MATERIAL HANDLING DEVICES OPERATION ENVIRONMENT 3D-TYPE PRESENTATION BASED ON LASER SCANNING SYSTEMS

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Abstract

The paper is focusing on the material handling devices operation environment 3D-type presentation based on laser scanning systems and point of cloud data approach. Main attention was fixed at overhead travelling cranes and their operation space zone with determined and random character factor influences the workspace spatial volume.

Supervising the transport means workspace get possibility mark out the optimum grade-separated trajectory for transferring cargo in automatic mode. On the base 3D type scans was generated digital model of the plant/laboratory hall, where crane has been installed. In the next step the same laboratory hall and their characteristic points was measure with the help geodetic device and compare with laser scanning data.

Other part of the paper is presenting a methodology for 3D type object scanning with use surface segmentation for reduce the number of points given by the industrial scan objects like a hall where an overhead travelling crane is operating. This procedure replace traditional 3D type scanner rotation mode with the planar mode of scanning. In this case the laser beam examines the object only in one direction, it is ideal for scan the workspace for the transport means with Cartesian operation environment and opens kinematics chain.

Keywords*: point of cloud, laser-scanning system, and material handling devices*

1. Introduction

The difficulty of processing millions of points given by the scan of medium and large-sized industrial objects by laser scanner constitutes a challenge to researchers or engineers working on this field [3-5, 8]. Development of reverse engineering methods [13, 15] with exponential growth of computing power enable use scanning methods in variety of field: building scanning [1], refinery installation, urban models documentation [3], accident documentation [2], old building assessing safety [12] and others [11].

Most of the available software packages used processing the data from 3D type scanner can't easily work with very large point clouds. The process of 3D modelling (mathematical representation of three-dimensional surface or solid) is time consuming and therefore expensive. For that reason any solution of automatic reconstruction for 3D objects are under investigation. Automatic reconstruction of physical objects with their geometrical structure can be subdivided into two kinds of methods: active methods use structured light (e.g. laser scanner) and passive method use 2D image with markers for calibration the camera [16].

This paper focus the possibility implementation laser scanner system and cloud of point data (first level scanning data presentation) for obtaining 3D type information concerning the work space for automatic control material handling devices.

2. Material handling operation space results laser scanning

In result of use laser scanner is a large number of points (so-called cloud of point) defined by *X*, *Y* and *Z* in scanning device local coordinates system [10]. A point cloud is a set of vertices in a three-dimensional coordinate system represents the set of points that device has measured. There are many techniques for converting a point cloud to a 3D type surface but the reconstruction especially precise surfaces from unorganized point clouds derived from laser scanner or other methods is a very hard problem, not completely solved and problematic. The best way is always create a computer model of an object which best fit the reality but contains as small as possible number of point.

Contemporary laser scanners enables a large quantity, dozen million point's number three-dimensional model. Data are collected in a short period of time and each individual point has additionally information about reflection intensity value. This functionality allows generating a point cloud in a local coordinate system with additional colour information in RGB type mode. To use cloud of point data to supervising the material handling device workspace compare receive digital model with scanning facility. The object of the measurement was a space work of double girder crane with hoisting capacity 15 tones and 12 meters span localized in Crane Laboratory at the AGH University Science and Technology Krakow.

2.1. Experiment description and measuring devices

Main target of the experiment was attempt to compared the data acquire from 3D type laser scan with data from professional geodetic device. To site measure was use electronic theodolite (Fig. 1.) integrated with an electronic distance meter to read distances from the instrument to a particular point.

