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MEASUREMENT OF 3D SPACE USING A 2D PROFILOGRAPH

POUŽITIE 2D PROFILOGRAFOV PRE MERANIE 3D PRIESTORU

Abstract

This article proposes a method how to create a measurement system which can be used as a terrestrial laser scanner. The system utilizes laser scanner LD-OEM 1000. It measures profiles therefore it is capable to capture an area 360 degrees around itself at the width of one laser impulse. Our method of the terrestrial scanning benefits from the fact that the measured profiles are in vertical plane and the rotation of the whole scanner allows us to create complete 3D model of the surrounding space. The article explains design of the controlling software and mechanical construction used for desired rotational motion of the whole scanner. Proposed method has been tested on real hardware and the achieved results are presented at the end of the article.

Abstrakt

Cieľom tohto článku je predstavenie prístupu, v ktorom sa za pomoci laserového skenera LD-OEM 1000 vytvorí systém, ktorý napodobňuje terestriálny laserový skener. Skener LD-OEM 1000 je profilový. To znamená, že v jednom momente je schopný zaznamenať priestor 360 stupňov okolo seba o šírke jedného laserového impulzu. Princíp terestriálneho skenovania spočíva v tom, že tieto namerané profily sú naukladané vertikálne, pomocou otočnej časti skenera a otáčaním celého skenera o 360 stupňov je vytvorený celkový 3D model okolia skenera. V článku je opísaný princíp akým bol realizovaný softvér pre riadenie aplikácie a konštrukcia pre dosiahnutie žiadaného pohybu skenovania. Navrhnutý prístup bol prakticky overený a dosiahnuté výsledky sú prezentované v poslednej časti článku.

Keywords

3D model, laser scanner, LD-OEM 1000, stepper motor

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1 INTRODUCTION

In various technical fields, such as civil engineering, castles in the reconstruction but also on smaller objects such as parts there is demand for fast and accurate measuring of distance and dimensions.

For these tasks are often used laser scanners dedicated to distance measurement. There are many kinds of laser scanners in various price levels dedicated to various tasks. Between the best quality laser scanners belongs the new generation manual laser scanner. This scanner is capable to create 3D models of small and medium size objects from car body up to small parts with high precision in real time.

Next example are terrestrial laser scanners. These scanners are used (another like manual scanners) for measuring of large distances. They are utilized for 3D model creation around scanner of hundreds of square meters. The scanner works that, rotational head is measuring its surroundings in vertical plane and gradually is rotating up to point when the whole space around it is measured. Typically one this scan is not sufficient and according to requirements is need to move the scanner and perform the scan at another location. The scanner can be moved only after the measuring is completed. Different 3D models of the object could be merged into single whole 3D model.

Our goal was to create similar principle of measuring as by terrestrial laser scanners using the scanner SICK LD-OEM 1000, which is capable to create only one vertical cut. Mechanical part will ensure the rotation of whole scanner around 360 degrees and software will save the measured plane cuts according to the angle. Resulting 3D model will be possible to post-process, for example to remove unwanted objects, to merge different 3D models or to smooth the disparities, etc.

2 CURRENT PROXIMITY METHODS FOR 3D MODEL CREATION

For creation of accurate geographic 3D maps of terrain is possible to use aircraft with installed laser scanners. Aircraft is flying sequentially over landscape and creates single slices of 3D model of terrain part by part and later they are merged into complex model. Laser scanners dedicated to aircrafts are using technology „waveform digitizing“ which compares the wavelength of transmitted and received light. In terrain are also used terrestrial laser scanners. This is laser scanner placed on stand which serves for creation of 3D model of scanner surroundings. Usually several measurements are taken and later they are merged into whole 3D model. Terrestrial laser scanner allows to create 3D models with high accuracy. Commercial market offers many of manual scanners (Fig. 1) for creation of 3D models. Those are devices able to record and create 3D model in real time with high accuracy. These devices are easy to operate. Scanner contains camera with high quality optics, able to record 60 frames per second. Using these cameras scanner detects its position relative to the scanned objects and its correct placement on virtual model.

