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3D MAPPING OF ROOMS USING 2D LASER SCANNER

MAPOVÁNÍ MÍSTNOSTÍ VE 3D S POUŽÍTÍM LASEROVÉHO 2D SKENERU

Abstract

The article describes construction of measuring device for 3D rooms mapping. Device uses 2D scanning laser range finder. Next, there is an introduced problem of cloud points processing, which is produced by measuring device.

Abstrakt

Článek popisuje konstrukci měřicího přístroje pro trojrozměrné mapování místností s využitím laserového snímače vzdáleností, určeného pro snímání v rovině. Dále se zde popisuje úvod do problematiky zpracování mračna bodů, který je produktem měření.

Key words

Laser scanner, map building, robotics, mechatronics

1 INTRODUCTION

The 2D laser scanners don't have to be used only for safety purposes, like robotics work cells in production industry (automotive) etc. In the world they are applied in mobile robotics and autonomy manufacturing transport very often too. Its advantage – opposite to cameras – is direct information about distances toward obstacles (or objects) in surrounding. Next laser scanner utilization – described in this article – is building of the 3D maps.

2 MEASURING DEVICE DESIGN

As main part for our device the scanning laser range finder URG-04LX from Hokuyo Automatic CO., LTD was selected. It is a mass product, relative cheap with acceptable technical parameters. This laser scanner is able to measure in range up to 4m with accuracy ±1%. Scan angle is 240°, angular resolution is 0.36° (360°/1024), and distance resolution is 1mm and scanning speed is about 100ms per scan. Scanner is characterized by low weight - about 160g and power consumption about 500mA/5V (start up current 800mA).

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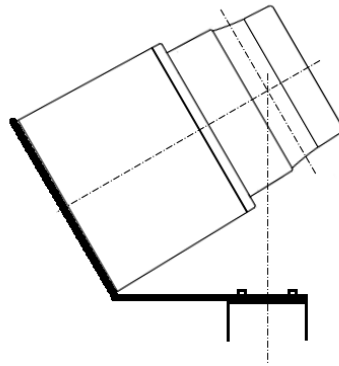
Fig. 1 Hokuyo laser scanner

Fig. 2 Mount position of laser scanner

For 3D measuring we must get the third axis. Easiest way to achieve it is properly mount the laser scanner on positioner driven by stepping motor – see Fig. 2. We used small two-phase stepping motor with 100 steps per rev. Control of this stepping motor is implemented in microcontroller PIC16F88. In control program is implemented microstepping control and we reach 800 steps per rev. Microstepping is realized by PWM method. Here was little problem with current filling of phases of stepping motor, because dependency of current and duty cycle is not linear and can't be computed from simple formula. In real current I_c is function of Dcycle and I_{max} see formula below.

$$I_c = f(\ I_{max}, Dcycle) \tag{1}$$

The phase drivers is realized by pair of full bridge driver IC L6202 DMOS. All the it's logic inputs are TTL and CMOS compatible, with operating frequency up to 100kHz. The very short switching time of transistors in bridge guarantee high efficiency. All transistors in bridge are protected. This IC allows very easy design power circuit with microcontroller and application of this IC do not require others components.

The power supply is 16-22V DC, with current capacity about 1.5A. Supply is directly used for bridges switches of windings of stepping motor. For supply of logic there is high effective step-down switching voltage regulator used with efficiency more than 75% .

Communication between PC, laser scanner and microcontroller is designed with one cable connected to standard serial PC interface.

Laser scanner communicates directly via serial line. PC sends to scanner commands and scanner sends acquired data back to PC. Communication speed is set at 115200 kb/s. It is suitable, but can be increase. As mentioned above, scan time is 100ms and every cycle produces about 1300 bytes. Transfer this data takes about 110ms.

The communication with microcontroller uses serial line. By help of unused USART control signals RTS and DTR we simulate I2C bus. Via these lines an I2C communication interface is realized.

