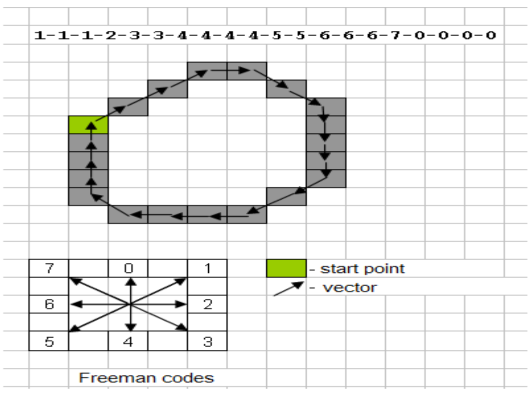

Figure 5. The example of Freeman chain code.

At this stage classifiers are made.One of the qualifiers is Hough transform, which is used for the classification of simple geometric objects: such asa circle, a triangle, a square.

The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing. The purpose of the technique is to find imperfect instances of objects within a certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called "accumulating space" that is explicitly constructed by the algorithm for computing the Hough transform.

The contours are defined by the binary image using the Canny edge detector. Each point is verified that it belongs to contour line. An example of the Hough transform is shown in Fig. 6.

Figure 6.An example of the Hough transform.

Each detection method has its advantages and disadvantages, which are presented in Table 1.

Table 1: Advantages and disadvantages of image processing methods.

Methods	Pluses	Disadvantages
Methods based on the use of Sobel, Laplace, Canny operators.	1. Easyimplementation. 2. High speed.	1. Method is sensitive to noise. 2. Method requires pre-processing the image. 3.Difficult to identify the contour.
Methods based on the use of Hough transform.	1. The ability to get a simple classifiers of typical objects (a circle, a line). 2. Easyimplementation.	1. Method is sensitive to noise. 2. Method requires pre-processing the image. 3. Difficult to identify the contour.
Methods based on the use of Haar-like features.	1. High speed. 2. Easy implementation. 3. Method is resistant to the noise.	Method requires a lot of computational resources.

In this paper, a method was chosen, based on the use of Haarprimitives. This method allows us to identify different route combinations: turns at different angels, "Г", "T" intersections.

The following set of Haarprimitives was used (Fig. 7).

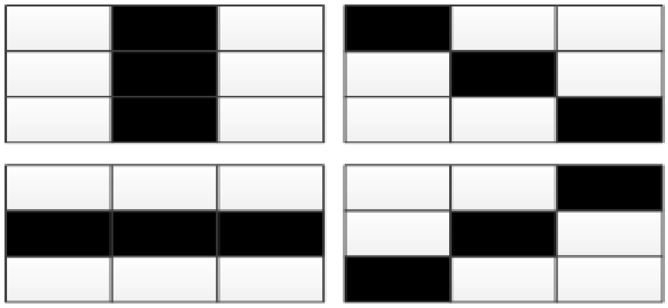

Figure 7. Haarprimitives used.

Let us assume that track line is a reflective strip no more than 5 centimeters wide. Then one cell of Haar primitiveis the matrix of 100x100 pixels. Thus Haarprimitive size – 300x300 pixels.

As the whole image is a matrix of 640x480 pixels and the parameters of one primitive are 300x300, then to increase the speed of calculation let us reduce the workspace tothe size of 180x340.It is located in the center (Fig. 8), Haar primitive being applied as a primitive center to the pixel considered.

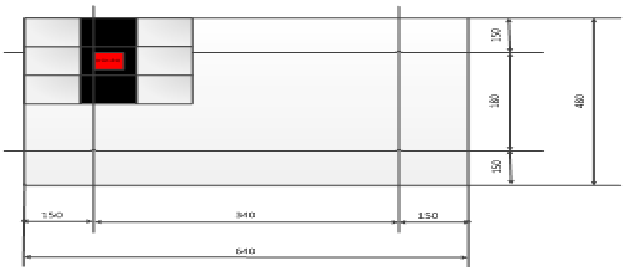

Figure 8. The graphics window considered with the use of Haar primitive.

A calculated value Haartrait (F) will be. F = X –Y,

whereX– the sum of the brightness values of the pixels, the closed bright part of the primitive, Y– the sum of the brightness values of the pixels, the closed dark part. To calculate the notion of integral images, discussed above, and signs of Haar can be evaluated quickly, for constant time. Use signs Haar gives brightness set-point point on the x-axis and y-axis, respectively. As a result we get matrix which contains Haar calculated features (Fig. 9).