Fig. 1 Laser scanner for creation of 3D models (left), mask for an object (right)

Next method of 3D model creation is using camera and software PhotoScan (Fig.1). This manner of automated modelling is based on 3D model creation from several images taken from various angles. Usually the photographer walks around the object and takes the first series of images. The second series is taken from another angle for example holding camera in another level. These two series are usually enough for 3D model creation with texture. The manner described above is not necessary to perform. The PhotoScan software could process also random placement of camera around object, at various viewpoint angles, and the images could be used from various camera types.

3 CONCEPT OF MEASURING UNIT AND MATHEMATICAL DESCRIPTION OF ITS FUNCTION.

The whole system looks like at terrestrial laser scanner. Hardware contains laser scanner SICK LD-OEM 1000, which scans the vertical plane. Scanner is placed on stand, which could be rotated around 360 degrees. The rotation is performed by a stepper motor. The scanning looks like that by every rotation of scanning head around 360 degrees the motor moves around one step. Application is controlled by a PC and stepper motor by a microcontroller ATmega8.

We define Cartesian coordinate system with *xy* plane oriented horizontally and *z* axis oriented vertically with its centrum bound with the laser scanner. If the axis of the laser scanner is parallel to the x axis, the coordinates of each measured point are:

$$x_k = 0 \tag{1}$$

$$y_k = r_k \cdot \cos(k \cdot \Delta\varphi + \varphi_0) \tag{2}$$

$$z_k = r_k \cdot \sin(k \cdot \Delta\varphi + \varphi_0) \tag{3}$$

where:

k - sequence number of the measured point during one turn of the scanning head,

r_k - distance of the *k*-th scanner sample [m],

$\Delta\varphi$ - angular increment of the scanner head between two scanner samples [degrees],

φ_0 - initial orientation of the scanning head (rotation around its axis) [degrees].

The step motor with gearbox rotates whole scanner after each turn of the scanning head (one scanned 2D profile) by one step around axis *z*. Therefore it is necessary to rotate vector [x_k, y_k, z_k] accordingly:

$$\boldsymbol{r}_{n,k} = \begin{bmatrix} \cos(\gamma \cdot n \cdot \Delta\theta) & \sin(\gamma \cdot n \cdot \Delta\theta) & 0 \\ -\sin(\gamma \cdot n \cdot \Delta\theta) & \cos(\gamma \cdot n \cdot \Delta\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_k \\ y_k \\ z_k \end{bmatrix} \tag{4}$$

where:

n - sequence number of the scanned profile,

$\Delta\theta$ - angular rotation of the step motor per one turn [degrees],

γ - gearbox ratio.

4 DEVICE CONSTRUCTION

The device consists of a stepping motor, the stepper motor control system, the harmonic gear and a stand for the laser scanner. The control system of the stepper motor is placed into the box made of ABS plastic. The control system includes the pulsed power supply 24V 6,0A, circuit with the microprocessor Atmel ATmega8 with MOSFETs BUZ11 controlled using driver TC470. Furthermore it includes a PWM control current limiter of the stepper motor to not burden the power supply.

On the shaft of used stepper motor the harmonic gear with ratio 1: 124 is connected. So the system is able to take 124 measurements by the movement of the full turn of the stepper motor. For finer measurement of the motor can be set to 180-degree turns and for the even finer measurement at a 90 degree or 45 degree. If the movement of the motor would be 20 degrees, the laser scanner might make up to 620 measurements around. There would be achieved a greater number of plane cuts to be measured by the laser scanner during one step, if the stepper motor moves by its thinnest step, which is 0.9 degree when the stepper motor rotates by half steps.

Fig. 2 Device construction

5 THE WORK WITH THE PROGRAM 3D STUDIO MAX 2015

3DS Max or 3D Studio Max [3] from Autodesk Media and Entertainment company is a professional 3D program running on personal computer for creating 3D animations, models, video and pictures. The program includes many options for modelling, texturing and rendering. There are many plugins to simplify and streamline the work in the program 3DS Max.