In the final we have measuring unit with one power supply and communication with PC via one cable connected into RS232 serial interface. This design allows in future simple possibility to use it on mobile robot with any control computer.
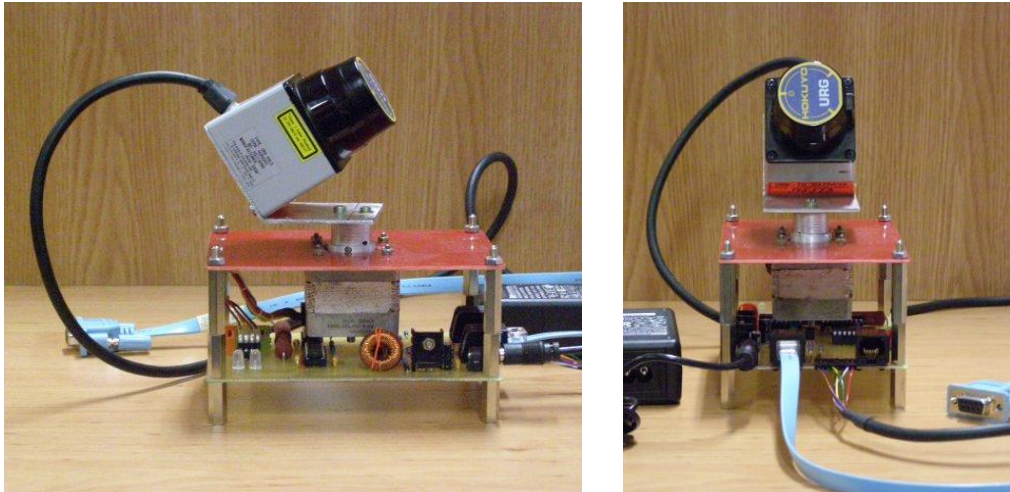
Fig. 3 Laser measuring device

3 MEASURING, RESULTS, FILTERING

Position of laser scanner on stepping motor, according Fig. 3 is unusual. It was designed due to easiness of software development. In this position the laser measuring plane is concurrent with majority of surfaces and edges in rooms. It easier allows detect problems and errors in algorithm. Disadvantage is blind cone above measuring device. But ceiling of room can be ignored now.

Coordinate system is selected according Fig. 4. As plane X-Y is selected directly plane of laser measuring. Measured distances by laser in plane X-Y are in polar coordinates and must be converted to rectangular coordinates X and Y. In second step the plane X-Y must be rotated around axis X with angle 60°.
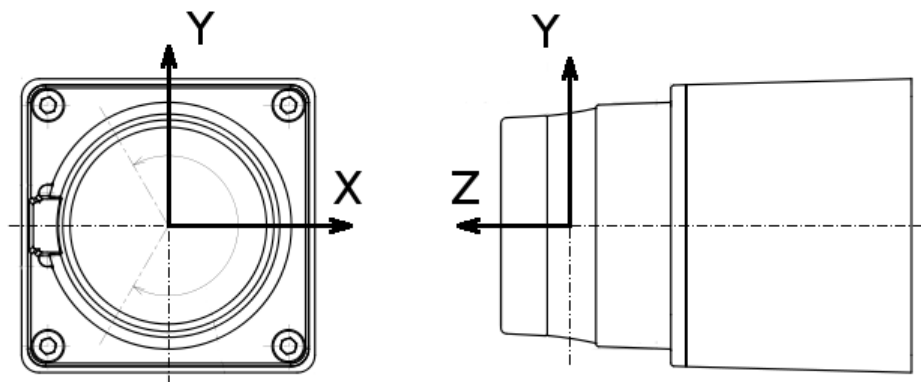

Fig. 4 The coordinate system

Now we have axis Z identified with stepping motor axis. Third step is rotating plane X-Y around axis Z according to actual stepping motor position. All points are now in real X-Y-Z coordinates. Result is cloud of points.

For visualization of cloud of points we use OpenGL library. In the Fig. 5 we can see the photography of measured corridor and in the Fig. 6 are 3D animations of cloud of points. In the left Fig. 6 we can recognize similar view like on photography. In the right Fig. 6 is view through ceiling (blind cone is visible).
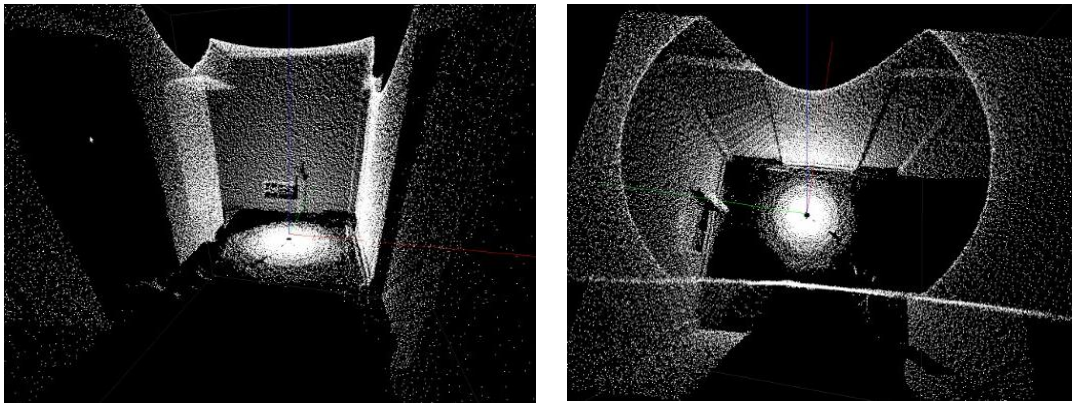
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Fig. 5 Measured corridor

Fig. 6 Visualised cloud of points

Cloud of points is not very effective and suitable for next processing. Our aim is to obtain planes and edges. Now we are solving problems with noise reduction, reduction of number of points and reliable detection of invisible space.

