# Images in 3D digitizing

***Esa Hannus, Osmo Palonen; Mikkeli University of Applied Sciences, Department of Information and Media Technology; Mikkeli, Finland***

## Abstract

*3D digitizing describes the variety of methods by which "digital copies" of physical objects can be made. These techniques can also be used in cultural heritage preservation and digitally archiving physical objects. Images play an important role in many ways in 3D digitizing processes, especially when the real visual appearance of the object should also be stored.*

*This document describes the meanings and possibilities of image usage in 3D digitizing. It is based on studies made in "Viva3" project at Mikkeli University of Applied Sciences. The project was about testing and developing 3D digitizing processes for different kinds of cultural heritage subjects. Image based solutions and other usage of images in 3D processes were tested with several pilot cases.*

## Backgrounds from the Viva3 project

Department of Information and Media Technology at Mikkeli University of Applied Sciences (Mikkeli UAS) has been developing, studying and teaching digital archiving and digitizing over a decade. Mikkeli UAS is part of the joint operational group of institutions operating in a field of archiving and digitizing in Mikkeli district.

Recently, Mikkeli UAS has been running a project called "Viva3", which is about testing and developing 3D digitizing processes for different kinds of cultural heritage subjects. The Viva3 project is not about creating digital 3D content, nor creating new science, but adapting the newest knowledge and widening Mikkeli UAS's knowledge and possibilities from the local point of view. The backgrounds to this document come from the Viva3 project.

In a field of cultural heritage preservation there are several former and on going projects related to 3D digitizing and archiving which have been giving ideas and guidelines for Viva3. To mention some of them: ViHAP3D, 3D-COFORM, EPOCH, FOCUS K3D, Europeana Carare and FACADE. Also the work of The International Scientific Committee for Documentation of Cultural Heritage (CIPA) and English Heritage etc. has been followed.

## About 3D digitizing and digital archiving

Based on project studies, the term "3D digitizing" is used in slightly different meanings in various fields of industry and science, if used at all. Roughly speaking, 3D digitizing is not often mentioned in context of archiving, but e.g. in context of industry it is used widely. Also in the field of cultural heritage preservation 3D digitizing comes up often, even in conjunction with digital archiving, like e.g. in proceedings by G. Pavlidis et al. [1] and Renju Li et al. [2]. The term is closely related to 3D modeling.

In this document the term "3D digitizing" describes the variety of methods by which physical objects can be turned into three dimensional (3D) digital form. The point of view comes from digital heritage – or virtual heritage – applications, but can be adapted also to other solutions.

But why to 3D digitize? For example, it is the only way the physical objects can be digitally archived. And archiving is needed because of all same reasons like with paper documents, films, etc.

### *Digitizing process*

The methods of 3D digitizing incorporate hardware and software for making 3D data capturing (or data acquisition), 3D measurements and 3D models. Basically, it is a process where three dimensional data about the shape of the subject is first collected, and then three dimensional digital model is modeled with the aid of collected data. In Viva3 project we ended up to describe the complete 3D process as shown in Figure 1 which also shows 3D digitizing as a part of the process. In a field of cultural heritage preservation, the overall process of the complete recording of objects has been presented e.g. like by G. Pavlidis (et al.) [1] as shown in Figure 2.