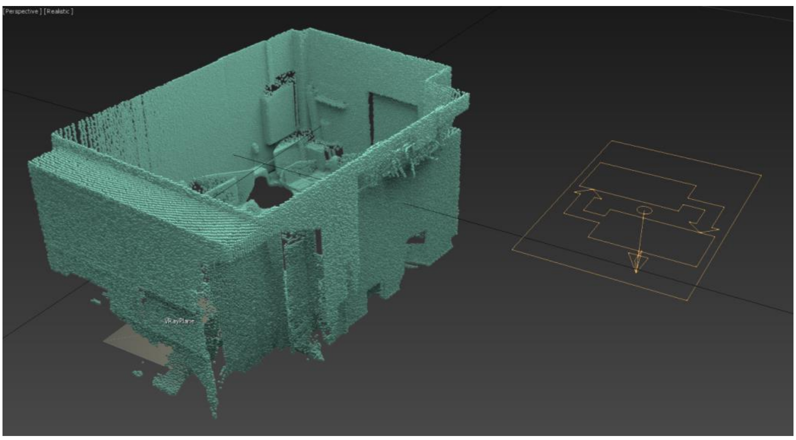

Fig. 3 Model created by the particle system PF Source

The software 3DS Max was used for our master thesis as a visualization tool for measured data processing as well as their arrangement. In the original setup the program has four windows: three previews for 2D view and one for 3D surround view.

Data received from the laser scanner and subsequently converted in the subroutine MaxScript take the form of clouds of points that can be edited (Fig. 3, Fig. 4). The measured points can be moved, rotated, moved away from each other or closer and delete unwanted items. The only problem is that such an alone points cannot be visualized. Also they cannot be exported in OBJ format because this format exports only polygon model or mesh.

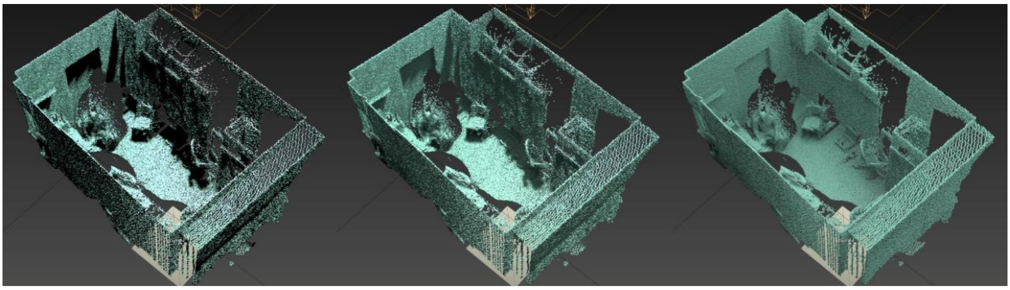

Fig. 4 Automatic creation of the subtle shades in the scene

6 ACHIEVED RESULTS

The produced measurements from terrestrial laser scanner LD-OEM 1000 shows a 3D model of the laboratory AB318. The measurement is composed of the 63 individual measurements by laser scanner LD-OEM 1000 facing each other on 2.903 degree. The conversion of the output data from the scanner to the x and y coordinates was executed for each measurement of one cut.