In first stage we use for filtration statistical method. It simple detects "bad" points in cloud. This way we detect invisible spaces too. But is not suitable for points reduction still.

Accuracy of laser is ±1%. On distance 4m can be the difference between two neighbouring points up to 8cm! This reality must be accepted in software. We developed method "tilling panels". This method interposes cloud of points by panels with assigned thickness. Finally, the algorithm converts cloud of points to polylines and reduce amount of data to 5÷10%.
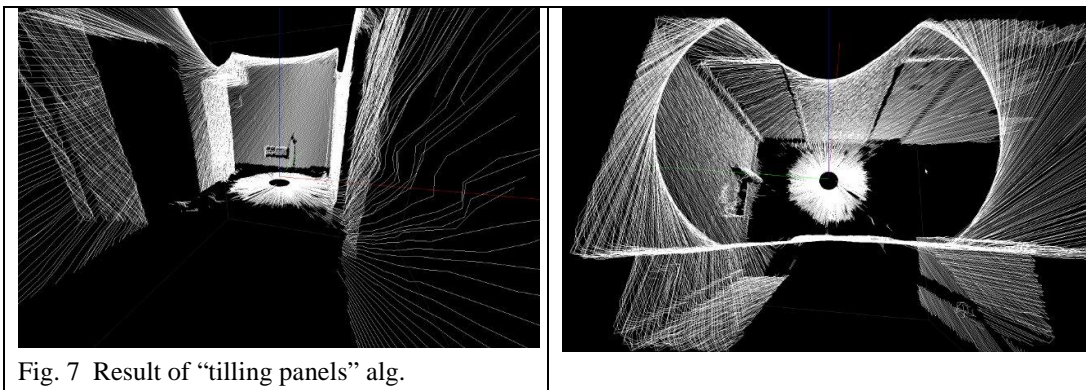
Fig. 7 Result of "tilling panels" alg.

How the algorithm "tilling panels" work can be explained on picture Fig. 8. On picture a) is filtered result from laser scanner without bad points. At the moment algorithm start tilling panels with given thickness on the cloud points and try close as much as possible points into single panel. When no more points can be closed, start tilling new panel from last point of previous panel. Every time all neighbouring panels have one collective point. Algorithm stops, when all points are closed in panels. The final state is on picture b). In next step on picture c) are contents of panels cleared and we have only neighbouring panels with collective points. All this neighbouring points are connected by lines. Final polyline is on picture d).
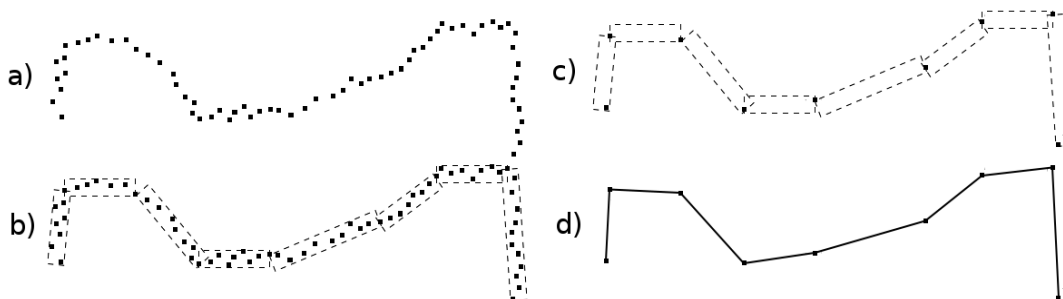

Fig. 8 Steps of "tilling panels" algorithm

4 CONCLUSION, NEXT DEVELOPMENT STEPS

In this article we introduce, how to create 3D laser scanner for rooms mapping. The final result from measuring device is cloud points. This format contains noise and is very large. We must filter noise and reduce quantity of points.

In next research we will try use better filtration algorithm, e. g. K-Means, Mean-shift or others. We will compare results and choose the best suitable for cloud points. After filtration we will try detect planes and edges in rooms and connect results from more places in rooms to minimize invisible spaces.

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