Part 2

METHODS AND TECHNOLOGIES

Editorial Note

In this part of the book digital methods and technologies employed in the COSCH case studies, discussed in the preceding chapters, are explained. Entries generally follow the same structure: definition, description, exemplars, and key literature. The basic principles of each method or technology are defined for a lay reader. This is followed by a specialist technical description and examples of significant applications and key literature. The reasons why the application of a particular method/technology may be useful for recording and studying material cultural heritage are explained. This information was correct at the time of writing, October–December 2016. Additional literature can be found in Selected Bibliography.

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3D DEPTH SENSING

GEORGE PAVLIDIS and SANTIAGO ROYO

Definition

Three-dimensional depth sensing can be defined as the ability or capability to tell the distances from a reference point, or observer, to all objects in a 3D scene. In technological terms, it requires a system able to take measurements, or employ computational methods, or a combination of those, to estimate distances from the system itself to all objects in its surroundings. In cultural heritage applications 3D depth sensing is at the heart of most 3D digitization systems (in some cases termed 3D optical documentation). Several restrictions apply, including the proper handling of valuable and fragile historic objects.

Description

Technically, 3D depth sensing is the process of acquiring the distances of all points in a 3D scene from a fixed point of reference, which in most cases is the sensing device itself. There are a number of different methods and technologies for sensing the depth in 3D space. Usually these methods are categorized into *light-dependent* and *light-independent*:[1] a *light-dependent* system senses light, in any way, in order to assess the three spatial dimensions, whereas *light-independent* employs methods not directly sensing light, but using geometrical and topographical principles. In addition, mainly within the category of light-dependent methods, a further sub-classification is based on the principle used or the technology being applied. These are the *active* and *passive* methods: *active* in a sense that the measuring system formulates the conditions of the measurements in order to acquire depth, whereas *passive* methods rely purely on computation applied to raw "unsupervised" measurements.

1 "Light-independent" is being used here only to emphasize a distinction among the various methods in 3D depth sensing.

Numerous methods can be found in the literature, and here is a list of the most cited in their category:

1. Light-dependent methods
   a. Active methods
      i. Laser triangulation
      ii. Time-of-flight scanning (or LiDAR, LADAR, range scanning)
      iii. Structured-light scanning
      iv. Shape from Photometry
      v. Shape from Shading
      vi. Shape from Shadow
      vii. Tomography (of any kind)
      viii. Holography
   b. Passive methods
      i. Photogrammetry
      ii. Structure from Motion
      iii. Shape from Silhouette
      iv. Shape from Stereo
      v. Shape from Texture
      vi. Shape from Focus (zooming)
      vii. Microscopy (of any kind)
2. Light-independent methods
   a. Topographic methods
   b. Empirical methods
   c. Contact sensing methods.

3D depth sensing has been the focus of intense research for a number of decades in various domains, mainly in computer vision and robotics. It has been a key point in developing autonomous systems and 3D digitization technologies. *In the context of cultural heritage 3D depth sensing can be considered as the basic process of a 3D digitization method used to capture the geometric and spectral characteristics of an object.* It has attracted serious R&D by multidisciplinary research groups in order to meet specific requirements in this domain. Since the main subjects of digitization in cultural heritage are precious objects of various sizes, such as monuments, architecture, archaeological sites, and historical urban areas, it is evident that there is a wide spectrum of challenges to be met by systems that would be capable of accurately recording the geometry and surface colour and texture in all these cases. The characteristics of the cultural heritage objects vary mainly along three axes:

1 Size and shape
2 Morphological complexity
3 Diversity in materials.

This three-dimensional space of object characteristics (fig. 11.1) results in a rather noticeable set of challenges in cultural heritage digitization projects. As the 3D depth sensing methods are adapted to specific cases, there is not a single 3D depth sensing method to fit all digitization projects. For example, as indicated in figure 11.1 the pink blob corresponds to a region in which laser triangulation methods can be successful, the green blob corresponds to a region in which range scanning methods can be used, and the cyan blob depicts a region in which Structure from Motion is expected to be successful. In order to choose the most appropriate 3D depth sensing method for a project, it is imperative to define the meaning of "successful" as stated in the previous sentence; the answer would include technical aspects (such as accuracy, resolution, precision requirements) and other managerial and usage limitations (such as the available resources including personnel, equipment, time and budget, possible restrictions in access and requirements of the end-user).

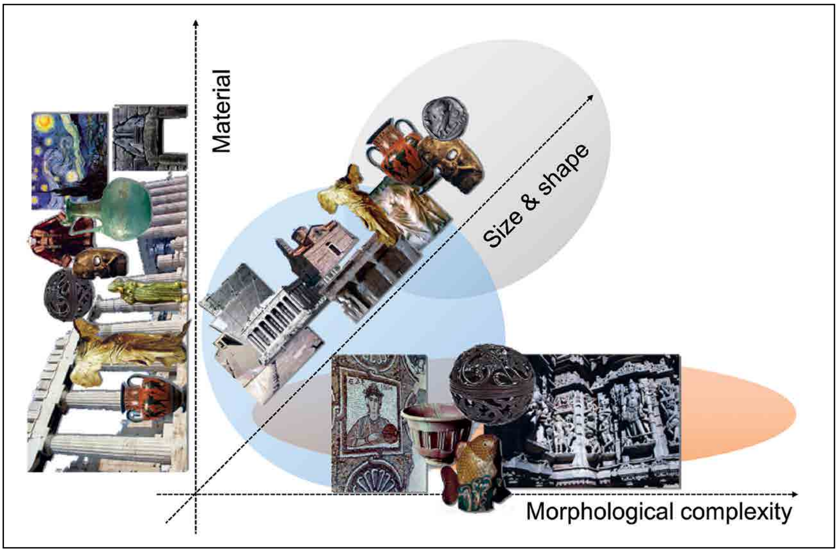

Figure 11.1. The three axes of characteristics of an object.
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With the recent significant increase in the processing power of computers, intensive computational methods, like Structure from Motion, are becoming popular because they are able to tackle large digitization projects with a relatively small amount of manual processing. In addition, solutions from the gaming industry, like the Xbox Kinect, are starting to appear in the next generation of smartphones. Products like Google's Project Tango, Intel's RealSense, and Apple's PrimeSense are bringing 3D depth sensing technology to consumer mobile devices. In these systems the basic time-of-flight principle is being used, in which the point-by-point laser beams of typical range scanners are being replaced by single light pulses. As these technologies mature and become more widely available, they will transform the traditional notions of photography, video, navigation, mapping, and gaming, and will open the way for future heritage digitization and documentation projects.

Significant Applications to Cultural Heritage

- 3D-ICONS Project Guidelines and Case Studies, http://3dicons-project.eu/eng/Guidelines-Case-Studies, 3D-ICONS Portal, http://3dicons.ceti.gr
- CARARE Project, www.carare.eu
- 3D-MURALE – 3D Measurement and Virtual Reconstruction of Ancient Lost Worlds of Europe, http://cordis.europa.eu/project/rcn/52648_en.html
- The Digital Michelangelo Project, http://graphics.stanford.edu/projects/mich/
- The CultLab3D project, www.cultlab3d.de/results.html
- Digital Heritage Toolkit, www.archaeogeomancy.net/2016/04/lidar-analysis-toolkit-for-arcgis/#more-926596

Key Texts

Li, R., Luo, T., Zha, H. 2010. "3D Digitization and Its Applications in Cultural Heritage." *Proc. 3rd International Conference of EuroMed*, Lemessos, 381–88. LNCS 6436. Heidelberg: Springer. doi:10.1007/978-3-642-16873-4_29.

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