Leica TPS1200 - TCRP1205

Telescope	
Magnification:	x30
Free objective aperture:	40 mm
Field of view:	1°30' (1.66 gon) / 2.7 m at 100 m
Focusing range:	1.7 m to infinity
Distance masurment	
Round prism (GPR1):	3000 m
360° reflector (GRZ4):	1500 m
Mini prism (GMP101):	1200 m
Reflective tape (60 mm x 60mm):	250 m
Shortest measurable distance:	1.5 m
Accuracy/Measurement time	
Positioning accuracy:	< 2 mm
Measurement time:	3 - 4 s
Data storage	
Internal memory:	32 MB (optional)
Memory card:	CompactFlash cards
Number of data records:	1750 / MB

Fig. 1. Electronic theodolite station [6]

In the destination of the possibility comparing the accuracy digital laboratory hall model obtain with the help 3D laser scanner with total station measurements, the interior of the laboratory hall was marked with black and white square disc constituting photo points (see Fig. 2.). Altogether 11 photo points were arranged. On account of the height of the hall and the lack of access, the ceiling of the hall wasn't marked. A geodetic tripod stand (for total station and 3D scanner) was fixed on the crane’s trolley; the double girder crane bridge was placed on the middle of the AGH UST Crane Laboratory hall. Result of carried out measurements are presented in the Tab. 1.

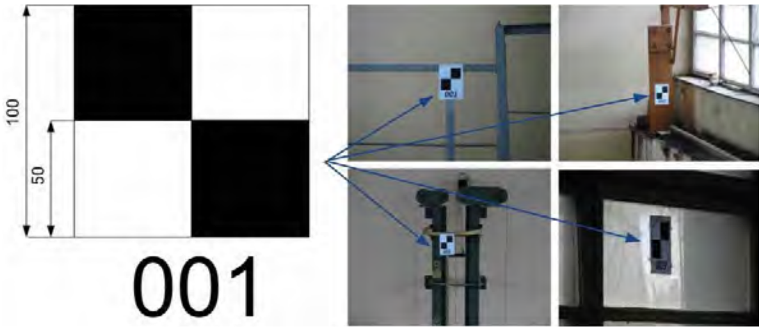

Fig. 2. Arrange of photo points in the AGH UST Crane Laboratory Hall

Tab. 1. Data obtained from total station

No	Foto points	Easting *(x)*	Northing *(y)*	Height *(z)*	Vector length
1	5	7.635	16.271	0.354	17.977
2	1	10.746	15.451	-2.853	19.036
3	2	11.945	15.082	-0.948	19.263
4	4	0.200	19.369	-0.355	19.374
5	7	9.000	5.481	0.838	10.571
6	3	-0.928	17.958	0.809	18.000
7	6	-3.860	10.147	0.773	10.884
8	9	4.629	-6.201	0.836	7.783
9	11	1.935	-13.386	0.808	13.549
10	10	-10.845	-8.504	0.806	13.805

On the same tripod stand position was mounted tribrach with 3D scanner (see Fig. 3.). Recorded data (point of cloud) was handling with the Leica Cyclone software. In the next step from the point of cloud was isolated photo points (see Fig. 4.) and with the help of digital tool built in the software, distance between centres of photo point to scanner was measured and compare with total station data. Distance of point to scanner with calculated absolute and relative error was presented in the Tab. 2. Additionally, every recorded file contain a point of cloud data has ascribed 2D cylindrical picture poses during the scan (see Fig. 5.).

Fig. 3. 3D type laser scanner [18]

Tab. 2. Data obtained on the base 3D scan

No	Foto points	Vector length	Absolute error	Relative error [%]
1	5	18.036	0.059	0.33
2	1	19.354	0.318	1.67
3	2	19.413	0.150	0.78
4	4	19.458	0.084	0.44
5	7	10.539	-0.032	0.30
6	3	18.011	0.011	0.06
7	6	10.849	-0.035	0.32
8	9	7.768	-0.015	0.19
9	11	13.500	-0.049	0.36
10	10	13.775	-0.030	0.22

