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COORDINATES CALCULATION OF DETECTED AND RECOGNIZED OBJECTS IN SURVEILLANCE SYSTEMS

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The detection and recognition of objects in images has found a wide application in many spheres. It is used in the surveillance system, cartography, robotics, medicine, etc. In many surveillance systems the localization of the detected object has a great significance. After localizing the object, it will be possible to carry out the calculation of its coordinates. The formulas for calculating the object-camera distance are rather theoretical. Conducting experiments and verifying formulas in practice would have a high significance, as the distance of the object from camera is an essential precondition for object's coordinate calculation.

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Introduction. The solution of the problem of the object coordinate determination can have a great importance. For instance, it can inform about the human's location in the case of his presence in a prohibited surveyed place. Through live stream video it is also possible periodically find the data on the man and car by processing and calculating the coordinates or find the direction and speed of its motion [1]. This can favor the implementation of preventive actions. In general, the determination of coordinates is quite relevant for the solution of many other problems. In this paper we consider a calculating mechanism for the distance of the detected and recognized objects in digital images, discuss conducted experiments of distance calculation formula verification. We propose also a method for calculating the coordinates of the latter. In particular, the problem of determining the coordinates of the objects in the surveillance systems is considered.

First, we will describe the detection in a video, and the determination of the distance of the identified objects from the camera. Then, using the obtained results, we will calculate the object coordinates [1, 2].

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The Determination of the Object Distance from the Camera. Let us consider the mechanism for determining the distance of the objects in a video [2]. To perform the calculation, it is necessary to have certain data, including the angle Ω of the camera shooting, which, in turn, depends on the kind of the camera used. Ω is the value, describing the visibility of the camera in the horizontal plane. For the given camera, this parameter is always known. The horizontal frame width of the image is also obvious.

Let us assume that there is an object, for example a car in the video-sensor view. Applying the object detection and recognition methods, it will be possible to define the type of the object [1, 3]. To implement the process of the object detection, the method of comparison with the stored samples in the database is one of the most frequently used principles.

To calculate the distance, the sample of the object is also used. First, the car is located close to the camera, so that it should appear in view completely with the right and left sides of the image, touching the car edges. Then the distance of the car a_1 from the camera is calculated.

In the surveillance mode, when the car appears in the image in the distance, the program system detects and recognizes the object. Then its dimensions are calculated in pixels L. The calculation of the object's distance d is introduced in the equation

$$\frac{d}{a_1} = \frac{p_w}{L}, \tag{1}$$

where p_w is the number of pixels in width in the image; L is the horizontal frame width of the detected and recognized object in the image. After transformations we will obtain the distance of the object d.

Thus, by means of the mentioned method, the depth of the detected and recognized object in the image is calculated, that is its distance from the camera [2]. Knowing the object's distance from the camera and using the camera coordinates, it will become possible to calculate the location of the object, i.e. its coordinates.

The Determination of the Inverse Relationship between the Object-Camera Distance and the Width of the Object in the Image in Practice by Experiment. Method of determining the distance of the objects in the video describes the inverse relationship between the distance of the object from the camera and the frame width of the object in the image. For calculation of the coordinates, the determination of the object distance in the image is rather important. Therefore, let us conduct the following experiment, which will show whether there is a linear inverse relationship between the distance of the object from the camera and the frame width of the object in the image.

In the left corner of Fig. 1, the object-camera distance is filmed from a side, the images in the center are filmed by the camera, and the Table on the right part includes the results of the experiment. In the first stage of the experiment, the object was placed at a distance of 1 *m* from the camera and filmed. The Table shows that the frame width of the object on the first image is 1266 pixels. In the second stage, the object was placed at a distance of 2 *m* from the camera, and in that case the frame width was 633 pixels. It is obvious that by increasing the distance of the object from the camera by 2 times, the number of its pixels reduced exactly by 2 times. In the third image, the object is at a distance of 3 *m* form the camera and its width in the image is 422 pixels. Compared with the first image, the object is 3 times farther from the camera and its frame width is exactly 3 times less than that in the first image. The results of the experiments have shown that the inverse relationship between the object-camera distance and the width of the object in the image is practically true.

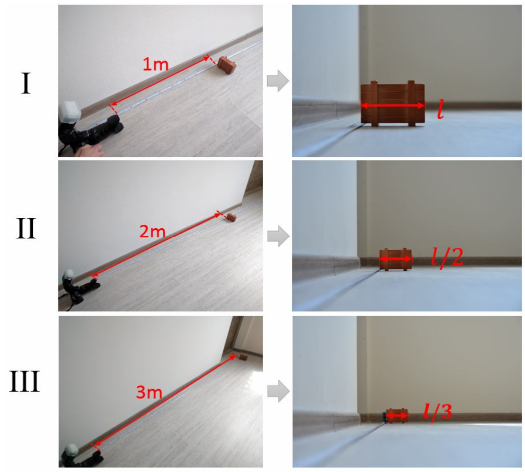

Image	Object length (pixels)
I	1266
II	633
III	422

Fig. 1. An experiment for determining the relationship between the frame width of the object and the distance in the image and the results.

