Algorithms of obstacle detection for autonomous mobile robot control

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Abstract

The approach of obstacle detection in this paper is considered. This approach is based on two sequential snapshot analysis. The methods of corresponding points finding are considered. We are using edge detection algorithms for this method approbation.

1. Introduction

The development of the algorithms for mobile robot control is the actual problem. The basic task for such robots consists in achievement of the given point in environment with optimal route, avoiding collision with the obstacles.

The main problem is learning of robot to be guided in some premise (laboratory, room), that have firm flat horizontal floor. The robot is equipped via system of ultrasonic sensors located on perimeter and the infrared scanner, that give a picture in a plane at height 50 sm from the floor surface in a range 180° and radius 2m from center of the robot. As was mentioned, such system of sensors provides good control of the robot in the event that the obstacles on height have been got in a plane of the robot review, otherwise it is necessary to use additional sources of the information about an environment for collision prevention. Such source of the information can be served by a videocamera established on the robot. It gives the junction-type image of environmental conditions on the basis of which it will be possible to determine the form, sizes and situation of obstacles that are not situated in sight of sensors.

2. Methods of obstacles search, based on the videoimage

It is necessary to extract two approaches for task decision of obstacle allocation. First of all one of them can be considered as passive.

Above-mentioned approaches are based on study of one instant snapshot from the camera, extraction and recognition on this image of suspicious zones. In a basis of this approach, as a rule, the rather worked technique of the scene is used [4, 5]. Use of such passive methods has the advantages. Besides, as passive it is possible to consider methods connected to recognition of some key information. As example the special figure on a floor assisting to distinguish it from obstacles, or lines specifying allowable routes, can be served. All this should be used, when there is an opportunity beforehand to facilitate a task of the robot orientation in a room. However it is obvious, that the passive methods are not universal and in a general case with their help it is impossible to receive complete spatial representation of the room. Therefore active methods using idea of stereo-vision are often applied. A number of the authors have considered an opportunity of distance up definition to obstacles, using two cameras, that can be carried in space. This allows to complete three-dimensional representation about an observable scene to be received by processing two images obtained from two points in the space.

The systems on the basis of the image processing via one videocamera were already submitted by some foreign scientists and certain decisions for some special cases are already received. The difficulty of processing is that on the basis of a flat picture of an environment it is impossible to receive volumetric representation about terrain. Therefore we have offered idea to use a movement of the robot for reception of the image of space in front of the robot from two points. This idea is based on simple supervision, according to which person much easier determines distance up to a subject, if the subject is moved (comes nearer or leaves) in a field of sight. That is the representation about a scene can be received by comparative processing of two consecutive snapshots received by movement of the robot. It is necessary to trace the moving of details on the second snapshot concerning first, and thus to determine a location of the objects in three-dimensional space. The problem is divided into 2 basic subtasks. The first subtask is to distinguish some detail from the first snapshot on the second snapshot and to determine displacement. Second one is to determine its coordinates in space via displacement of a detail. On the basis of this information it is possible to make a conclusion about detail belonging to plane floor and, hence, whether it is possible to consider it as a part of an obstacle.

3. Search and tracking of the image details on two snapshots

This task is analogous to a task of the large image fragment search that most similar on the given small fragment. For its decision various spectral and neural networks algorithms can be used [1-3, 6]. The task becomes simpler and it is possible beforehand to predict in what direction the fragment on the second snapshot will be displaced. That is the size of space for search can be considerably limited and then dimension of a task and time of search are reduced.

Besides it is necessary to develop the method for definition of perspective details in the image for which the moving can be easier traced (easily to separate from an environmental background). It is desirable that these details should be edges of an obstacle, that is key points in space, on which it is possible authentically to define the form of obstacles. For their finding the various algorithms for allocation contours, sides of objects extraction, and also heuristic algorithms designed for a specific room with known obstacles can be used. One of the approaches that allow strongly to simplify this problem can be considered as the following. All key points of obstacles in a room are pasted by the use of some labels and therefore we have opportunity to recognize then on the image from the camera. For example, it can be sheet of the given color (for the color camera) or some symbol (for black-and-white camera). The labels are easily allocated on the first snapshot and their displacement on second snapshot is easily traced. Certainly, this approach is not necessary for orientation in a unfamiliar room, where beforehand it is impossible to put labels. However this approach can be very valuable at a debugging stage of a robot.

