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PATH SEARCH ON STAIRS AUTONOMIC MOBILE ROBOT MOVING INSIDE A BUILDING

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Abstract

When autonomic mobile robot works inside a many-storeyed building, it contacts with computer by airwaves. Computer processes visual information obtained from robot's video camera and according to this information controls the robot. Passing from one floor to another is performed through the floors connecting stairs. Without possibility to orientate on the stairs mobile robot may choose wrong path or bad position of movement in regard to a stair and fell down from the staircase. In the study we are using a mobile robot equipped with the video camera and light source. The robot is orienting according to bars of rays on the staircase construction, determining beginning and end of the stairs and extrinsical object. A view fixed by video camera is processed using Canny and Hough transformation synthesis. Activate form allows orientation on the stairs at any time of day, even with given textural impurity of the stairs when contours of the stairs are blurring into general textural entirety.

Key words : *autonomic mobile robot, computer vision, stairs, structured light.*

1. INTRODUCTION

The main systems of orientation are technical and computer visions that are used by autonomic mobile robots (AMR) or autonomic mobile movement platforms. Both have advantages and disadvantages. It could be stated that computer vision (when all information is transferred to computer or computers network) processes, analyzes and formulates control commands and sends them back to AMR. Theoretically it has unlimited power and program resource. A negative aspect of this system is security of quality of information obtained and transferred. In technical vision all information is processed by AMR itself, but this depletes its limited power resource. However both are used for AMR control. Orientation in the environment is possible by using features of objects when they are available. It is efficient to use a video camera with help of which a view of environment is being accepted and a known object is being detected on it [1] in accordance to position of which AMR is able to orient. In search of objects' features or determination of movement path, good result can be obtained by using synthesis of two sources of environment observation, video camera and laser scanner [7]. For environment scanning and object detection it is popular to use a stereo vision for which two spot lasers are used, one for horizontal plane and another for vertical. With this system the stairs are being recognized according to the length of vertical lines, in other words according to the possible stairway length that can be 12-25 cm [8]. Stereo vision is used in autonomic movement platform by using two video cameras for recognition of stairs and steps detecting their contours and separating line of *Hough* transformation [6]. Also one linear laser was used for recognition of stairs, which forms vertical lines according to the form of the stairs where algorithm of *Douglas-Peucker* is used for processing of visual information, that is, for detection of key spots. There are processed both visible lines of stairway and riser [4]. Features of the stairs are detected by using one video camera, the view is analyzed using expanded filter of *Kalman* [9], where laser scanner serves as additional channel to get information on the object [3,13]. Sufficient light present in the view obtained, for recognition of

video camera lines *Otsu* method and *Hough* transformation are used [5]. AMR moving towards set direction can determine that it is moving on stairs according to the data of sensor of inner position that is tracing intervals of position change of particular time-span [14,12]. This variant can detect the fact of stairs presence with help of laser ray directed down according to the front of platform and forming its reflection from moving plane, and evaluating change of distance as beginning of new stair [2]. This method is suitable for orientation of AMR position on the stairs according to side wall as well [11]. Big influence in stairs recognition and orientation during movement has the height video camera and laser are mounted, instantaneous amount of stairs detected and distinguishing from possibly detected step depends on this [10].

The goal of the research: According to the stairs' features to determine a path of movement on the stairs and obstacles on it.

The research method: Geometrical modeling, *Canny,* principles of *Machalabo*, *Hough* transformation.

