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RevoScan – Automatic Device for 3D Digitisation: Concept, Application, Test Results**

1. Introduction

For several years there has been a dynamic development of services in areas related to the digitisation of objects of different sizes both for museums as well as computer games, films, advertising etc. Digitisation of 3D objects is a relatively new area of services, the development of which began several years ago with the advent of laser scanners, dissemination of digital photography and the growth capabilities of graphics software and hardware.

Digitisation of 3D objects is a branch of technology and services developed all over the world and implemented in cultural institutions [3], advertising, film, and computer games. During the studies conducted in Bosnia and Herzegovina [3], it was found that more than 70% of respondents believe that the idea of virtual museums is "good", and 76% wanted to have access to 3D objects in virtual museums. However, the same authors indicated two main obstacles for the development of virtual collections: the difficulty in creating virtual reality and the costs of the technology. The same problem is also raised by other researchers [4] who, at the same time, note the problems related to the features of the objects to be digitalised such as surface colour, texture or gloss [4]. The solution to this problem is maximum automation of the performed works, using advanced algorithms for acquiring orientation, filtration of data, and texturing of the obtained 3D models [4].

Currently, the process of digitisation of museum collections is carried out through the use of multiple sub-processes from various fields, starting from scanning with terrestrial laser scanners used in industry and land surveying, monochromatic and structured light scanners, manual acquisition of high-resolution digital photos, through to time-consuming processing of acquired data (photos and point

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clouds), optimisation of the obtained data, and integration of the image data with geometric data, to final visualisation of the object and its publication. This involves the need to use multiple devices and computer programs, repeated export as well as import of data to and from a variety of programming environments. It is a complicated process that requires expertise in many areas, access to a variety of hardware and software, and above all it is time-consuming and expensive. Many publications include proposals of digitisation solutions [4], specific examples of digitisation works [2], and an analysis of their accuracy [1].

Between 2013 and 2015 Terramap Sp. z o.o. conducted the research project "Development of an automatic device for digitisation of historic and industrial objects" which received financial support from the Operational Programme Innovative Economy 2007–2013, action 1.4 – Support of Targeted Project. The result of this project is a measuring device for 3D digitisation that enables data acquisition and processing. A characteristic feature of this system is the automatic acquisition of information about both object geometry (spatial digitisation) and the colour information in the RGB colour space (high resolution digital photos). Dedicated software for the device allows for the scheduling and controlling of the process of data acquisition, processing and development of materials ready for presentation. The advantage of the developed system is a significantly shorter digitisation time, which directly contributes to reduced unit costs of digitisation.

2. General Description of the Device

The project's goal was to build an automatic measuring device for the digitisation of objects of small dimensions which would allow acquiring and processing of data on the colour and geometry of such objects. The industrial research and development works were carried out on the automation processes of digitisation of 3D objects using digital close-range photogrammetry (including spherical photography) and terrestrial laser scanners.

The project involved an examination of the entire process of digitisation of objects of small dimensions, starting from the acquisition of spatial data on the object, through to processing of such data, to the publication of a virtual model of the object.

The assumption made at the early stage of concept works was that the device should ultimately have the following main functionalities:

- automatic acquisition of high-resolution digital photos (ground pixel 0.1–0.3 mm) with information on the camera calibration and georeference of photos written as metadata;
- automatic object separation, resistant to the blending effect on shiny objects (effect of the background blending into the object);
- quick, automatically generated object visualisation in the form of a set of "all-round", separated photos in the range of 0–90°;

- attaching the information from the object record in the case of a museum object;
- automatic creation of the metric 3D model of the object in the form of a “mesh”, with optional process supervision by a qualified operator;
- automatic texturing of the obtained 3D model, with optional process supervision by a qualified operator.

The device consists of the following components (Fig. 1):
- rotary table with a glass top,
- two measuring columns allowing the camera movement in the horizontal and vertical plane,
- camera head with an option to set the camera angle relative to the table,
- digital camera with a movable polarisation filter,
- background which is the source of polarised light,
- light tent,
- set of photographic lights, constant and flash,
- control module (controllers of servomotors and stepper motors),
- software controlling data acquisition and processing.