Next approach is universal. It based on edges detection and key points definition on them. As key points we consider angles on the images, and such unusual edges as circles, ellipses.

First approach is not appropriate to apply, because this system must be working in unfamiliar conditions, but this approach can be considered as variant for known rooms for more precision navigation.

Second approach is more complex, because it is necessary to extract much details from image and it demands complex scene analysis.

Images, which we have got from videocamera have much color information, and it is necessary to reduce this information. Next features from the images: edges, which contain lines and unusual points, should be extracted.

For solving this problem we need to apply some filtration algorithms. We must make this images more simply.

One of approaches to this simplifying is color reduction. For example if we have 256 colors image, we can reduce them to 64 colors without losing significant information.

Next step of image transformation is edges detection procedure. We can use some approaches for edges detection. More known of them are Sobel and Kalman filters, Hadamard transformation.The results of edge detection presented in the fig.4.

As shown in figures it is possible to allocate sets of lines and to trace them from displacement on the following snapshot. We have considered heuristic approaches for this problem solving.

We have carried out some of heuristic algorithms for unusual key points definition on the first snapshot. We must find them on the second snapshot. The main aim of this algorithms is finding of such points or objects, which it is simply to find on next snapshots (ends of lines, angles, intersections). These algorithms are based on various approaches such as masks applying to transformed image.

4. Algorithm for definition of a point coordinates

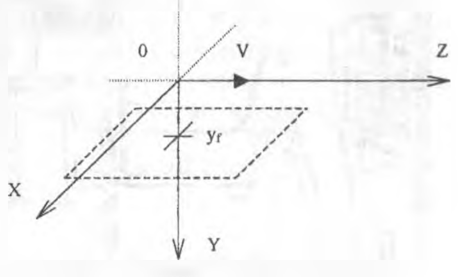

Figure 1 An arrangement of coordinates axes and plane of a floor in a field of the robot sight

We shall consider a case represented in a fig. 1. The robot is forward moved on a floor plane in a V direction, the camera is directed in that direction. Let's arrange axes of coordinates as shown in a figure 1, and we shall establish a point 0 on the center of the camera. The axis Z will be forward directed, and X and Y - to the right and downwards.

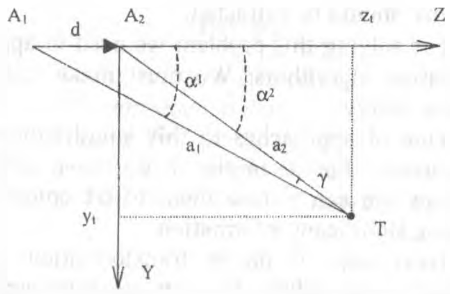

Figure 2. Point coordinates calculation.

Let's robot moved and has passed distance *d* between points A_1 and A_2, in each of which the image of a room on a course of a movement (fig. 2) was received. Let there is a point O, that for simplicity are placed directly on a direction of a movement without a deviation on an axis X. That point is allocated both on first, and on the second snapshot. On a deviation of a point from center of the image, knowing the camera resolution, it is possible to determine corners α_1 and α_2 (see fig. 2). Let's determine coordinates of a point O in the moment, when the robot is in a point $A2$.

Then

$$\frac{a_2}{\sin\alpha_1} = \frac{d}{\sin\gamma},$$

where a_2 - distance A_1O

As $\gamma = \alpha_2 - \alpha_1$, and $z_t = a_2 \cos\alpha_2$, that

$$z_t = \frac{d \sin\alpha_1 \cos\alpha_2}{\sin(\alpha_2 - \alpha_1)}.$$

Similarly the following relation can be received:

