

Design of laser scanners data processing and their use in visual inspection system

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Abstract. Visual product inspection is an important element, whether in-process or output product inspection in today's industry. The present paper describes an approach to the visual inspection, based on the usage of line laser scanners. Their task is to obtain coordinates of individual geometric profile elements of the scanned object in the form of raw data in .csv output. Paper also describes design of processing and sorting of these raw data using fuzzy logic basics and creating output from this data in a format suitable for subsequent processing using neural networks. In order to enable the subsequent evaluation of the processed data and the visual representations generated therefrom, a procedure for combining the individually obtained images of the surface of the rotating object into a single linear image is also proposed. The described procedure can accelerate and simplify the whole process of visual inspection of determined objects.

Keywords: Visual inspection, Laser scanners, Image processing

1 Introduction

Visual inspection, whether direct or indirect, is one of the valuable tools of non-destructive product inspection methods. Visual inspection with appropriate lighting is often one of the first methods for detecting and locating suspect areas on inspected objects. In the past, it was a highly subjective approach to quality control and there was no documentation to describe its progress. The success of the result depended mainly on the trained operators, the cleanliness of the environment, the properties of the test object, the quality of the optical devices and the correct illumination (when using an industrial camera as recording device) of the area of investigation. These parameters are of course very important even today, but the equipment used is much more sophisticated. Visual inspection is one of the basic methods of non-destructive testing. In the visual inspection process, the worker follows the prescribed procedures, which can range from simple inspection of objects with the naked eye to detect external defects to the performance of various measurements to ensure compliance with the required standards. Nowadays, optical systems, where possible, include real-time imaging and various analysis using computers. [1, 2, 3]

The first step to enable visual inspection with analysis using a computer program is to obtain the input data correctly. Different types of files can be used as input data, where in visual inspection, as the name implies, this data will be in the form of a visual representation of the scanned object or its selected parts. [4]

2 Capture method and data export

In the research described in this paper, line laser scanner was chosen to capture the surface of the selected object. The object to be scanned is an automobile tire (Fig. 1.), in the described case specifically its sidewall. A micro epsilon scan-CONTROL 2600-50 device, with resolution up to 640 dots per line was used to scan the product. Scan-CONTROL Configuration Tools and 3D View software was used along with this line scanner, which is an interactive 3D visualization software designed for displaying and exporting 3D captured data during the scanning, supplied directly by the manufacturer. [5]

Table 1. Achieved scan resolution.

Resolution	Value [mm]
Axis x	$\approx 0,100$
Axis y	$\approx 0,060$
Axis z	$\approx 0,004$

Mentioned sensors operate on the principle of triangulation, in which they can provide a resolution capability in the z-axis up to 0.004 mm. This value represents the resolution of the sensitivity of the sensing point from the device sensor (Fig. 1.).



Fig. 1. The scanned object and detail of the selected area during the scanning process.

The captured data was exported from Microepsilon 3D View in two data file types. As pictures in .png format (Fig. 2.) and also in the form of coordinates of individual points

saved in .csv format. The .csv file contains the position of the individual scanned points of the scanned object profile in the Cartesian coordinate system in the x, y and z axes (Fig. 1). The exported .png format serves for a basic illustration of the surface that has been scanned and stored in a specific .csv file.

3 Processing of data from scanning

The obtained .png files were used to illustrate scans of the tire surface while the data source for further processing was the .csv file.

For generating the visual content, the z-coordinate of the points obtained from the scanning was used. One scan contained approximately of 15.5 mil. points classified in 25000 lines aligned in the y-axis with the number of scanned points per line ranging from 580 to 630. During scanning process, 11 images of individual tire sidewall portions were taken, as shown in Fig. 2.

