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AN ATTEMPT TO EVALUATE THE APPLICATION OF 3D SCANNERS IN CONSTRUCTION DIAGNOSTICS AND TESTS

PRÓBA OCENY MOŻLIWOŚCI ZASTOSOWANIA SKANERÓW 3D W DIAGNOSTYCE BUDOWLANEJ I BADANIACH

A b s t r a c t

For over a decade there has been a rapid development of technology in the construction of 3D scanners, resulting in increased precision, speed and reliability. The scope of their application has also been continuously extending. This paper describes possible applications for 3D scanners in construction measurement and evaluation. The uses described include measuring concrete surface roughness and surveying architectural details.

Keywords: scanner 3D, optical triangulation, time-of-light, surface topography

S t r e s z c z e n i e

Od ponad dekady notuje się burzliwy rozwój techniki w zakresie budowy skanerów 3D, które charakteryzują się coraz większą precyzją skanowania, szybkością i niezawodnością. Stale zwiększa się też zakres ich stosowania. W artykule omówiono przykłady możliwych zastosowań skanerów 3D w pomiarach i diagnostyce budowlanej. Przedstawiono pomiar chropowatości powierzchni betonu oraz inwentaryzację detali architektonicznych.

Słowa kluczowe: skaner 3D, triangulacja optyczna, czas przelotu, topografia powierzchni

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1. Optical methods of coordinate measuring

3D scanners allow non-contact measurement of the geometry of spatial elements. For over a decade there has been a rapid development of technology in the construction of these devices. This is possibly thanks to the fast development of electronics, especially optoelectronics and the progress in microprocessor technology (increase in computing power). 3D scanners use light as information carrier for measured sizes. They are based on measuring the reflection or scattering of light from the surface of the examined object. Optical measurement methods used in 3D scanners can be divided into passive and active ones [1]. Passive methods (e.g. photogrametry) do not require any additional, artificial source of light. However, these are the methods of giving small measurement resolution. Active methods are based on the use of an additional, artificial light source (projectors, lasers) by means of which different kind of structure points, lines, patterns (Fig. 1) or coded patterns [2] are displayed on the surface of the tested element. The most commonly used active methods are: the method of time-of-flight (TOF), structured light projection, laser triangulation method, a laser tracker system or moiré projection.

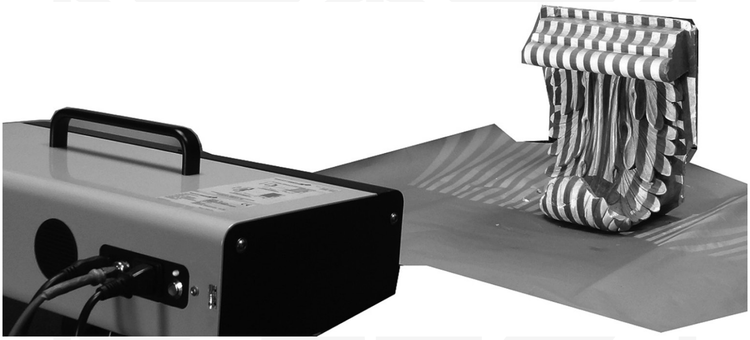


Fig. 1. Projection of stripes on the scanned object. Scanner: Smarttech Surface Scan3D

TOF and laser triangulation methods use the light emitted by the laser so they can be used to measure large and distant objects – ranging up to 2 km. The TOF method uses precise measurement of time between the emission of light impulse and its return, which allows to record the distance between the measured point and the measuring device. The laser triangulation method uses a picture (points, stripes) which is displayed by the laser on the surface of the measuring element. The methods based on structured light allow the measurement of smaller objects due to low energy efficiency of light sources used.

1.1. The principle of measurement methods based on the structural light

Scanners using structured light are characterized by a simple structure and high accuracy. The device consists of two basic components: a projector and a camera. The projector displays the characteristic raster pattern (stripes, waves, circles) [3], which distorts the uneven surface of the measured object (Fig. 2).

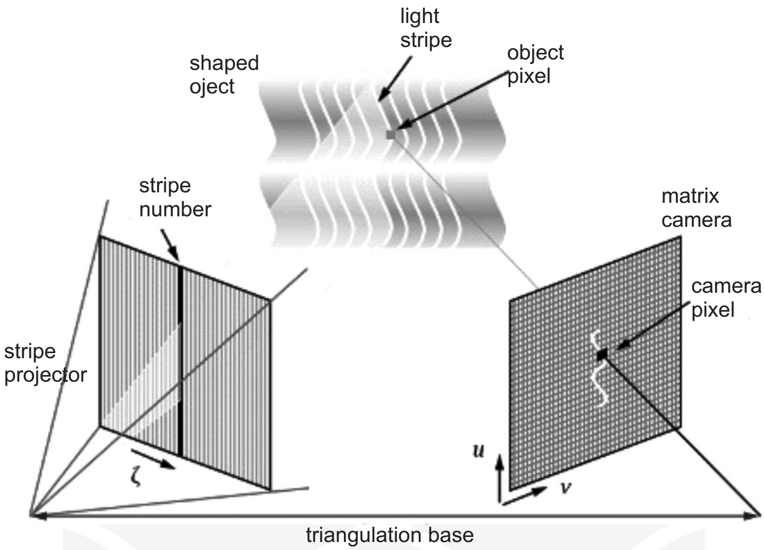


Fig. 2. The measuring principle based on the structured light [4]

In the image registered by the light-sensitive matrix of the camera, a thrown pattern is discovered. On this basis angles in a triangle formed by the camera, projector and scanned point of the object shall be calculated. Knowing the distance between the camera and the projector the location of a given point in space can be determined.