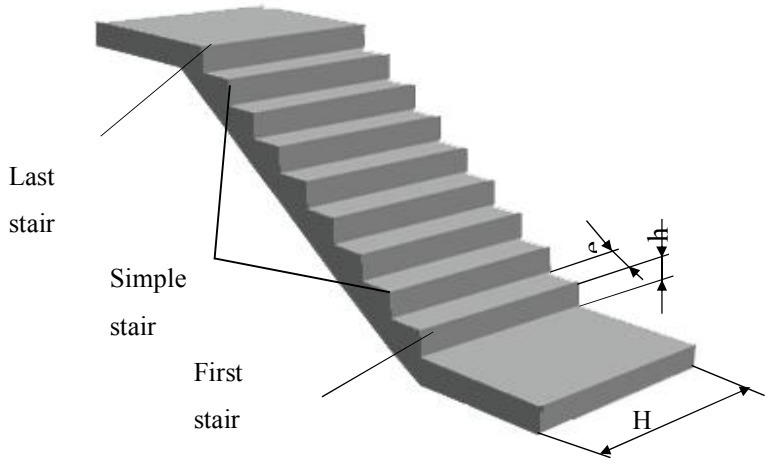


Fig. 1. Stairs' scheme, *e* – width of stair, *h*- height of riser

2. CREATION OF GEOMETRICAL MODEL OF STRUCTURAL LIGHT BAR ON THE STAIRS CONSTRUCTION

In this case we will perform geometrical modeling in striving to determine a change of form of structured light (SL) bar in accordance to the stairs' geometrical form.

We have three sections in Fig. 2, V_1, V_2, H in common case:

$$V_1 = \left|\overrightarrow{ab}\right| = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2}\ ; \tag{1}$$

$$V_2 = \left|\overrightarrow{cd}\right| = \sqrt{(x_d - x_c)^2 + (y_d - y_c)^2}\ ; \tag{2}$$

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$$H = \left|\overrightarrow{ef}\right| = \sqrt{\left(x_f - x_e\right)^2 + \left(y_f - y_e\right)^2}\ ; \tag{3}$$

V_1 and V_2 are parallel to each other:

$$\frac{a}{c} = \frac{b}{d}, k_1 = k_2. \tag{4}$$

where k is direction coefficient.

H is straight to them:

$$e \cdot a + f \cdot b = 0, k_3 \cdot k_1 = -1; \tag{5}$$

$$e \cdot c + f \cdot d = 0, k_3 \cdot k_2 = -1; \tag{6}$$

and divides them in twain.

$$\frac{V_1}{2} = \frac{V_2}{2}; \tag{7}$$

Distance between V_1 and V_2 equals S:

$$S = \sqrt{\left(x_c - x_a\right)^2 + \left(y_c - y_a\right)^2}; \tag{8}$$

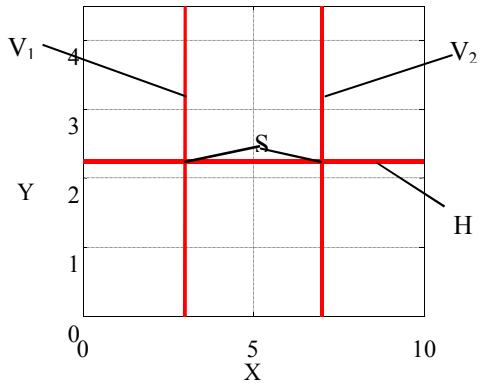


Fig. 2. Bars of SL source on smooth surface

Fig. 2 presents red color bars SL source on smooth surface. As seen from the picture, it is composed of three sections, two of which are parallel to each other (vertical), and one (horizontal) is perpendicular

to them. Geometrical model of the stairs is created by using *Matlab* software in accordance to the measurements of real stairs in proportion M 1:10. Geometrical model consists of three stages shown in Fig. 4, which are sufficient for analysis of form of structured light bar. Lets assume that SL source is in front of the staircase construction and is canted so that centers of intersection of horizontal SL bar H and verticals V_1,V_2 , among which is section S, is on the second riser. Horizontal bar H is formed on a smooth plane and takes full length of stair construction. This is a formed section the length of which is:

$$H = \sqrt{(x_{n-1} - x_n)^2 + (y_{n-1} - y_n)^2 + (z_{n-1} - z_n)^2}; \tag{9}$$

