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TRANSFORMATION OF POINT CLOUD INTO THE TWO-DIMENSIONAL SPACE BASED ON FUZZY LOGIC PRINCIPLES

Summary: The article describes the process and results of transforming a point cloud, obtained by scanning a particular object using line profilometers, into two-dimensional space using a selected method. The values in the image format obtained from the transformation are compared with the output from the software that is supplied with the used profilometers. The use of the described approach and methods are helpful in the process of finding out various parameters of selected objects.

Keywords: profilometers, point cloud, line scanning

TRANSFORMACJA CHMURY PUNKTÓW W DWU-WYMIAROWĄ PRZESTRZEŃ Z ZASTOSOWANIEM ZASAD LOGIKI ROZMYTEJ

Streszczenie: W artykule opisano proces oraz rezultaty transformacji chmury punktów. Chmurę punktów otrzymano poprzez skanowanie rzeczywistego obiektu używając profilometru liniowego, następnie była ona konwertowana w dwu-wymiarową przestrzeń za pomocą wybranych metod. Wartości charakterystyczne (format) obrazu otrzymanego po transformacji są porównywane z wynikami uzyskanymi przy zastosowaniu oprogramowania dostarczanego przez producentów profilometru (jako firmowe). Stosowanie opisanych ujęć teoretycznych oraz metod algorytmicznych jest przydatne do wyznaczania różnych parametrów analizowanych obiektów.

Keywords: profilometr, chmura punktów, skalowanie liniowe

1. Introduction

3D scanning is basically the process of analyzing an object or environment with objects in the real world and then creating a digital version of the object in the virtual world. One method is 3D scanning based on the use of line profilometers to scan

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the shape and surface of components. The result of such a process is a so-called point cloud, from which a realistic three-dimensional model can be acquired. However, in some cases, it is useful to create a two-dimensional image from the scanned data, as it is the case of the research described in this article. Such outputs can also be used for the application of another methods in process of solving various tasks, such as finding specific geometric or position parameters of the scanned object, processing acquired data by an algorithm for identifying certain elements, or comparing the values of determined parameters of the measured objects with the values of strictly defined standards. [1]

2. Data acquisition by scanning

The first step in the process of retrieving a virtual point cloud from a real object, is to scan it properly. During the described research, MICRO-EPSILON ScanCONTROL 2600-50 line scanner was applied for this purpose, whose basic parameters are listed in Table 1. [2]

Table 1. Line scanner MICRO-EPSILON 2600-50, used during the research and its basic parameters.

Model	scanCONTROL 2600-50
Reference resolution	4 µm
Resolution X-axis	640 points/profile
Scanning speed (Y axis)	Up to 300 Hz
Light source laser	Semiconductor laser 658 nm
Output/input	Ethernet

The scanCONTROL 2600-50 scaner operates according to the principle of optical triangulation. When a laser line is projected onto the target surface via a linear optical system. Then the diffusely reflected light from the laser line is replicated on a sensor array by the optical system and evaluated in two dimensions. During the scanning a row of lines are simultaneously illuminated by the laser line. Apart from the distance information (Z-axis), the exact position of each point on the laser line (X-axis) and also (Y-axis), which represents the acquisition of points at specific time intervals, are acquired and output by the system. [2,4]

During the scanning process, the used sensing device is mounted on a specially manufactured mount, which ensures its accurate positioning in the desired working range and at the same time secure its position during the entire data acquisition process. As a scanning object, a "caliber" for bead bundles of tires was determined. The object is made of steel, its outer diameter is 660mm and its height and thickness is 20mm. All dimensions are manufactured to an accuracy of 0.01mm. The "caliber" is located on the rotary table plate, and is driven in constant spinning movement by a motor FESTO EMMS-AS-70-M-LS-RS. The assembly used to attach the scanner and rotate the object while scanning, is shown in Figure 1. [3,5]