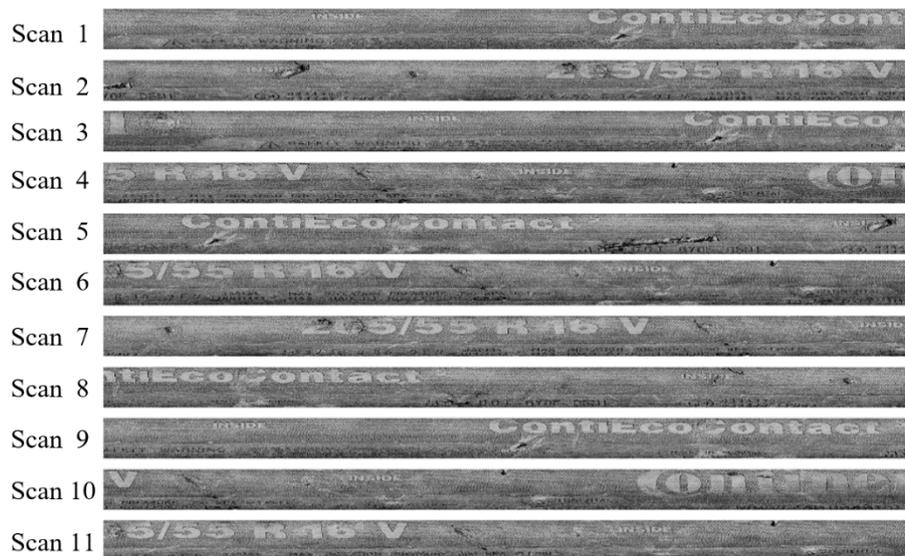


Fig. 2. Illustrations of the tire surface generated by the software from the scanner manufacturer.

These scans are generated by micro-epsilon software that offers a basic visual preview of the scanned surface. In this case, the output data does not contain geometric information, it is only a 2D representation of a surface scan with resolvable geometric shapes.

When processing data in .csv format, the image was first generated from an unclassified point cloud. Described algorithm is based on the generation of images based on raw z-axis data to produce an image with a high degree of interference as it is displayed in Fig. 3. [6, 7, 10]

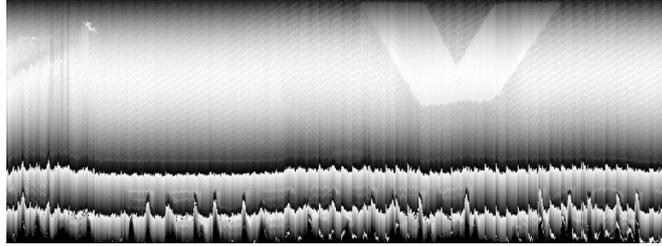


Fig. 3. An image generated from raw z-axis data with a high degree of interference.

In order to achieve the desired image quality and to allow further work with data, it is necessary to sort the image into a 640 x 25000 matrix. The value of 640 is characterized by a maximum number of points scanned in a line (x-axis) and the value of 25000 indicates the number of such lines which are consecutively scanned (y-axis). The points were classified using x coordinates of each point and its position definition in the x coordinate were continuous values from -25 to 27 mm. The classification was performed using fuzzy logic principles, which determined the position of individual points based on the overall scan. Subsequently, this image was generated and is shown in Fig. 4., in which the detectable geometry of the tire scan is suitable for further processing.

By further processing is meant the possibility of utilization associated with the application of neural networks and pre-trained algorithms for detecting areas of interest or text recognition. Another approach is to use a comparative method to compare etalon data and a scan of the controlled product. The checked product can be searched for anomalies, or differences with respect to the etalon sample. In this case, the method of detecting anomalies was chosen because of its universality and verification of the theory where emphasis was also placed on finding errors or objects that are not commonly encountered in practice or that the system has not yet encountered.



Fig. 4. The processed image generated from the sorted scanned data.

The sorted image shown in Fig. 4. is further processed. The main feature of this state of processing is the recognizable tire sidewall surface geometry. Another assumption is to scan the entire product. The problem was the hardware that did not allow to capture more than 25,000 lines. In this case, attention was directed to the number of scans per second, with approximately 250 scans per second, when this number actually fluctuated around the specified value. As a result, mentioned parameter was set based on a compromise between the scan time (approximately 170 seconds) and the result image resolution and sharpness. In this way, the amount of line scans obtained was not sufficient

to scan the entire tire due to the mentioned hardware limitations. The creation of a complete scan had to consist of combining several scans into one. The resultant image was created by combining scans 1, 2 and 4 as shown in Fig. 2. Scan number 1 was set as a base to which scan number 2 and then this continuous image was supplemented with a portion of scan 4. The connection was made on the principle of pairing of border areas of 2000 lines. Defining a match was by looking for a global minimum (1).

$$E_{min} = \sum(a_i - b_i)^2 \quad (1)$$

Individual scans were connected to each other on the basis of such a match. The scan boundaries are shown in fig. 5, where scan 2 and scan 4 were combined and as a result a continuous scan of the entire perimeter of the tire sidewall with a smooth transition was created.