Fig. 1. View of the device

A computer-controlled rotary table with the 800 mm diameter glass top accommodates objects of a maximum horizontal dimension of 600 mm, height of 1000 mm, and weight up to 50 kg. The tabletop position control system allows for the setting any angular sequence for the table in the 0–360° range.

The measuring columns are made of steel, aluminium and components printed in the 3D technology. Along with the camera head allowing to incline the lens axis relative to the tabletop, the columns make it possible for the camera to take up any position in space in relation to the digitised object. Their design and rigid connection with the table ensure that the camera finds the required position in space with high accuracy. As a result, when used with the calibrated photographic set (lens + camera) the internal and external orientation elements are known for each photo, which speeds up the data processing and improves the quality of 3D modelling.

The technology of separation of the object from the background which was developed for the device is based on light polarisation and an application for the invention has been made to the patent office. Using a polarised light source (currently LCD TV-sets) and a movable polarisation filter (Fig. 2), we have developed an object separation algorithm resistant to the blending effect which often occurs on shiny objects when other separation technologies are used (e.g. greenbox).

Fig. 2. Movable polarisation filter unit

The device is equipped with the Nikon D800 digital camera featuring the 36 Mpix matrix, and a set of fixed-focus lenses with focal lengths of 28 mm, 35 mm, 50 mm, 85 mm, and 105 mm. In the current configuration it ensures the withdrawal distance from the table axis of rotation up to 1.15 m in the horizontal plane, and up to 1.20 m above the tabletop level. The minimum photographing distance is limited by the focusing capability of the lens used. The geometrical arrangement of the table, measuring columns and camera head makes it possible to take photos in any position in the hemisphere containing space from the tabletop level to the nadir lying in the table axis of rotation.

3. Control Software

In the basic configuration the device measures real objects in the form of a sequence of spherical, cylindrical or elliptical photography, depending on the geometry of the digitalised object and the operator-defined “approach plan”. It is also possible to manually define the camera position within the operating area for a single photo. Optionally, it is also possible to rotate the vertical column by 90° and take photos in the classic photogrammetric arrangement with the set longitudinal or transversal coverage. This option can be used to digitise objects such a paintings or reliefs lying on a table or hanging on a wall.

The device control software has the following functionalities:

- design management module – proprietary software, integrated in the system;
- camera calibration data storage module – proprietary software, integrated in the system;
- photographing design preparation module – proprietary software, integrated in the system;
- photo exposure control module – proprietary software, integrated in the system;
- photo taking control module – proprietary software, integrated in the system;
- colour calibration module – based on a third-party software, integrated with proprietary software;
- automatic module for the separation of objects from the background, resistant to the blending effect – proprietary software, integrated in the system, using the polarisation phenomenon; the module was developed on the basis of a patent application WYN 404917 of 30.07.2013 "Method of separating objects from the background for digital images with the use of polarised light and the system for implementation of such method";
- automatic object visualisation module – proprietary software, integrated in the system;
- object metadata module – proprietary software, integrated in the system.

In addition, proprietary software packages were developed for the device and are used to build 3D models of digitalised objects on the basis of the acquired material.

4. Results of the Device Tests

A series of prototype tests were conducted within the R&D project in terms of the mechanics, control, control software and data processing software. The process of data acquisition, making the object masks and preliminary visualisation now takes between 60–120 minutes, dependent on the complexity of the object geometry and the number of designed pictures. The process of object separation from the background is correct for most objects, and the obtained masks are free of errors and artefacts (Fig. 3).

The tests of data processing software developed during the research project proved the software to be effective in both generating a dense cloud from the photos, a model in the form of a triangle mesh and a textured photorealistic 3D model (Fig. 4).