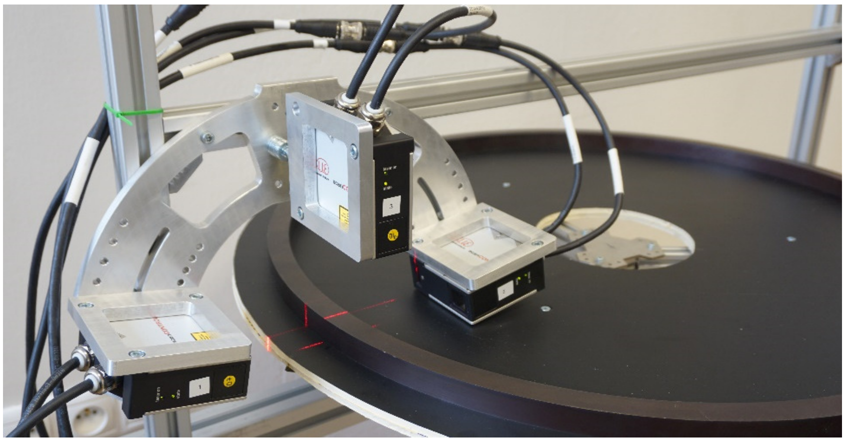

Figure 1. Assembly for attaching scanners and rotating the scanned objects.

During the measurement, the caliber is positioned and centered on the turntable so that it is always within the scanner's measuring range (Figure 1). Subsequently, the table performs two 360 ° revolutions at which the area in the scan range is captured. The signal received by the profilometer can be then sent via Ethernet to the computer for further processing.

3. Export and processing of acquired data

At the first step, scanCONTROL 3D View software was used to retrieve and partially process data from microepsilon scanners. Data processing options in this software are, for example, applying kernels and filters, which is suitable for the initial processing of information obtained by scanning an object. From the perspective of further data processing it is possible to export them into four basic data types:

- .csv
- .png
- .ply
- .stl

Within the described research for further data processing, a .csv file has been generated in which the points characteristics are stored. Each representation of a point is in the form of location information in cartesian space using the **x**, **y** and **z** coordinates. The main dimension defined as **z** characterizes the height, **x** represents the width, and **y** represents the collection of points at specific time intervals which allows to create cloud of points created from the line scan in the **x** and **z** axes. The second type of generated file is in .png format and result of this process is shown in Figure 2.

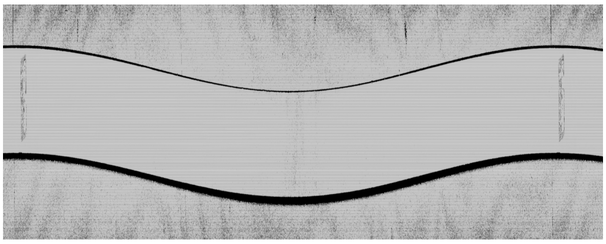

Figure 2. Image of the scanned object taken directly from the software ScanCONTROL 3D View.

This type of file is only for informative use due to inaccuracies occurred during scanning of the object's surface and due to representation and transformation of geometric information into a two-dimensional illustration. For this reason, the .csv file export has been selected as the primary data source.
The measurement that was performed consist of setting the two main scan parameters, which are the number of scanned profiles per second and the number of stored profiles in the software buffer. Value of scanned profiles was during the test set on 40 and number of profiles in buffer on 6400. As a result, the generated file consisted of 19202 lines. One row represented the scan information of one profile for a particular axis. Overall, there were 6400 lines for each axis. Subsequently, information ranging from 602 to 634 values was stored in each row, while 640 can be maximum number of values in one row. The maximum value is theoretical only, because it belongs only to the perfect recording of the reflected beam from the scanned surface. Exported values in .csv data format has been extracted and separated in the consideration of its affiliation. The first step was to transform information from the coordinates of the points in the **z** axis. The results are displayed as a .png image file in Figure 3.