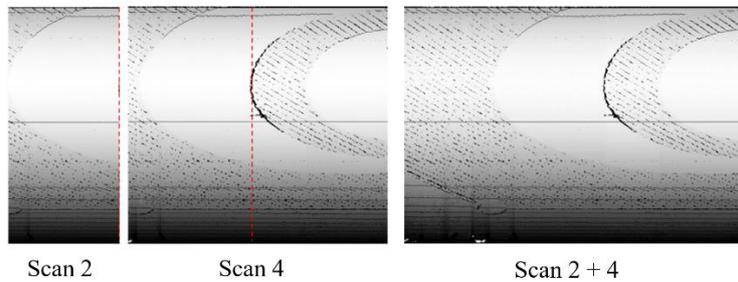


Fig. 5. Preview of continuous scan created from partial scans 2 and 4.

Scan 1 was added to the continuous scan, where only the missing area was added to the parts from scans 2 and 4. Because of the completion, it was necessary to determine the boundaries from both sides of the scan and add this part to the continuous scan 2+4. produced a continuous 1+ 2+ 4 scan. The final continuous scan is then suitable for detecting anomalies in the geometry of the inspected object, which may be deemed inappropriate under predefined conditions and thus affect the overall quality of the inspected product. Anomaly highlighting is generated by comparing etalon data that is guaranteed to be error-free and inspected data that has a certain probability of error.

Before comparing an etalon and an inspected sample, it is necessary to locate and pair the selected area on both scans. When a match is found, it overlaps and produces an image with highlighted differences. Due to the non-constant scanning of the points, microscopic displacements occur, especially at the border regions. Another non-constant value is the scanned edges in the run-in area in the product rotation direction. At these parts of the geometry, the beams reflected at the wrong angle, which meant that the geometry points forming some of edges were not sensed. These are depicted as black areas in the images. The areas highlighted in this way do not match when compared and thus create line differences in the compared image, which are filtered for better entity contrast. As a result, only the difference area with a larger pixel cluster is highlighted than the 4x4 pixel filter applied. [8, 9,12,13]

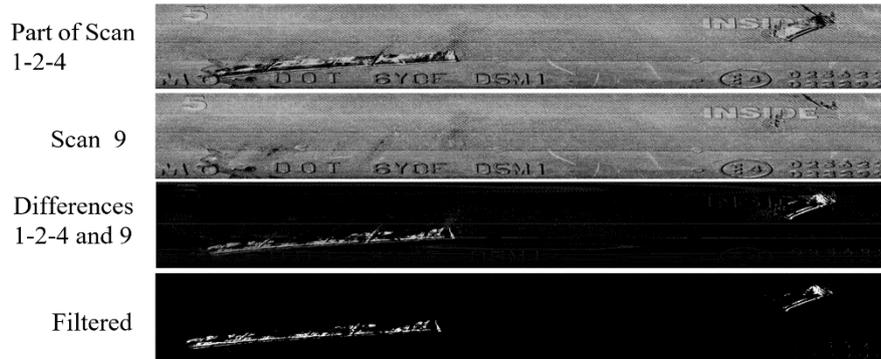


Fig. 6. Demonstration of anomalies occurring on the scanned object.

In Fig. 6. Two specific areas with geometric differences that indicate a possibility of anomaly are highlighted in white. In this case, the scanned object would be evaluated as failure, if it were an application directly in industry. Subsequent to categorizing the product according to the type and severity of the defect found, an evaluation would be made as to whether the product is suitable for repair and there is possibility to eliminate the defects or be suitable for being completely eliminated from the manufacturing process.

4 Conclusion

Visual inspection as a non-destructive method of product control is one of the basic method of detecting external inaccuracies. The article presents a way of finding and highlighting anomalies on a specific object with specific properties, which is an automobile tire and its sidewall in particular. The described method of obtaining data for further processing is based on the surface scanning with a line laser scanner. From the point of view of further processing of acquired data, it is possible to create the system in two different ways. First is an intelligent fault-finding using trained artificial neural networks, and the other is a comparison method between an etalon and inspected object. When using a system with trained artificial neural networks, certain learned objects are searched, but it is difficult to identify a new, unknown object for the system. In the comparative method, the system is resistant to the occurrence of unknown anomalies. These anomalies are highlighted without the system being adapted to look for specific types of geometric anomalies. Differences in images can mean two possible states, either an anomaly or entities occurring on the object, but which do not have a constant position for each product. The limitation of this system is the compromise between scan quality, scan time and computational performance of evaluation hardware. With the sensing parameters set, satisfactory resolution (Table. 1.) in the z and y axes was achieved, but these parameters were limiting the resolution in the x axis. Increasing the resolution in the x-axis would be possible by scanning a smaller product width or by using different scanning device with a higher number of scanned points.

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