Vertical bars of SL source V_1 and V_2 are transforming into multi-refractional straights in accordance to the form of the stairs construction in the place where they have a contact to stairs construction surface, which means they are composed of the sections that have a consistent interrelationship and their length depends on measurement of stairways and risers. Measurements e_n, h_n are calculated from the equations:

$$e_n = \sqrt{(x_{n-1} - x_n)^2 + (y_{n-1} - y_n)^2 + (z_{n-1} - z_n)^2}; \tag{10}$$

$$h_n = \sqrt{(x_{n+1} - x_n)^2 + (y_{n+1} - y_n)^2 + (z_{n+1} - z_n)^2}; \tag{11}$$

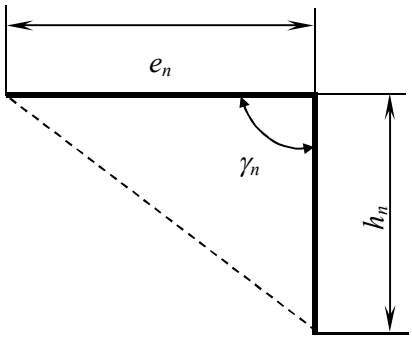


Fig. 3. Evaluation of stair angle in accordance to 2 known distances (fragment of multi-refractional straight V_n)

According to the calculated lengths of sections we can calculate what is the angle composed of vertical sections interconnected on the point [13]. This shows a presence of stair if there is angle γ between two sections which, in theoretical aspect, should be straight, which means, it makes 90^o between two interconnected sections V_1 and V_2 in the bars of multi-refractional straight. Angle γ_n is calculated according to the theorem of the straight triangle:

$$\gamma_n = a\tan(h_n \cdot e_n^{-1}) - a\tan(\frac{1}{h_n} \cdot e_n) + 180; \tag{12}$$

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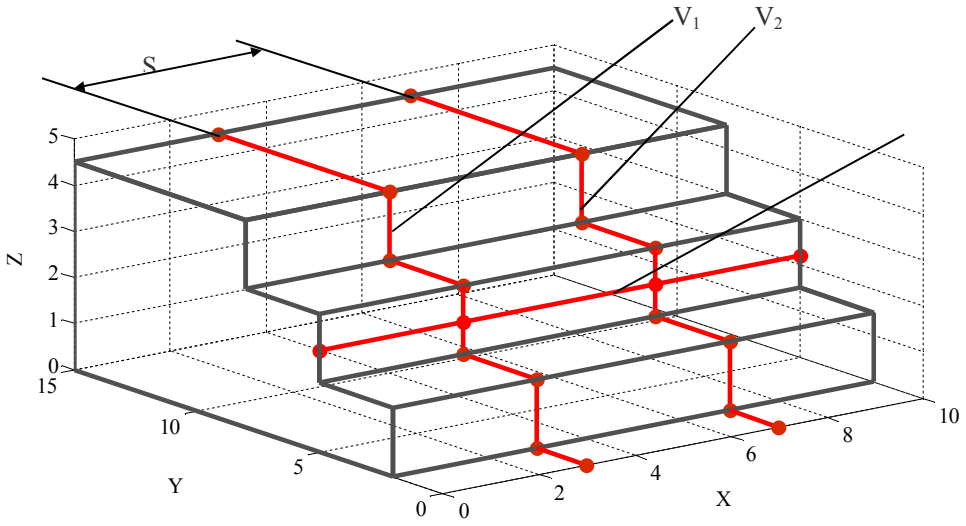


Fig. 4. Geometrical stairs model M 1:10 with structured light bars in common case

In evaluation of transformation of forms of V_1 and V_2 of SL bars into multi-refractional straights and horizontal continuous bar H and its constituent section S, obtained from Fig. 4, the features in searching movement path on stairs are tangible really enough. Therefore it is purposeful to perform practical experiments on real stairs, summing up that AMR has to move not only upstairs bus downstairs as well.

