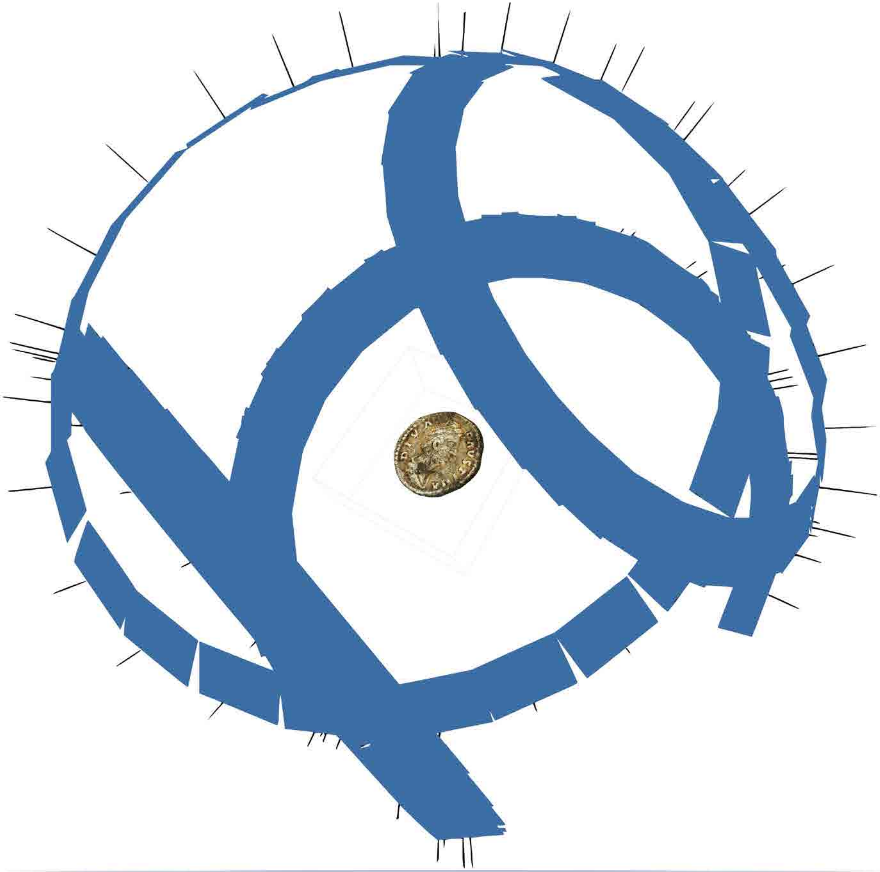

Collection Development, Cultural Heritage, and Digital Humanities

DIGITAL TECHNIQUES FOR DOCUMENTING AND PRESERVING CULTURAL HERITAGE

Edited by **ANNA BENTKOWSKA-KAFEL** and **LINDSAY MacDONALD**

ARC HUMANITIES PRESS

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DIGITAL TECHNIQUES FOR DOCUMENTING AND PRESERVING CULTURAL HERITAGE

COLLECTION DEVELOPMENT, CULTURAL HERITAGE, AND DIGITAL HUMANITIES

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STRUCTURED LIGHT 3D SCANNING

DIRK RIEKE-ZAPP and SANTIAGO ROYO

COSCH Case Studies that have employed this technology: Roman Coins, Kantharos, White Bastion

Definition

Structured light 3D scanners project a known pattern of light (stripes, dots), typically regular and periodic, onto the object. The result is captured using one or more cameras, and the 3D information of the object is recovered by software using different triangulation or projection geometries. Very dense and accurate point clouds may be obtained. The configuration and approach used enables adjustment of the surface resolution, using multiple exposures, or adjusting the field of view of the system.

Description

A structured light 3D scanning system is non-contact and consists of a projector and at least one camera. Data acquisition and analysis are controlled by dedicated software running on personal computers; both are integral parts of the measuring system. The calculation of 3D data is based on the triangulation principle; typical triangulation angles are approximately 30°. The camera is mounted in a calibrated position relative to the projector, and the scanning system projects light patterns onto the object surface. The contrast of the light patterns influences the quality of scan results. Therefore, working in direct sunlight is often not possible or advisable. For good results, working indoors or in shaded areas outdoors is recommended. Scanning of reflective or (semi-)transparent surfaces is problematic for any optical scanning system. Difficult surfaces include shiny metal, glass, marble, bones, teeth, and many plastic materials. Covering the surface with whitening spray eliminates reflection or transparency problems, but is not applicable to all objects. Scanning critical objects that may not be spray-coated is often possible