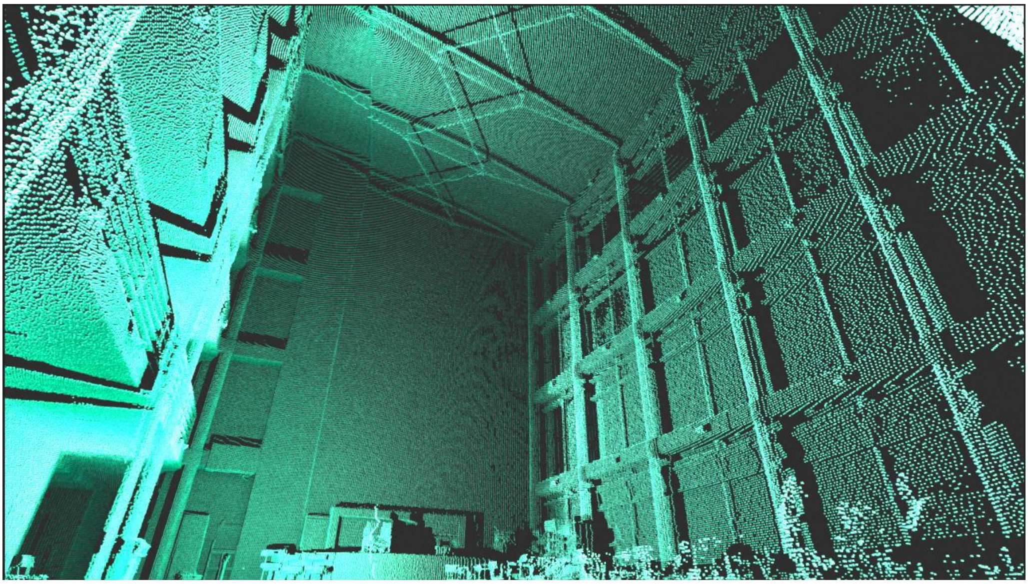

Fig. 5 3D model of entrance hall

After measurement another calculation has been made using 3ds MAX maxScript, where renders the resulting data as a cloud of points. We removed points measured on the ceiling from the model for better insight into the final model. Although this is a rough measured data, it is easy to see not only the dimensions of the room but also the individual details such as the location of doors, windows and scanned user near the machine. We made next measurement with 10 times smaller step of stepper motor as in the previous case, so we get 10 times more information and more detailed model of the laboratory (Fig. 6).

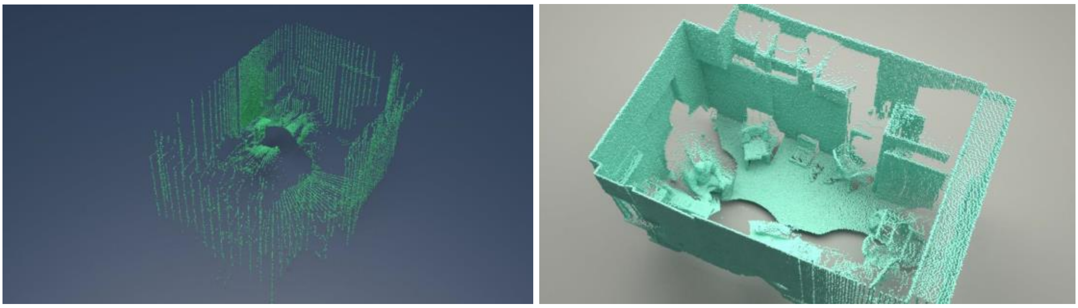

Fig. 6 The model of the laboratory AB318 produced by rough measurements and fine measurement

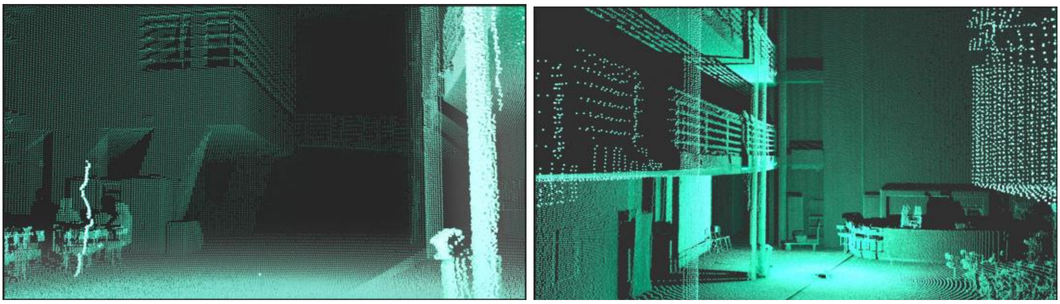

Fig. 7 3D model of entrance hall (other angles)

7 CONCLUSIONS

Using 2D laser scanner LD-OEM 1000 we created a simple terrestrial laser scanner. We made the construction on which we placed the scanner. This system also includes a stepper motor for precise rotation of the scanner. We have designed the control method for the stepper motors. The main part of the system are the microprocessor Atmel Atmega8 and four MOSFETs switching by drivers TC470 and controlled through a microprocessor.

The communications with the laser scanner and microprocessor is made by the software part which was programmed using Microsoft Visual Studio and Atmel Studio. Furthermore, we have programmed the software to process the data from the laser scanner to create a 3D model of the surrounding area around the scanner.

We scanned the laboratory, passage, hallway by this device and we created the 3D models. The output of the system is a cloud of points which can be used to create an accurate model of space. This device is not suitable for scanning the small objects.

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