RECOGNITION OF STAIRS WITHOUT RAILINGS ACCORDING TO STEP ATTRIBUTES, PERFORMED BY MOBILE ROBOT MOVING INSIDE BUILDING

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Introduction

There are many various methods and means how a mobile robot watches the surrounding environment, looks for stationary and dynamic objects according to familiar attributes when moving along a path that is planned or created spontaneously, in accordance with activity circumstances [8]. When a mobile robot (MR) moves inside a building that is in a state of emergency, mostly the main objects surrounding it are stationary. In general cases, object recognition [5] is a very important task for robot orientation system. The most frequently used information collecting method is the use of non-contact systems, such as laser scanners and machine vision, which are designed for collection of data about the environment surrounding a robot [9]. With a laser scanner, it is possible to create a three-dimensional image of an object rather accurately [1] or to orientate oneself in the environment. Optical devices are used for the environment analysis by applying machine vision. An environment model of images received via optical devices is created in those systems programmatically. The model is more accurate when there are many images made from different positions [4]. If MR wants to get to the next floor, it has to find the stairs, though they are not the main goal of robot's task but only a movement route segment (that may be also variously shaped) with a specific surface [3]. Stair framework is composed of steps that are integrated into a homogeneous system by a stair structure. Step height *j* may vary from 12 to 22 cm and its width *e* may vary from 25 to 40 cm. The optimum step width in public buildings is 30 centimetres, in staircases of residential buildings it is 12-15 cm, the steps of attics and basements can be merely 8-10 cm in width [2]. The main stair steps are formed considering step height and width, correlation of which is defined by three formulas: of convenience $e - j = 12$ cm, footstep $2j + e = 62$ cm and safety $e + j = 46$ cm. However, deviations are also possible: according to step width $26 \le e \le 32$ and step height $14 \le j \le 20$ [6].

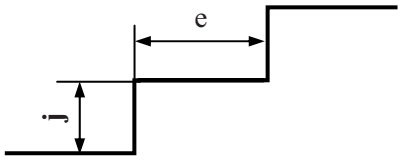

Fig. 1. Dimensions of stair step:
j is height and *e* is width

Research aim is to analyze statistical step data and recognize stairs according to initial attributes of stair steps.

Research methods are analysis of statistical parameters, non-contact environment observation by using the light reflection effect.

MR moving along a corridor of a multi-storey building scans the environment with a laser scanner (see Fig. 2) looking for stairs, so that it could get to the next floor. The scan algorithm is presented in Fig. 3. MR detects an object.

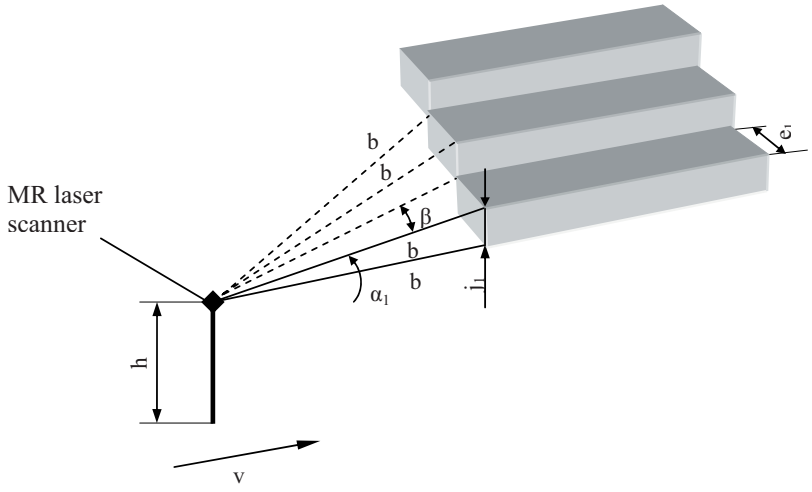

Fig. 2. Stair scanning

That allows producing a reflection b_n in vertical direction and checks its height j_1 that must meet the following condition: $14 \leq j \leq 20$.