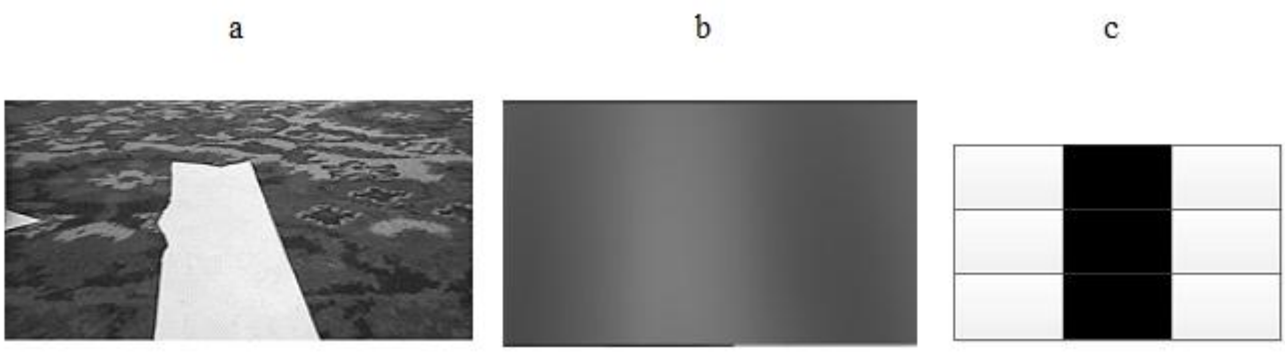

Figure 9. Graphic illustration of the Haar matrix features: a – original; b – calculated features; c – primitive.

After calculating the features we have points and then make approximation.

This method can identify the different types of track let us introduce some limits.The track can be a straight line which is either parallel to AGVs mobile platform or at an angle relative to the platform.

These points are approximated by a straight line. Then, root mean square deviation is calculated:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(y_i - f(x_i)\right)^2}{n}}.$$

Where $f(x_i)$ – extremum points, y_i – the value of approximating function, n– the amount of points.

We define the orientation of the robotic platform track. The example of track identification is shown in Fig. 10.

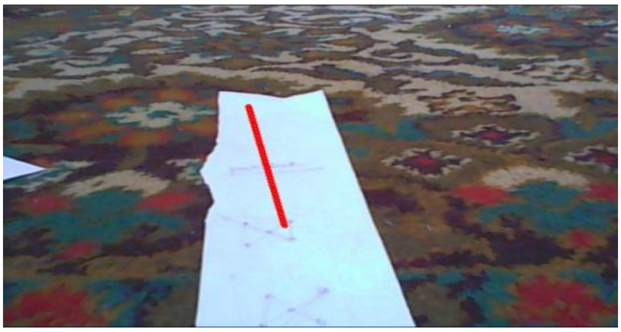

Figure 10.The example of track identification based on the use of Haar features.

Algorithm recognition track.

Let us consider the control algorithm structure. As we have the position of the line track and the center of the window,then we can determine the position of a robotic platform with respect to the track and to compensate the deviation of the platform from the tracks [8].

Then the feedback in system is the angle between the line of the track, and the vertical axis of the considered window [9]. Graphic illustration of the control algorithm is shown in Fig.11.

a b

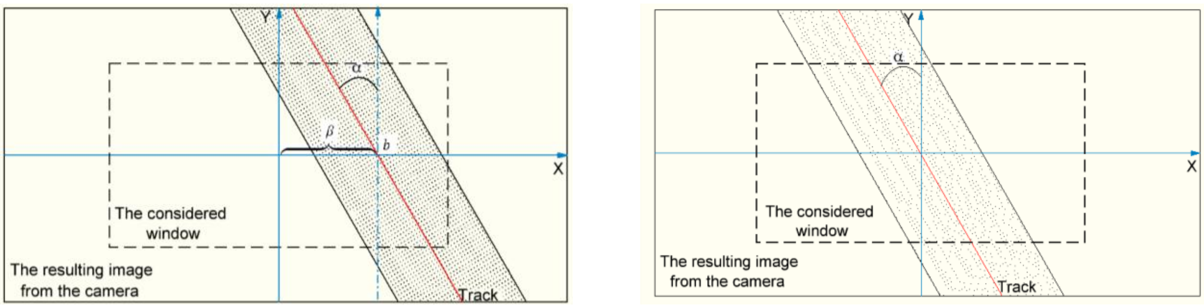

Figure 11.Presentation of the track line when the image is processed with the Haar features: a) track line islocated in the center of the window; b) track line is not located in the center of the window

The control algorithm can be presents as follows:

- image capture from the camera robotic platform;

- calculation of the integral image, the construction of matrix features based on the Haarprimitives, definition of the movement direction [10];
- compensation for the deflection angle between the track and the robot platform;
- the control of robotic platform actuators.

Figure 12. Illustrationplatform deviation from the road while driving.

We tested the movement on the track, in the form of parabola. The values of the platform deviations from the route were obtained (parameterβ,Fig. 12). The developed control system compensates for disagreement error, but there a static error is less than 200 mm.

Summary.

Recognition algorithms was represented as the following image processing algorithm: Image capture, Image enhancement, Image characteristics calculation, Contours detection, Classification. Trace detection has been tested with the mobile robot on the track and showed the possibility of applying this algorithm to organize the movement of the mobile robot on the track. Designed control systems of the motion robotics vehicle on track can be used as part of warehouse management systems Automatic Guided Vehicle, and also as robots of service sphere and may be part of the safe city system.

Conclusion.

The control algorithm was presented as follows: image capture from the camera robotic platform; calculation of the integral image, the construction of matrix features based on the Haar primitives, definition of the movement direction; compensation for the deflection angle between the track and the robot platform; the control of robotic platform actuators. The tests of movement mobile robot on the track showed, that values of the platform deviations from the route is acceptable (less than 200 mm), where the testing track was in the form of parabola.

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