The Coordinate Calculation Method. There are numerous systems by means of which the coordinates of the objects accessible to us can be obtained, for instance, by installing a GPS system next to the camera, we can determine the camera coordinates $(x_0,\ y_0)$. Obtaining these data preliminarily, we can use them for further calculations. For determining the azimuth, i.e. the angle between the camera direction and the North pole a digital compass will be also used. At present, such compasses have become accessible and can be found in modern smartphones.

By means of the compass, it is possible to take the angle between the North pole and the camera center.

Let us designate the angle between the object and the North pole by β (Fig. 2). In the case when the object is in the center of camera, i.e. angle β is equal to the azimuth of the camera center, the problem of finding its coordinates can be solved, having the parameters mentioned above: the coordinates $(x_0,\ y_0)$, the angle β between the North pole and the camera center, as well as the distance d of the object from the camera obtained by the method described in [2].

The object is located within the coordinates $(x_1,\ y_1)$ is relative to the North pole, the coordinates of the camera are $(x_0,\ y_0)$, the angle is β, and the distance is d. Their calculation is introduced in the equations:

$$\begin{aligned} x_1 &= x_0 + \delta_x = x_0 + d\sin\beta, \\ y_1 &= y_0 + \delta_y = y_0 + d\cos\beta. \end{aligned} \tag{2}$$

Now, let us consider the case, when the object is not in the center of the camera.

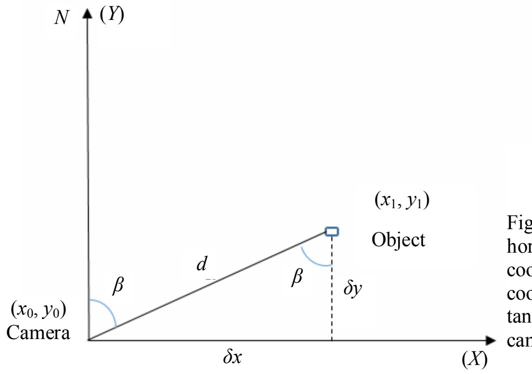

Fig. 2. The projection of the horizontal plane. The camera coordinates (x_0, y_0), the object coordinates (x_1, y_1), the distance of the object from the camera d, the camera–object azimuth β.

First, we will calculate the absolute angular shift of the object from the center of the camera. Here, we will use the shooting angle Ω of the camera, which is certain for each type of camera and is a known value. We will calculate the object's shift from the image center by finding the angle a in the Fig. 3. Let us first calculate the number of pixels between the points B and C and denote it by BC. Then we will take the frame width of the camera and denote it by AD. The image shows the conformity introduced in the equation

$$\frac{\alpha}{\Omega} = \frac{AB}{CD}, \quad \text{i.e.} \quad \alpha = \Omega\,\frac{AB}{CD}. \tag{3}$$

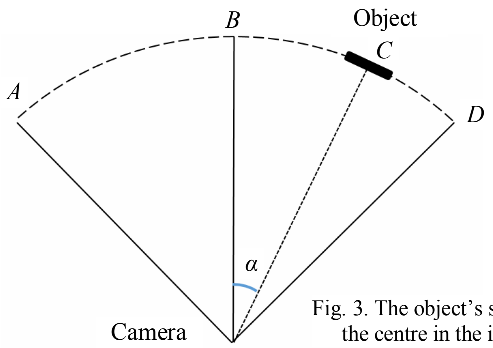

Fig. 3. The object's shift from the centre in the image.

Calculating the angle α, we will add it to the azimuth angle of the camera center and obtain β. Then by the formula (2) of the coordinate calculation, we will find the coordinates $(x_1,\ y_1)$ of the object.

Based on the results accuracy of above described experiments, we can confirm that the accuracy of determination of the object coordinates will also be carried out with the similar accuracy.

Using the algorithm described in [4], coordinates determination of detected and recognized object can also be performed on an image containing false targets by ignoring them.

Conclusion.

1. An experiment has been conducted to determine the inverse relationship between the object-camera distance and the width of the object in the image, which is used to determine the distance of the object in the image. It has a great importance while calculating the object coordinates. The results of the testing showed that the inverse relationship takes place with a great accuracy, since along with the changing the distance of the object the number of the object's pixels was changing linearly.

2. The parameters, required for the calculation of the coordinates of the object detected and recognized in the image, have been obtained. To determine the object coordinates, it is necessary to have the position coordinates of the video-camera, the direction azimuth of the camera center, the shooting angle of the camera, and the frame width of the image. The method for calculating the coordinates is relevant for cameras with different shooting angles.

3. The formula, calculating the camera-object direction azimuth at any position of the object in the image has been derived. To solve that problem, the camera shooting angle, the azimuth angle of the camera center, and the frame width of the image have been used. With the obtained formulae the calculation method for the object coordinates has been described.

4. It has also become possible to determine object distance in the image, while there are false targets included in the image.

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