2.1. Streamlined algorithm of path search on the stairs

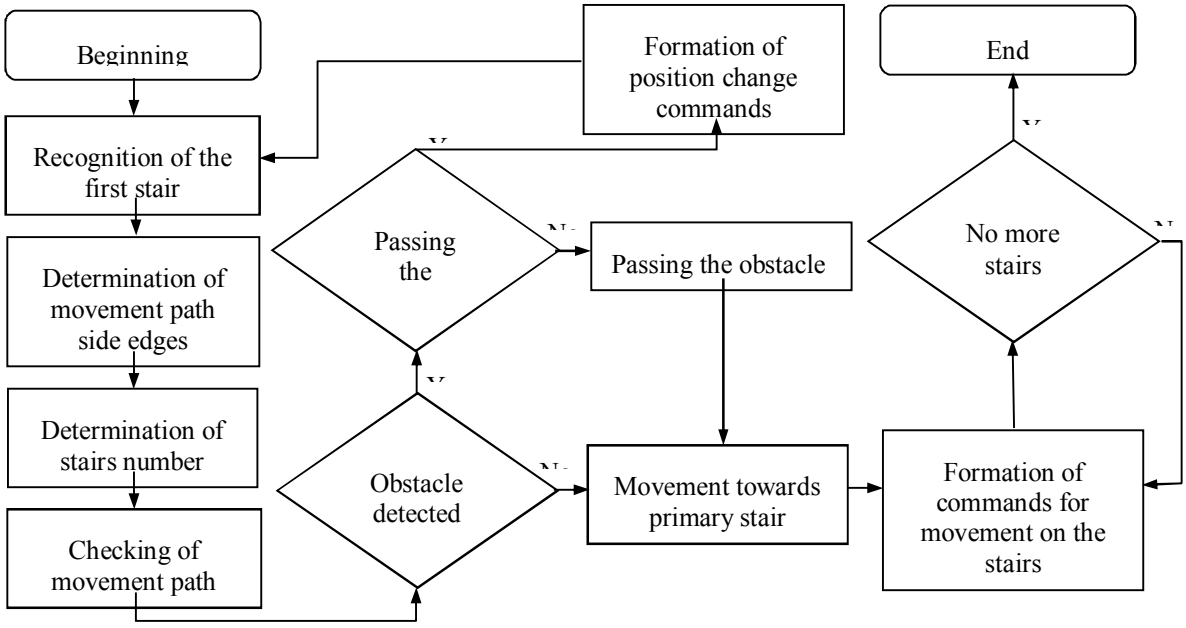


Fig. 5. Streamlined algorithm of path search on the stairs

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Recognition of a primary stair proceeds in accordance to the changes of form of vertical V_1 and V_2. Changes between V_1 and V_2 have to be symmetrical and corresponding features of stairs. Features of stairs depend on direction of AMR movement which is shown in views of Fig. 7 *b,c* and Fig. 9 *a,b*. This condition and features show that path of AMR will go through the stairs in safe distance from the sides of the construction. Number of stairs is detected from the side multi-refractional straights. Horizontal section S between two vertical bars that are fragments V_1 and V_2 , shows that there is no obstacle or stair defect between them. When obstacle is present, section S between two verticals has interruption and that would be a feature that there is an obstacle on the path through the stairs. In accordance to the size of the obstacle, AMR decides if it is needed to look for another path by making a circuit of the obstacle or to go over the obstacle without any change of the movement path.

3. PRACTICAL EXPERIMENT OF PATH SEARCH ON THE STAIRS

Path search on the stairs is performed in accordance to the form of SL bar. In this particular case, SL bar should show up geometrical features of stairs. During the practical experiment there were used a source of red color SL, which means rays of 650 nm length, and video camera. This device of environment scanning has a possibility of vertical movement and is mounted at the front of AMR.