$$y_t = \frac{d \sin\alpha_1 \sin\alpha_2}{\sin(\alpha_2 - \alpha_1)}.$$

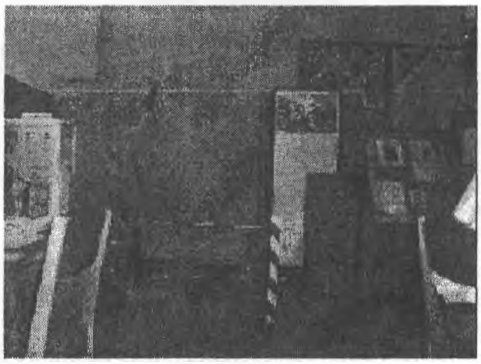

Figure 3. Experimental snapshot

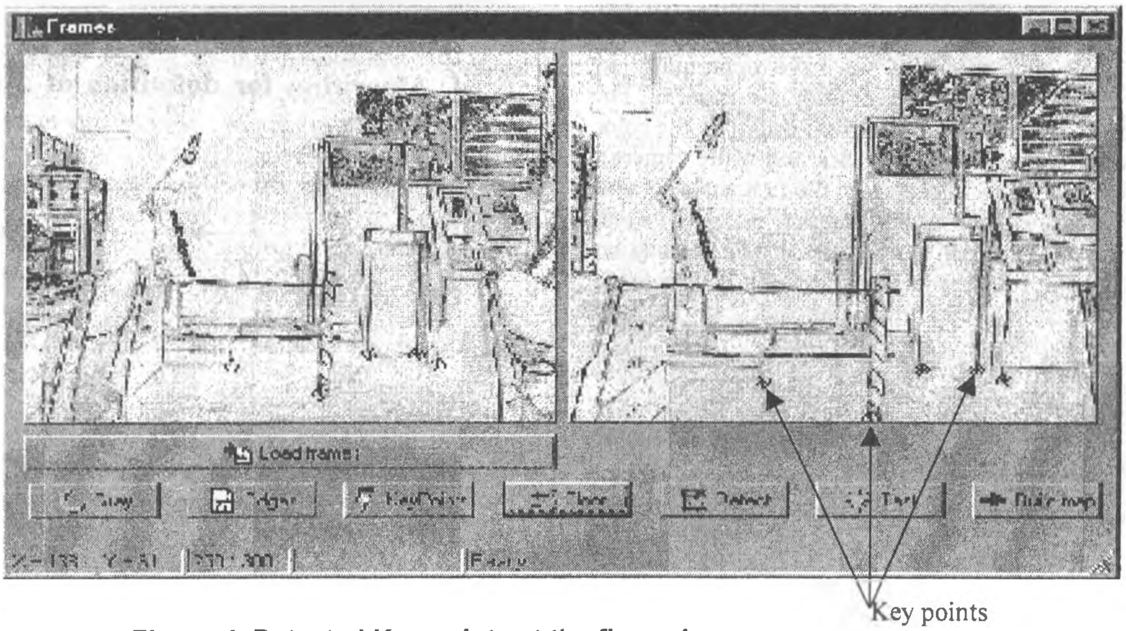

Figure 4. Detected Key points at the floor plane.

These formulas are easily extended for a three-dimensional case, when it is necessary to determine coordinate x_t. Thus it is possible to consider a point in two planes, perpendicular according to axes X and Y. We know vertical and horizontal resolution of the videocamera, then we know angles of reviews on the key point:

$$z_t = \frac{d\ sin\alpha_{x1} \cos\ \alpha_{x2}}{\sin(\alpha_{x2} - \alpha_{x1})}$$

$$y_t = \frac{d\ sin\alpha_{y1} \sin\ \alpha_{y2}}{\sin(\alpha_{y2} - \alpha_{y1})}$$

$$x_t = \frac{d\ sin\alpha_{x1} \sin\ \alpha_{x2}}{\sin(\alpha_{x2} - \alpha_{x1})}$$

On the fig.3 the original videoimage is presented. After image processing we obtain the first snapshot with detected edges. Then we get next image from videocamera and do same transformations. The transformed images in fig.4 are presented. On the basis of z_t and y_t it is possible to make a conclusion about a location of a researched point in space. It should be noted that the most important information is it's belonging in space on an axis Y for a floor plane. The key points which are detected in the floor plane only are shown.

5. Conclusions

The above mentioned algorithms effectively used for reception of a spatial picture of environmental conditions, i.e. the construction of a spatial map of terrain is made possible. However on a way of the decision of this task there are many difficulties, such as shadows, reflections, sharp changes of environmental conditions and etc. The difficulties also arise with moving objects. This algorithm is basically applicable for the static obstacles that are saved their location in space. However given algorithm has also number of advantages, such as:

The optimality of realization from the point of view of hardware expenses, that is the using of one videocamera for formation of a high-grade picture of environmental conditions is possible.

As the image should change on beforehand determined law, the task of definition of the appropriate key points on the image is rather simplified in realization.

Operating with small volumes of the information, that considerably improves stage of the image processing and acceptance of the decision.

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