1.2. Description of 3D scanner selected for testing

In measurements of small objects, scanners, whose operation is based on structural light can be used. Currently, manufacturers use in their devices the LED light of different colors (white, blue, green). Regardless of the type of the light used, scanned objects cannot be exposed to other strong light sources. It is one of the drawbacks of this type of equipment. In further studies a scanner **Smarttech Surface Scan3D** of white light technology has been used. The resolution of used matrix is 10 megapixels which enables the measurement, in one cycle, of about 10 million points. The scanner has an uncertainty of measurement at the level of 0.015 mm. Scan resolution is 0.05 mm. The constant measurement volume (x, y, z) is 200 mm × 150 mm × 120 mm. The use of constant measurement volume and closing projector and the camera in a compact, rigid casing allows a single calibration. There is no need to calibrate the scanner before each measurement. The certificate issued by an accredited laboratory confirms the scanner parameters.

2. The use of 3D scanners in the studies

The primary use of 3D scanners is in reverse engineering and quality control of products. However, they were widely applied in many other areas. In the construction industry they are most commonly used in the inventory and digitization of objects and architectural details (Fig. 3). This allows to control the movements of the objects and the evaluation of destructive changes in materials exposed to aggressive environment. In the future, it will be possible to restore damaged objects with high accuracy.

a) b) c) d)

Fig. 3. Stages of the inventory of architectural details: a) the effect of the stripes on the object, b) point cloud, c) render, d) triangle mesh

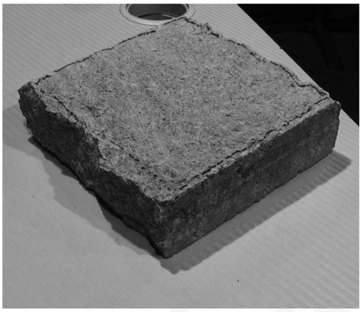
In laboratory studies, in the field of construction, 3D scanners have been used among other things in the measurement of material defects due to destruction during destructive testing (fire resistance, frost resistance, durability), in assessing the scratch of concrete elements, in the measurement of deformation of the structure and its elements subjected to load and in 3D thermography. The author proposes the use of 3D scanners for measurement of the surface topography of concrete surfaces that require fixation with a new concrete.

2.1. Measurement of the surface topography of concrete

The strength and durability of anastomosis of two concretes at different age groups depends on many factors. One of them is the preparation of the old concrete surface which can be achieved by various methods (sand blasting, shot blasting, chiseling etc.). This results in the different surface topography, which influences the strength of anastomosis [5]. The parameters describing the surface topography are discussed in standard ISO 25178:2 [6]. The list of these parameters is presented in Table 1.

For initial assessment of the potential use of a 3D scanner on white structural light for measurement the surface, a topography test was carried out on a small concrete element of which one surface was prepared by chiseling (Fig. 4). The point cloud obtained as a result of measurement was converted in Geomagic software so as to obtain the orientation of the coordinate system required by the standard [6]. At the same time a part of the cloud of points representing an area of 50 mm × 50 mm was isolated. The isolated part of the point cloud was imported to the CPP software, a custom program enabling the analysis of surface topography according to the ISO 2517:2 standard. The calculations obtained with the CPP software were compared with MountainsMap [7], a commercial software with similar application. The calculation results are shown in Table 1. Fig. 4b shows the graphical representation of the measured surface obtained in the MountainsMap.

a)



b)

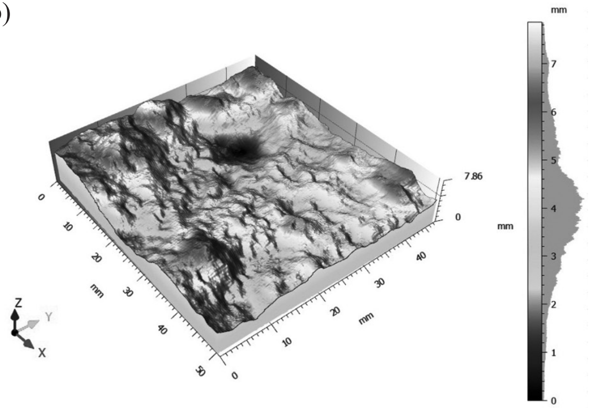


Fig. 4. a) a photography of a concrete sample testing, b) a graphical presentation of the surface obtained in the program MountainsMap

Table 1

Parameters of the surface topography according to ISO 25178: 2 derived from the measurement by 3D scanner

Symbol	Parameter	Value MM	Value CPP	Unit	Diff. [%]
Sq	Root Mean Square Roughness	1.25	1.23	[mm]	1.34
Ssk	Skewness	0.157	0.154	–	1.76
Sku	Kurtosis	3.29	3.22	–	2.21
Sp	Maximum Peak Height	3.77	3.77	[mm]	0.00
Sv	Maximum Valley Depth	4.09	4.09	[mm]	0.00
Sz	Maximum Height of Surface	7.86	7.86	[mm]	0.00
Sal	Autocorrelation Length	6.73	6.63	[mm]	1.45
Str	Texture Aspect Ratio	0.282	0.279	–	1.22
Sdq	Root Mean Square Surface Slope	0.492	–	–	–
Sdr	Developed Interfacial Area Ratio	10.8	–	[%]	–

3. Conclusion

A dynamic development of technology in terms of optoelectronics and microprocessors enables wide application of 3D scanners, also in research in the construction sector. The measurement results in the form of a cloud of points, obtained with a scanner using white, structural light, are correctly processed by custom and dedicated software for determining surface topography parameters according to ISO 25178:2. The results obtained in both programs are comparable, and the difference in results does not exceed 3%. Therefore, it is possible to use 3D scanners to test the surface of concrete prepared for reinforcement with new concrete, and the application of custom software makes it possible to obtain reliable results.

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