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The use of Optical Markers in The Angular Position Control System of Objects

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***Abstract:** Relevance and goals: Pattern recognition systems are increasingly used in modern technology. The development of the theoretical base of image processing and the widespread use of free open source libraries make it possible to use new solutions in a variety of applied problems. One of these tasks is to determine the angular position of the object in the study of its radar response. A feature of the task is the impossibility of direct control of the position of the object through the mechanism of its drive, and the use of additional position sensors is also unacceptable. The purpose of this study is to determine the possibility of practical use of optical markers for solving the problem, as well as assessing the quality characteristics of recognizing markers of various types.Materials and methods: The solution of the problem was achieved using the methods of controlling the position of an object by optical markers by analyzing the image of the object. At the same time, the functions of the OpenCV machine vision library adapted to the task and the general elements of the machine vision theory were used. Also, a hardware platform was chosen that provides autonomous device execution, taking into account the required performance.Results: In the course of the work, a choice of suitable types of optical markers was made and qualitative characteristics were obtained for determining the coordinates of markers in different observation conditions. The library functions were adapted to work with the selected markers. The analysis of the speed characteristics of the system when working on the selected hardware platform.*

***Findings:** Studies have shown the possibility of practical use of optical markers for solving the problem, and also allowed to choose the most suitable type of markers. The selected hardware and software platform provides the ability to solve problems in real time.*

***Index Terms:** Optical markers; pattern recognition; angular position; radar; Webcam; real time; the center of mass of optical marker; Tracking Algorithms; OpenCV library*

I. INTRODUCTION

The urgency of image recognition tasks is not in doubt. Modern technology has already widely used such technologies in the framework of image classification, tracking objects, pattern recognition, etc. However, the practical aspects of implementing such tasks are often the intellectual property of the firms developing these devices.

Traditionally, the tasks of pattern recognition belong to the field of artificial intelligence. The main direction of the development of pattern recognition systems (PRS) is the development of the theory and methods of constructing devices designed to solve individual problems for application purposes.

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II. ADJUSTING THE VIDEO CAMERA OF THE ANGULAR CORRECTION OF THE RADAR COMPLEX

One of such tasks is the adjustment of the video camera of the angular correction of the radar complex [1] (Fig. 1). In the framework of the problem considered in [1] and [2], the issue of the initial positioning of a video camera using the known azimuth angle of the suspension cable has already been solved.

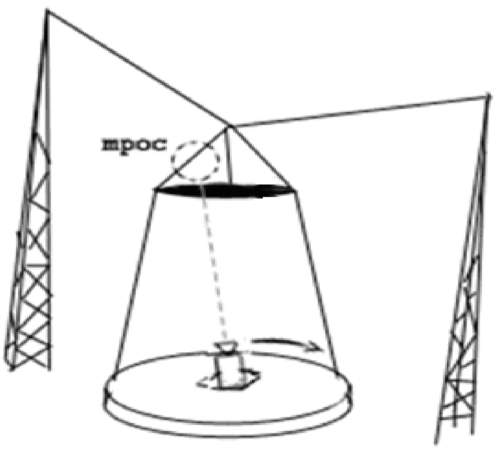

Fig.1. Object under study on the suspension cable.

The object or its model is suspended from a cable stretched between the supports and can be rotated due to the stretch marks attached to the rotary disc mounted below the object. The task of the system being developed is to determine the angular position of an object in space during its rotation using a turntable. At the same time, given the lack of rigidity of the object's suspension and features of the measuring complex, there is no other way to determine this parameter than visual observation and recognition of the position of the object in the video data stream in real time.

Similar tasks are very often encountered in specialized installations, for example, in installations for determining camber-toe wheel of a car [3], [4]. Moreover, each task has its own specifics and often requires an individual approach to implementation, as evidenced by the presence of multiple electronic platforms for the exchange of experience, open projects and developments, for example http://recog.ru/.

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III. DETERMINATION OF THE ANGULAR POSITION OF THE OBJECT BY ITS IMAGE

To determine the angular position of an arbitrary object from its video camera image, various options are possible. For example, it is possible to fix an optical image of some structural element of an object, followed by tracking it. Such solutions are gaining popularity due to their versatility. However, the implementation in this case is much more complicated, due to the presence of many disturbing factors [5]. The disadvantage of this solution is, moreover, the variability of the choice of tracking elements, and, as a consequence, the effect on the accuracy of the result. This also leads to more complex system software. The use of specialized optical markers that make it possible to unify the object tracking algorithms and improve the measurement accuracy seems to be the most acceptable option.

The possibility of their use is confirmed in the works of the authors [6]. Markers do not make changes in the studied characteristics of the object and can be located in the most characteristic points of the object. To determine the angular position of the object, in this case 2 markers are used, through which a straight line is built, the angle of which is determined in the coordinate system of the camera image. The size of the markers should be minimal enough to sustain recognition and reduce the influence of the geometry of the object.

It is obvious that the characteristics of the system in this case will be determined by the selected type of markers and the algorithms for their selection on the image. The choice of points of a straight line through markers can also significantly affect the accuracy of the result. The curvature of the object's surface can in turn lead to a distortion of the image of the marker, which requires an additional assessment of the effect of this parameter.

Also, when choosing the type of markers, it is necessary to take into account the permissible image resolution from the video camera to ensure the processing of information in real time. It should be noted that real-time requirements can lead to a significant limitation of the methods for isolating and tracking markers. In the works [7] and [8], the options for reducing the computational complexity of the operations of tracking objects in images are shown.

In connection with the high demands on the accuracy of measuring the angular position of the object, experiments were carried out that made it possible to determine the qualitative characteristics of the use of various markers and to identify problem areas of the system.