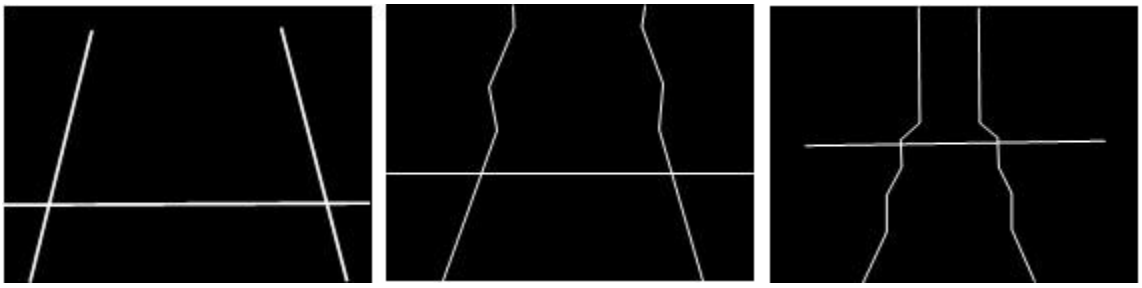


a) b) c)

Fig. 6. Search for AMR movement path upstairs: a,b,c fragments of path scanning stages

As expected the light of SL gave a visually tangible effect, which can be processed by software and allows performance of calculations required. As seen from the traced view in Fig. 6, in order to find orientation features of the path as simple as possible, it is purposeful to binarize a view available and to perform a set of view improvement procedures and eliminate objects that form irrelevant information from the view theretofore. In this particular case we are interested in form of SL bar only. In order to distinguish it from the common ground we are performing segmentation in the traced view of red color by using principle of *Machalabo*. After segmentation of red color SL bar we filtrated its *corona*, by using method of *Canny* contour exclusion. The rest ground was made black and segmented SL bar is binarized, and we find the sections in the view by using *Hough* transformation. View processing performed by using *Matlab* software functions combinations is shown in Fig. 7.

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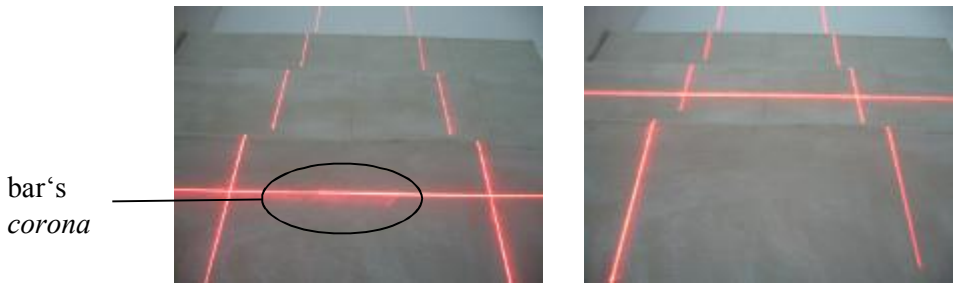


a) b) c)

Fig. 7. Filtrated and binarized view of Fig. 6

Analyzing section *S,* in variants *a*, *b* and *c* of Fig. 7 it is seen that it has no interruptions, which means there are no obstacles in the area of its connection with the surface and the surface is smooth. According to its perimeter area, AMR can move upstairs. Vertical straights V_1 and V_2, in Fig. 7 variant *a* are straight which means they are on the smooth plane, in variants *b* and *c* it transforms into multi-refractional straights that consist of sections having consistent interrelation as e_n and h_n in Fig. 3, where two neighboring sections constitutive of multi-refractional straight V_1 or V_2 are forming straight angle γ_n.