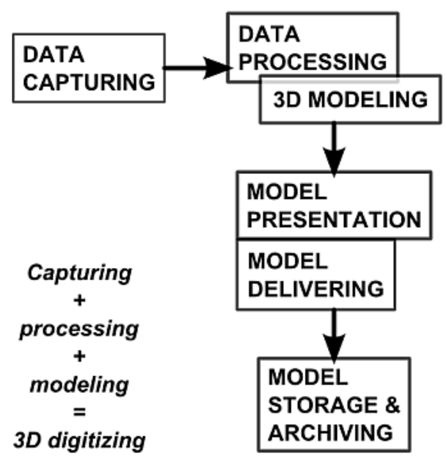


***Figure 1.*** *The 3D process and 3D digitizing (E. Hannus/Viva3)*

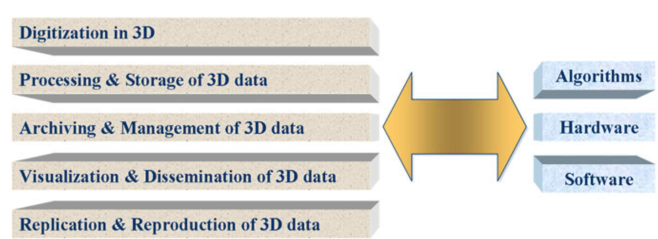


***Figure 2.*** *Complete recording of cultural heritage (G. Pavlidis et al.)[1]*

### *Digital 3D object*

Usually, the final result of 3D digitizing is a 3D computer graphics object, the 3D model, which can be looked from different angles with the aid of computer software. Wikipedia says: "3D models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc."

The model has a surface like the real world object. The digital surface can technically be represented in several ways such as polygonal mesh which is defined by vertices (aka points) connected by line segments, or so called NURBS Surfaces which are defined by spline curves controlled by control points. In a modeling procedure, the measured or otherwise captured information is turned into surfaces that make up a 3D model, and the possible texture is attached.

### *Equipment, techniques and methods*

Widely taking, 3D digitizing can be done without any special equipment by taking some measurements and maybe photographs of the subject, and using them as aids when modeling by using traditional 3D modeling software such as 3DS Max, Blender, Maya, Cinema 4D. More often it is thought that the process includes shape data capturing by some technical instrument, data processing and 3D modeling with instrument related software and maybe finalizing the model by using normal 3D modeling software. Also the texture or other information such as color space or reflectivity may be captured with different instruments.

There are several techniques to capture the geometry aka shape and other information out of an existing physical object. Techniques are implemented in hardware equipment, and together they make up the 3D digitization method.

Both techniques and equipment have their limits for suitability on different kinds of objects to be digitized. For example, the size of objects issues technical limitations as well the complexity and material of objects [1]. Also the indented usage of the digitized object may have an influence on the selection of the suitable digitizing method. Briefly, not all methods (aka techniques or equipment) suit for all kinds of objects or usage purposes. The method can also be composed of two to several sub-methods, which could be used alone in different situation.

3D digitizing methods can be categorized in many ways based on equipment used, the technical operating method, purposed usage, portability, accuracy, operating range, type of captured data, what information can be captured, etc. What ever is taken as a category base, it often includes sub-categories, and some equipment or techniques have mixed features and won't fit in any category solely. In general, the division could be made between contacting and non-contacting methods [3]. In contacting methods, the object is physically touched by the instrument. In non-contacting, information is captured remotely within some distance. From the heritage preservation point of view, often important division question is the ability to capture texture aka the visual outlook of the object. When speaking about the resulting geometry information, in the first place the data capturing method may produce e.g. simple points, lines and surfaces or a cloud of millions of points.

Coordinate measuring machines (CMM) are industrial 3D digitizing instruments. This category includes also digitizers which have a form of a human arm. 3D information is produced by touching the object and resulting data is simple points, lines and surfaces, unless the instrument is equipped with the so called laser head [3] which turns CMM into a very close range scanner and makes it produce point clouds.

Devices called scanners could be based on line of laser light or other light source or structured patterns of light which are projected on target and then optically observed. The result is calculated by triangulating reflected line or pattern [2]. A laser scanner can also refer to an instrument which sends and receives a laser beam and calculates the range by time of flight. There are different forms of laser scanners like A. Walford explains: "a) tripod mounted larger units for field work and large object/area scanning, b) desktop units for smaller objects, and c) hand-held or arm-based" [4]. Scanners typically produce point clouds, but some times ready made 3D polygon meshes.

Traditional photogrammetry technique, stereo photogrammetry, is done with special cameras and the instrument called a stereo plotter. Another technique, convergent photogrammetry needs only normal cameras but certain software. Stereo and convergent photogrammetries produce simple points, lines and surfaces. Also scanner like data can be produced by means of photogrammetry with the method called a photo-based scanning [4].

Widely taking, tomography and other X-ray etc. based instruments in medical science are also 3D digitizing equipment. Instruments based on similar technologies are also used in some specialized industrial solutions.