Simultaneously with the tests of the proprietary software, we ran the tests of applying the Agisoft PhotoScan Professional software to generate 3D models from the dataset acquired by the device prototype. A fully automatic processing with the use of a batch file was prepared for the acquired data. The quality of the generated 3D models (Fig. 5) justifies the conclusion that: "A device for fully automatic digitisation of 3D objects has been developed."

Fig. 3. Object mask and the object automatically separated from the background

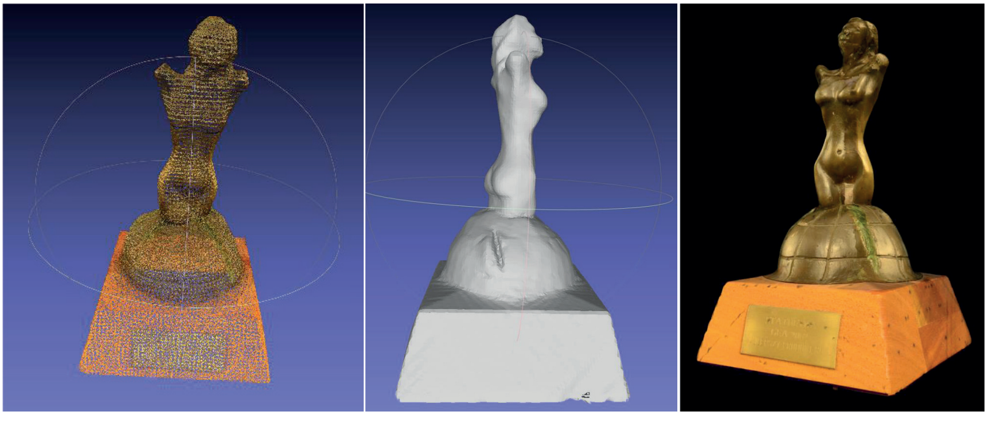

Fig. 4. Results of operation of the 3D model algorithms implemented within the research project

Fig. 5. 3D models automatically generated on the basis of data from the device prototype

The last stage comprised the verification of the geometric quality of the obtained 3D models. This involved the comparison tests of 3D models obtained by means of the device and models obtained with the use of the NextEngine and ArtecEva laser scanners. The surfaces were compared using the 3D Compare tool available in the Geomagic Control program. Depending on the type of scanned surface, the surface standard deviation was 0.2–0.3 mm.

5. Summary

At present the full measuring efficiency of the device has been reached and implementation works are underway to optimise the digitisation process of 3D objects. Thanks to automation, the digitisation process of 3D objects has been considerably shortened and the manual operations have been reduced to a minimum. This has significantly improved the productivity and reduced the unit costs of 3D digitisation.

The device will be used in the digitisation services performed by Terramap sp. z o.o. and will also be marketed to other businesses and institutions under the brand name RevoScan. The target customers are digitisation studios, the advertising and film industries, and computer games manufacturers.

References

[1] Fassi F., Fregonese L., Ackermann S., De Troia V.: *Comparison between laser scanning and automated 3d modelling techniques to reconstruct complex and extensive cultural heritage areas.* [in:] *3D-ARCH 2013 – 3D Virtual Reconstruction and Visualisation of Complex Architectures, 25–26 February 2013, Trento, Italy*, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XL-5/W1, 2013, pp. 73–80.

[2] Menna F., Rizzi A., Nocerino E., Remondino F., Gruen A.: *High resolution 3D modeling of the Behaim Globe.* [in:] *XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia*, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXIX-B5, 2012, pp. 115–120.

[3] Rizvic S., Sadzak A., Ramic-Brkic B., Hulusic V.: *Virtual museums and their public perception in Bosnia and Herzegovina.* [in:] *ISPRS Trento 2011 Workshop, 2–4 March 2011, Trento, Italy*, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXVIII-5/W16, 2011, pp. 421–427.

[4] Shunyi Zheng, Yang Zhou, Rongyong Huang, Langming Zhou, Xuan Xu, Chengyi Wang: *A method of 3D measurement and reconstruction for cultural relics in museums*. [in:] *XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia*, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXIX-B5, 2012, pp. 145–149.