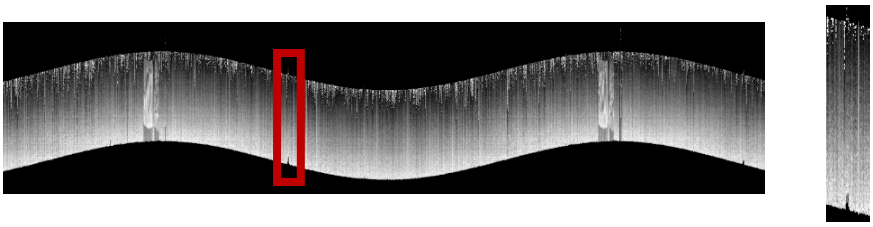

Figure 3. Transformation of inforomations from the coordinates of the scanned points in the z axis.

Information containing point cloud outside of the caliber was filtered out and only the values representing the surface of the scanned object were kept in the final visualization. The red framed detail in the Figure 3, shows the offset of the scanned object's value caused by the way data is exported in a .csv file, where all data is aligned to one side. If the number of scanned points in one line is less than the maximum number of scanned points per line, there will be a visible shift in the values. The position of the points in the line is defined in the section containing the values for the **x**-axis. For this type it is necessary to sort all values of points with respect to value of **x**-axis in data. For each row, this step was accomplished by distributing values to a particular row by defining values obtained by applying the fuzzy logic principles. The number of values contained in the data for the **x**-axis was 21444, which were subsequently sorted into 640 positions. After this alignment, the data representing the z values was again visualized, considering the positions of the **x** values.

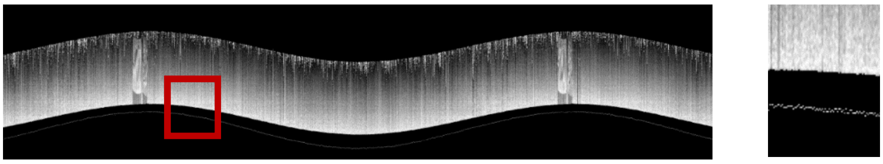

Figure 4. Output in .png format after sorting and ordering values

When comparing Figure 3 and Figure 4 it is more than clear that the values have been classified. However, at this step a reflection appeared in the data which is displayed by a thin line of white pixels copying the shape of the scanned object. This this undesirable part of output image was subsequently removed in the next step. For such data, it was already possible to determine the mean value for the caliber axis, on the basis of which the eccentricity due to the positioning of the caliber was calculated in a manner where the caliber axis was not in the coincidence due to the position of the axis of the rotary table platform.

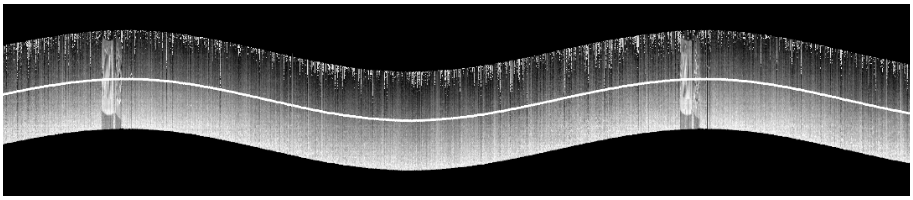

*Figure 5. Axis of caliber calculated from **x**-axis data.*

In Figure 5 the axis for which values from the **x** data component were calculated. After sorting the axis values and comparing them with defined zero reference, the eccentricity was calculated where the arithmetic mean of the twenty furthest values from the zero level was calculated. The resulting maximum eccentricity value obtained by the described approach was at the value of 3,451 mm.

4. Conclusion

In this paper a system of scanning and evaluation of caliber eccentricity for measuring devices was created. As the measurement approach was chosen to create point cloud by scanning with the ScanCONTROL Compact 2600-50 line scanner. At the same time, software from microepsilon, 3D-view was used for the purpose of the data acquisition in the .csv files. This data was subsequently processed to filter out unnecessary elements of the data and classify it with respect to the information obtained in the .csv file. The sorted and modified data could then be used to calculate the eccentricity of the caliber location relative to the axis of rotation of the table on which it is situated. This experiment serves as a base material for inspection equipment to compensate inaccuracies arising from surface scanning and measurement characteristics.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0283

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