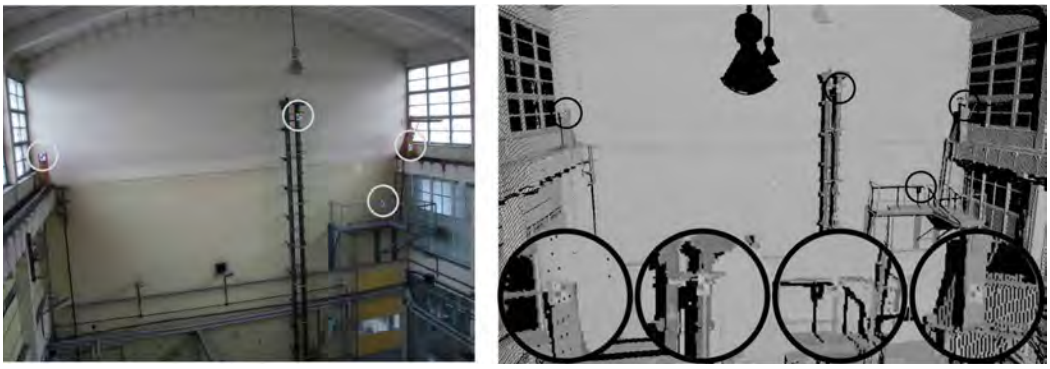

Fig. 4. From left: 2D photography - AGH UST Crane Laboratory hall with the photo points, 3D laboratory hall scan with visible photo points markers

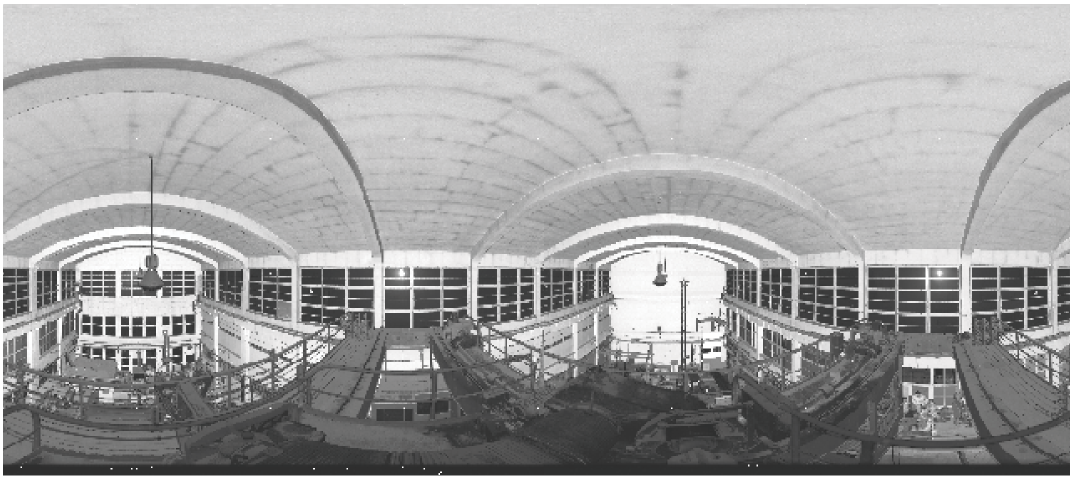

Fig. 5. Unfolding 3D structure to cylindrical 2D picture

3. Results and discussion

On the measurement base was created a graph combine the value of vector length measured with total station and laser scanner (see Fig. 5.). The vector length for total station was calculated with the relation (1):

$$\left|\vec{U}\right| = \sqrt{\left(B_x - A_x\right)^2 + \left(B_y - A_y\right)^2 + \left(B_z - A_z\right)^2}, \tag{1}$$

where:
A = (A_x, A_y, A_z) - vector start points,
B = (B_x, B_y, B_z) - vector end points.

Vector length of 3D scanner was calculated as a point to scanner dimension from software to point of cloud data analysis.