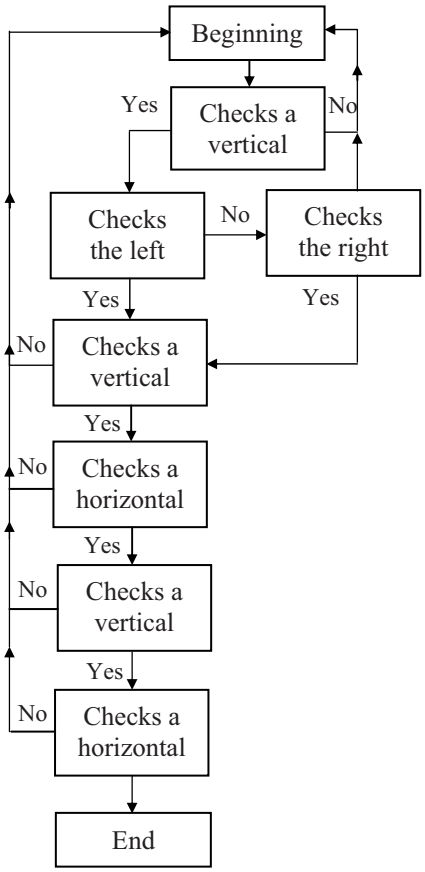

Fig. 3. Algorithm used

If this is satisfactory, MR regards it as a reflection from the side edge of the first step and tries to establish on what side the second step is possibly located with regard to j_1. It checks for existence of possible second step on the right side at a distance according to the condition $26 \leq e \leq 32$; if it is not there, then it checks the left side. Upon detecting a reflection according to a vertical, it checks if j_2 meets the condition $14 \leq j \leq 20$. If it is met, the width e_1 of the first step that must meet the condition $26 \leq e \leq 32$ is calculated. Then it looks for the third step at the j_2 height, but on the left side this time; when it finds the lowest point of its side edge, it calculates width e_2 of the second step that also must meet the condition $26 \leq e \leq 32$. When MR evaluates the obtained data and compares it to the statistical data of stairs existing in reality, it makes a conclusion that these are stairs and they are on the left from it, because if it wants to climb them, it will need to turn left and form a climbing algorithm according to obtained step parameters.

Data obtained by MR scanner is presented in Table 1: angles of distance b and scanner turns.

Table 1. ***Parameters established by MR laser scanner***

Stair step	Distance b(m)		Angle cos(α)	Angle cos(β)
	The lowest point	The highest point		
First	2.532	2.512	0.154	0.207
Second	2.526	2.53	0.153	0.206
Third	2.544	-	-	0.205

The height of the first step:

$$14 \leq j_1 = b_1^2 - 2 \cdot \cos(\alpha_1) \cdot b_1 \cdot b_2 + b_2^2 = 0{,}15 \leq 20; \quad (1)$$

The height of the second step:

$$14 \leq j_2 = b_3^2 - 2 \cdot \cos(\alpha_2) \cdot b_3 \cdot b_4 + b_4^2 = 0{,}15 \leq 20; \quad (2)$$

The width of the first step is calculated:

$$26 \leq e_1 = b_2^2 - 2 \cdot \cos(\beta_1) \cdot b_2 \cdot b_3 + b_3^2 = 0{,}27 \leq 32; \quad (3)$$

The width of the second step is calculated:

$$26 \leq e_2 = b_4^2 - 2 \cdot \cos(\beta_2) \cdot b_4 \cdot b_5 + b_5^2 = 0{,}27 \leq 32; \quad (4)$$