IV. MARKER RECOGNITION

To recognize markers and determine the angle of the object's position, the free library OpenCV was used. OpenCV is a library of computer vision, image processing and general-purpose numerical algorithms with open source code, implemented in C / C ++ and allows functioning on various hardware platforms [12].

As a hardware platform, a bundle of a Logitech HDPro Webcam C920 camcorder (HD720 resolution) and an OdroidX2 board with the installed lubuntu 12.10 operating system were selected.

The choice of the OdroidX2 platform is due to the requirement of mobility of the system implementation. The board is equipped with a four-core Samsung Exynos 4412 1.7GHz processor (ARM Cortex-A9), a Mali-400 video accelerator (Quad-core, 440MHz, support for decoding video 1080p) and 2 GB of RAM.

The video camera was connected to the processing board via USB 2.0.

The following types of markers were selected as the test subjects (Fig. 2):

1. Aztec marker
2. Graphic black and white marker (proposed by the customer)
3. Colored markers (HSV)

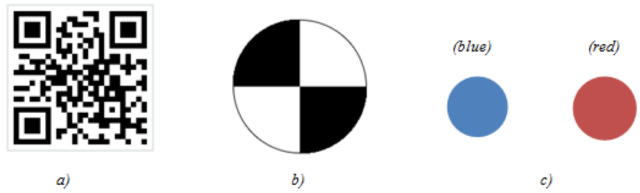

Fig. 2. Investigated types of markers. Aztec (a), graphic black and white (b), color markers HSV (c)

Taking into account the experience of tracking objects [10, 11], as well as the general elements of the theory of computer vision [9], the recognition algorithms of the OpenCV library were adapted for each type of markers. After that, the accuracy of determining the center of the marker under the influence of various disturbing factors (lighting, distance from the camera, the color of the main object, etc.) was studied, and a number of experiments were carried out to determine the angular position of the object and measure the performance of the recognition system.

During the experiments, the webcam used was mounted on a tripod and aimed at a rotating disk with corner markings located below. The color of the disc is white. Markers with a distance between centers of 20 cm are pasted onto the disk. The distance from the disk to the camera varies from 60 cm to 150 cm. LED lighting was used.

The results of the experiments are shown in the table 1:

Table 1 - results of the experiments

Parameter \ Marker	*Aztec*	*graphic black and white*	*HSV*
marker size [cm] / color	3x3 / black	3x3 / black and white	3x3 / lime and blue
the accuracy of determining the center of the marker in a static state (“jitter”) [percent to the size of the marker]	0	0,5%	9%-14%*

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The error in determining the angle of the object, [deg]	0,01-0,05	0,005-0,01	0,2-0,7
sensitivity to light (reduced light / percentage of the marker in the frame)			
2 times	97%	98%	70%**
3 times	80%	87%	41%**
4 times	52%	64%	24%**
The distance to the marker [cm] / percentage of the marker in the frame	30 / 100% 40 / 90% >50 / 1-5%	30 / 100% 40 / 100% >100 / 100%	30 / 100% 40 / 100% >100 / 90%***
The effect of the background of the object (dark [%] / light [%])	50 /100	80 /100	100 /100
Maximum tracking performance at HD 720 resolution (fps)	up to 23	up to 30	up to 30

* required to adjust or illuminate markers
** HSV correction required for stabilization
*** used to adjust the color of the markers

Aztec marker consists of a QR code with an encrypted symbol. This marker is well recognized by the test system and has fairly high quality indicators.

Coding the marker symbol allows you to work 360 degrees around the entire circumference, since the marker is asymmetric. Aztec marker has the following disadvantages:

1. Does not allow strong image distortion, i.e. its deformation (for example, when bending) because recognition fails. There are options for correcting these distortions [13], the use of which will slightly increase the complexity of implementation;

2. It works at a small distance, about 50-80 cm, taking into account the good visibility and clarity of the marker. Also, this marker requires a very high optical resolution, which can lead to an unacceptably high computational load, taking into account real-time processing.

Graphic black and white marker represents a circle with black and white sectors of 90 degrees. The absence of small elements allows to increase the detection range. At the same time, when determining the center of mass, it is necessary to take into account the presence of geometric distortions of the circle, which can lead to a significant error in determining the angular position.

To reduce this error is possible by implementing a special algorithm for finding the center of a circle.

The HSV color marker is a circle filled with a uniform color. The absence of any elements inside the marker allows you to make it the smallest possible size, thus avoiding the deformation of the marker when gluing to curved objects.

The center of a recognizable marker is defined as the center of mass of the recognized points and is found by the standard functions provided by the OpenCV library.

The use of different colors will allow you to work in a range of 360 degrees to measure the angular position.

An important requirement for the stability of recognition of this type of markers is the balance of light illumination.

Analysis of the results shows that the necessary conditions for a successful solution of the problem are:

1. Contrasting background of the marker in relation to the color of the object.

2. High-quality lighting (preferably without a flicker of 50 Hz) - LED lighting is recommended.

3. Presetting the system for the marker used and measurement conditions.

4. High-quality camera lens (or a camera with better performance).

V. CONCLUSION

On the basis of the conducted research, it can be concluded that the use of markers is possible and the simplest method of determining the position of an object within the framework of the task, however, taking into account the existing limitations, it is advisable to use black and white markers with a simple internal structure that allows you to uniquely determine the point for constructing a line. Of the studied markers, the second type of marker satisfies this condition (Fig. 2 b).

However, Aztec markers or their derivatives can also be used provided that the requirements for optical resolution and the computational complexity of the algorithms are reduced.

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