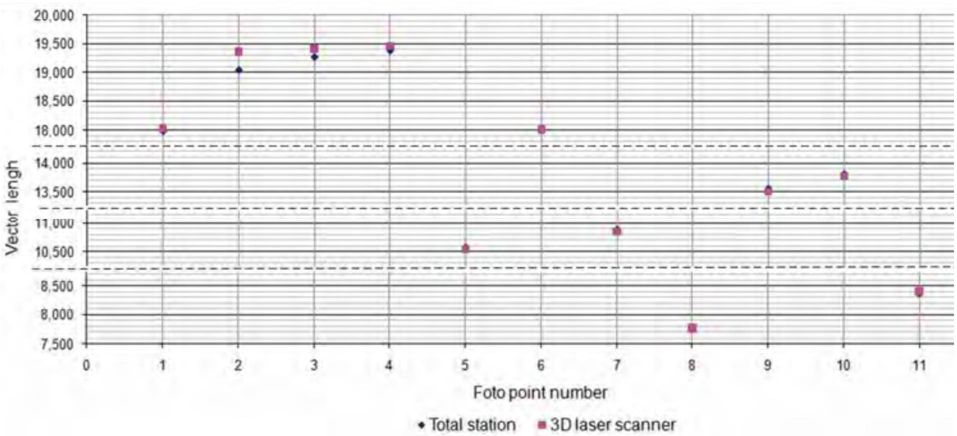

Fig. 6. Comparison between total station and 3D laser scanner measurement

The Fig. 6 obviously show that 3D scan exact map even difficult environment that is machine room with a lot of object. This fact confirm a need to conduct other research about use 3D laser scanner to supervising material handling devices work space, especially overhead travelling crane because 3D scan is very accurate (see Fig. 7.) and make perspectives for further research.

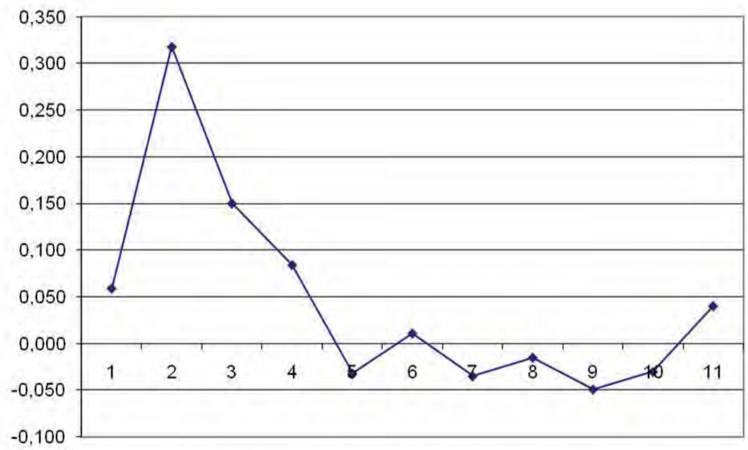

Fig. 7. Absolute error between 3D laser scanner and total station measurements

4. Methodology for object scanning with use point of cloud for surface segmentation

The huge amount of data included in point of cloud is cause to search method and especially algorithms enable fast and efficiency information processing [9, 10]. There is a variety studies combine's extract the 3D information on the base diverse technique. Some studies combine photogrammetric technique with laser matrix markers in the form of point or line [16], but point of cloud poses through laser scanning is natural set of matrix contains markers describes 3D scene. This chapter presents a specific methodology to obtain real surfaces from a huge scanned object at simultaneous reduction the data volume to processing. Using presented technique it is possible to extract 3D information in individual section, including parameters of depth.

Establish that a point of cloud contains only the point connect with scanning object (without any interference) we can give an approximation that is possible generated a set of surface areas reallocate regards them (see Fig. 8.)