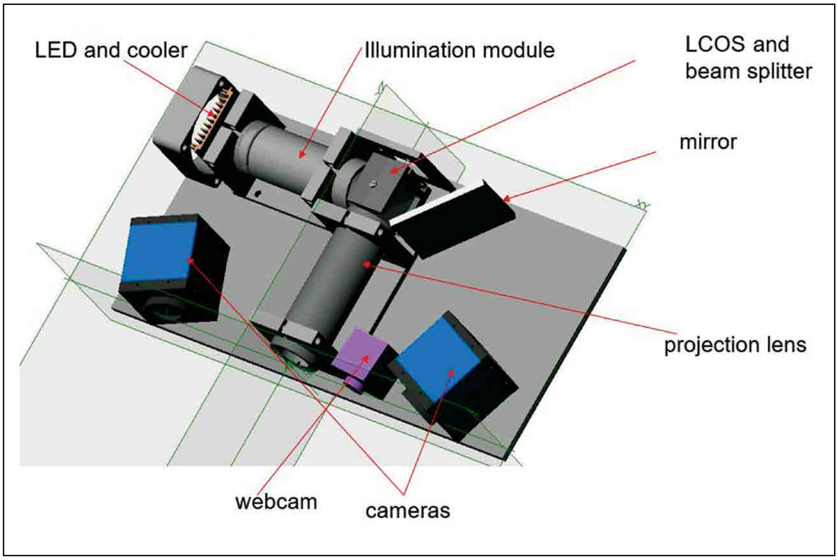

Figure 22.1. Schematic of a typical compact structured light scanner with two cameras (webcam only for alignment) developed by the Centre for Sensor, Instruments and System Development at the Universitat Politècnica de Catalunya (UPC-CD6). © UPC-CD6, 2010.

with additional effort, by further scan positions or angles, user interaction or software filtering.

The object size covered in a single scan is limited by the projector's brightness as well as the feasible distance between projector and camera. The field of view for a single scan setup typically ranges from 30 mm to 2000 mm; the camera system's depth of field determines the system's measuring depth. Furthermore, there is a link to depth resolution, as larger areas imply lower resolution/accuracy because spatial resolution is dependent mostly on the number of samples per unit distance, so denser sampling means, in most approaches, a better depth detail under comparable angle of view (disparity) conditions. Larger or complex objects are captured by multiple scans that are aligned and merged into a single 3D model by dedicated software, which may include acquisition of the same area under different scales for more complete documentation. Thermal instability of the projector can be compensated for by adding a second camera for stereo measurement (see fig. 22.1 for a typical arrangement). The projector usually works with light in the visible spectrum or the near infrared. Most industrial fringe projection systems employ the short wavelength of blue light, which produces better scanning results on semi-transparent or reflective objects and allows better control of

Figure 22.2. Compact structured light scanner with stereo camera system. © AICON 3D Systems GmbH, 2016.

Figure 22.3. Cross of the Scriptures, Clonmacnoise, Ireland. Source: 3D ICONS Ireland, www.3dicons.ie/3d-content/52-cross-scriptures-clonmacnoise, reproduced under CC www.3dicons.ie/process/licensing.

ambient light. Some structured light systems project patterns in the near infrared spectrum, making them invisible to the human eye. Monochrome cameras capture more light per pixel, produce less pixel noise, and thus ensure better 3D data quality than colour cameras. Scanning systems with colour cameras on the other hand have the advantage that shape and colour are captured at the same time. Scanners with colour cameras are only available with white or infrared light projection.

A basic structured light system projects a single random, binary pattern. Image correlation techniques are used to identify these patterns in the camera image for calculation of 3D coordinates. Data acquisition of structured light systems is fast and suitable for dynamic measurements. Correlation of image patches results in significantly lower 3D resolution compared to image pixel resolution, fine details like steps or edges are captured with medium fidelity. Background illumination and contrast are not separated for analysis of the scene. Structured light systems are often used for digitization tasks and medium accuracy control measurements. The output data is typically saved as point cloud information.

A special configuration of a structured light system is the fringe projection system, which projects a sine wave variation of multiple fringes onto the object surface. The camera records projected patterns that may consist of different combinations of coded patterns or a variety of fringes with different phases, enabling the application of different types of phase-shifting algorithms for improving accuracy and yielding dense sampling. A fringe projection system provides a single 3D reading per pixel and resolves fine details with very high fidelity. The projection of multiple patterns separates scene contrast and ambient illumination from the object, allowing for better control of background illumination. Data acquisition by fringe projection systems is slower than with single-shot systems. The acquisition time of fast fringe projection sequences ranges from 1 s to 0.01 s, depending on projection speed and surface properties. Fringe projection systems are well established for the 3D digitization of complete surfaces as well as for high-resolution scanning of small to medium-sized objects (fig. 22.2). The output data are typically saved as a point cloud or triangulated mesh. An internationally recognized standard for accuracy assessment of optical 3D measuring systems based on area scanning is given by VDI/VDE 2634, Parts 2 and 3.

Significant Applications

3D-ICONS Project Guidelines and Case Studies

- http://3dicons-project.eu/eng/Guidelines-Case-Studies
- 3D-ICONS Portal, http://3dicons.ceti.gr.

Structured light scanners were used for short-range, small-scale cases, for example The Market Cross (Glendalough, Ireland) and the metope "Suicide of Aiace" (Paestum, Italy). 3D-ICONS is a large database of several cultural heritage objects scanned using several techniques including structured light. http://3dicons.ceti.gr.

3D-MURALE—3D Measurement and Virtual Reconstruction of Ancient Lost Worlds of Europe

- http://cordis.europa.eu/project/rcn/52648_en.html

A combination of techniques including active illumination for 3D reconstruction was used to recover different scales of detail, combined with texture analysis.

The CultLab3D Project

- www.cultlab3d.de/results.html

Combination of different aspects related to 3D scanning of cultural heritage objects to provide a general-purpose digitization tool for small objects in Museums

Literature

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