When AMR needs to find path downstairs

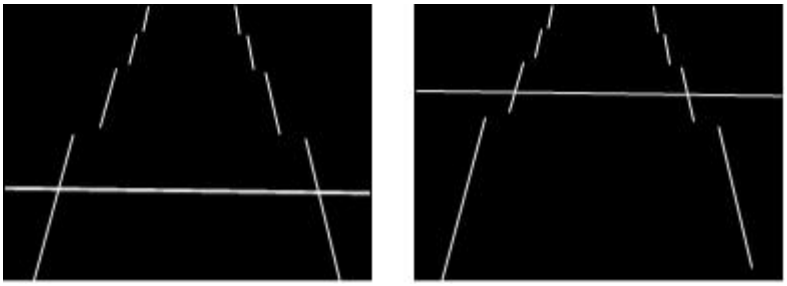


a) b)

Fig. 8. Search of AMR movement path downstairs: a,b fragments of path scanning stages

Procedures of processing of video information are analogous as in determining the path upstairs.

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a) b)

Fig. 9. Filtrated and binarized view of Fig. 8

Features of path for movement downstairs are transformations of forms of the straights V_1 and V_2 to the sequence of sections having vectoral direction, where in common entirety with H they have features of pyramid form. Inner section of the straight H, like earlier, shows throughput of AMR movement path, with no interruptions, which means that there are no obstacles in its area of connection with the surface and the surface is smooth. According to its perimeter radius AMR can move downstairs.

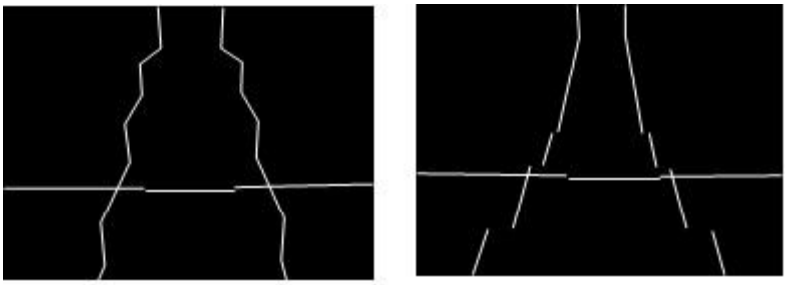
Tracing of extrisinsic object on the path of AMR movement on the stairs



a) b)

Fig. 10. Checking of path throughput for AMR movement on the stairs: a –extrisinsic object found upstairs, b- extrisinsic object found downstairs, fragments of scanning stages

During the experiment an extrisinsic object was placed to make an obstacle on the path of AMR movement which was scanned while checking path throughput. In the Fig. 10, there are interruptions of section S seen visually.



a) b)

Fig. 11. Filtrated and binarized view of Picture

View processing procedures for Fig. 11 are analogous to that of determining path upstairs or downstairs. But in this case horizontal section *S,* with help of which the path throughput of AMR is checked, has interruptions that show presence of the obstacle on the stairs. As indicated in Fig. 7 and 9 when there are no obstacle on the path of AMR, *S* is solid. According to the number of interruptions in section *S* it is possible, in theoretical aspect, to determine a number of obstacles present on the path, and according to the beginning (X_0, Y_0, Z_0) and the end (X_1, Y_1, Z_1) of interruption height in the coordinates it is possible to determine a size of the obstacle. Obstacle's height is important to AMR while making decision if to make a circuit by searching for new path on stairs or its technical possibilities allow going over the obstacle with regard to power input.

CONCLUSIONS

After performance of the practical experiment it was determined that theoretical transformation of structured light bars form in accordance to the model of stair construction when AMR is moving upstairs, inaccuracy of stair sections intersection angle makes 10,7% assuming that in case of theoretical modeling it is perfectly straight. Performed experiments showed that features of boundaries of movement path are directly depending on direction of AMR movement. It was noticed during the experiment that in determination of path stairs construction according to the form of structured light bars is very important quality on which accuracy of identification of path orientation features, selection of movement position and formation of teams depend. This method is suitable for determination of movement path on rough and smooth surface as well. However this method of movement path searching has a disadvantage. Working environment of AMR has to be light conductive. This disadvantage could be eliminated using additional ultrasonic sensors.

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