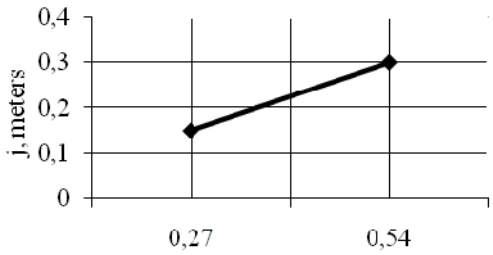

Fig. 4. The correlation of height and width of the first step j_1, e_1 and the second step j_2, e_2 of the stairs detected by MR, calculating from the first step, is presented

Conclusions

1. By applying the methodology where stairs are recognized according to step parameters, MR can analyze not the whole object but only a fragment and sequence within it, considering the possible statistical data of a real object of this kind. In this case, it was established that the step height is 15 cm and width is 27 cm.
2. At least two steps must be analyzed by using this method in order to establish a sequence. The analysis of one step may mislead MR. MR can equate a step to an object that has similar parameters.
3. With the help of this methodology, stairs may be recognized from steps when MR approaches them from the front. There would be a difference if a reflection was obtained from horizontal edges of a step.
4. When recognizing stairs according to step statistical data and evaluating the possible variation

of their parameters, the stairs will be recognized the same if there are steps of different height but their parameters meet statistical step parameters. In that case, MR will have to consider this when creating or correcting an advance climbing algorithm.

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Summary

There are many methods that may be used by a robot to orientate itself in the environment and recognize objects. In most cases they are rather complicated, requiring substantial power resources of a mobile robot. Therefore, when a mobile robot is assigned to perform a task independently, the attention is concentrated on the solving of possible unforeseen situations accompanying the main goal. All other activity of a mobile robot, until it reaches its final goal, is supplementary and must be performed by a robot in the course of movement. Recognition of stairs essentially is a mobile robot's supplementary activity on the way to the main goal, but their recognition is very important. Not having recognized stairs a mobile robot would never be able to climb to the next floor, which means that the final goal would never be reached. If it recognizes wrongly and starts to climb, it may fall down or will attempt the climbing procedure many times until it consumes all power in its cell. Therefore, in this publication a possibility to recognize stairs according to dimensions of their steps, with reference to statistical stair step data, when a moving mobile robot analyzes the surrounding environment with a laser scanner, is analyzed.

Keywords: mobile robot, stairs, step.

MOBILAUS ROBOTO, JUDANČIO PASTATO VIDUJE, BETURĖKLINIŲ LAIPTŲ ATPAŽINIMAS PAGAL PAKOPOS POŽYMIUS

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Santrauka

Yra daug metodų pagal kuriuos robotas gali susiorientuoti aplinkoje ir atpažinti objektus. Dauguma atvejų jie yra gana sudėtingi, reikalaujantys nemažai mobilaus roboto energetinių resursų. Todėl, kai mobiliam robotui yra pavesta savarankiškai atlikti užduotį, dėmesys telkiamas į galimų nenumatytų situacijų prie pagrindinio tikslo sprendimą. Visa kita mobilaus roboto veikla, kol pasieks galutinį tikslą, yra kaip papildoma, kurią robotas turės atlikti judėdamas. Laiptų

atpažinimas iš esmės ir yra mobilaus roboto papildoma veikla pakeliui į galutinį tikslą, bet jų atpažinimas yra labai svarbus. Mobilus robotas, neatpažinęs laiptų, niekada neužlips į sekantį aukštą, vadinasi, ir galutinis tikslas niekada nebus pasiektas. Atpažinęs klaidingai ir pradėjęs lipti, jis gali nukristi ar lipimo procedūrą tiek kartų bandys kartoti, kol išeikvos visą energijos elementą. Todėl šioje publikacijoje nagrinėjama galimybė atpažinti laiptus pagal jų pakopų matmenis, remiantis statistiniais laiptų pakopų duomenis, kai judėdamas mobilus robotas lazeriniu skeneriu analizuoja aplinką.

Prasminiai žodžiai: mobilus robotas, laiptai, pakopa.

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