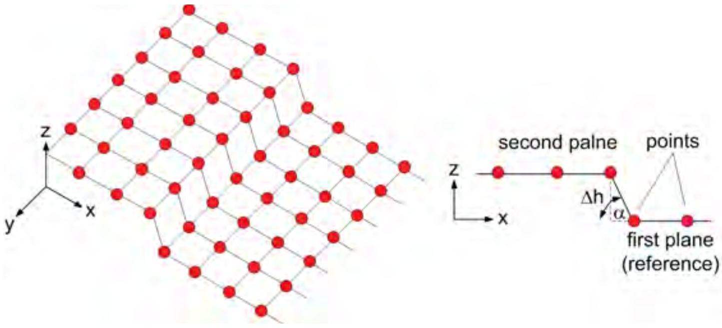

Fig. 8. Point of cloud data structure

Use property of partial derivatives the mathematical model of the presented point of cloud data structure is possible represent by set of equations (2):

$$\begin{cases} f_x^{'}(x_n, y_n) = 0, \\ f_y^{'}(x_n, y_n) = 0, \end{cases}$$

establishment that $(x_n, y_n) \in D$, where D is a open subset of plane and function f is twice differentiate and her second derivative is continuous with use of Hessian matrix transformation and Schwartz lemma it is possible to derive equation for local minimum and maximum of the presented planes (3):

$$\begin{aligned} & f_{xx}^{''}(x_n, y_n) > 0 \text{ co dla } \delta(x_n, y_n) > 0 \Leftrightarrow f_{yy}^{''}(x_n, y_n) > 0 \rightarrow \text{local minimum}, \\ & f_{xx}^{''}(x_n, y_n) < 0 \text{ co dla } \delta(x_n, y_n) > 0 \Leftrightarrow f_{yy}^{''}(x_n, y_n) < 0 \rightarrow \text{local maximum}. \end{aligned} \quad (3)$$

On the base model presented on the Fig. 8 was projected and constructed a laser scanning system with possibility scan only in one direction [16]. The heart of the system is laser line emitter mounted in the fixture with revolving arm (see Fig. 9.). The system works with laboratory double girder crane with max hoisting capability 150 kg and 2 meters span, localized in the Laboratory of Automated Transport Devices and Systems AGH University Science and Technology Krakow.

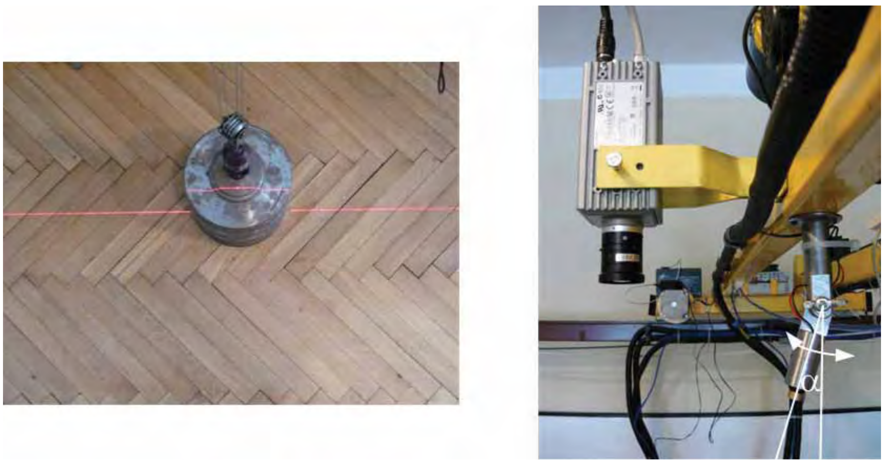

Fig. 9. A laser 3D scanning system operated in one surface

5. Conclusions

This paper describes an effort in transport means work space registration task. Presented methods and tools allow stating that 3D type laser scanner is very functional device in work space supervising for material handling device, especially overhead travelling cranes.

The develop and progress in automatic control and steering in transport means, especially material handling devices, foster to develop new methods and tools supporting them. Supervising the transport means work space [17] get possibility implementation more automatic solution for example mapping the work space of transport devices and enable to mark out the optimum grade-separated trajectory of transferring cargo in automatic mode with use a chosen algorithm [14] in real time.

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