## Images in 3D digitizing methods

Briefly, in some methods images are used within the technical construction of the method, some other methods are solely based on image based techniques. Widely speaking, also all computer vision based methods could be counted as image related solutions.

For some applications such as cultural heritage preservation the visual appearance of the resulting 3D model is often very meaningful, and not all of the 3D digitizing methods can produce it automatically good enough or at all. The use of photographs as a texture for 3D model, how ever the model was made, is often needed. Methods based on photographs or combining them with other techniques may be most suitable solutions for these visually demanding applications.

When photo based methods or other methods are used together with other methods in order to produce the final 3D model, it can be called a mixed method. Mixed methods have been used in several cases in the field of heritage preservation. All following cases could be enhanced by mixing methods.

### *Images in traditional modeling*

Traditional 3D modeling is basically drawing points, lines, surfaces and objects in digital 3D space of software. When doing modeling by traditional 3D modeling software, images may of course be used simply as visual, non-measurable guides without importing them into software at all.

In other way, images can be imported into software and be set up in 3D modeling space of software so, that they can be used as direct modeling guides. This was also done in the Viva3 pilot case of a small building, The Stone Sacristy of Mikkeli (Figure 3) [5]. Modeling is done by drawing orthogonally against images. This method also has some low level of metric accuracy, so in a way it

 

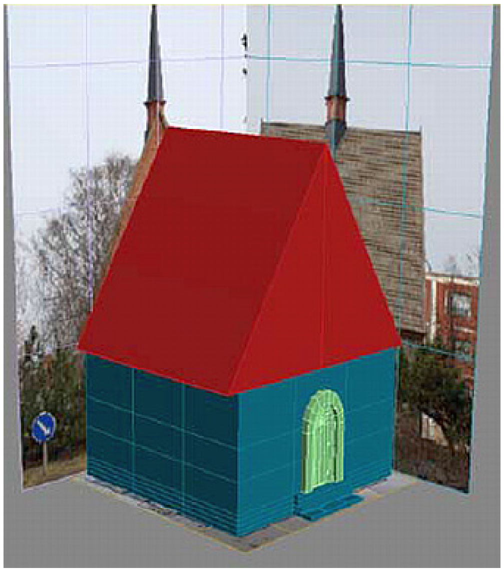

***Figure 3**. Side view photographs and a floor plan are set up into modeling space of a traditional 3D modeling software, and modeling is done orthogonally against photographs (J. Lehtinen/Viva3) [5]*

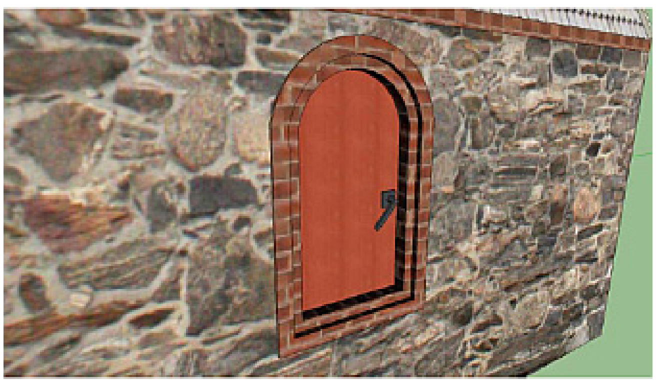

***Figure 4**. 3D model textured by photograph using a traditional 3D modeling software (J. Lehtinen/Viva3) [5]*

can be taken as one 3D digitizing method.  The resulting model can be textured with photographs used in a modeling process (Figure 4) [5].

### Images and laser scanning

In addendum to point cloud, some laser scanners are also capable of capturing the colored images of the object. For example, terrestrial time-of-flight based instruments usually include also a built-in camera, or external camera can be mounted on the system. The camera is sharply calibrated to scanning part and each of the millions of points can get a color value (Figure 5).

After data processing in scanning based 3D modeling, the photographic images taken by the scanning system can be used to texture the surface of the resulting 3D model. The image is projected on the surface, and this may cause projection errors on the parts of the model which happen not to be orthogonal to the place where the image was taken, especially if the distance from the device to the target was long. When it comes to visual image

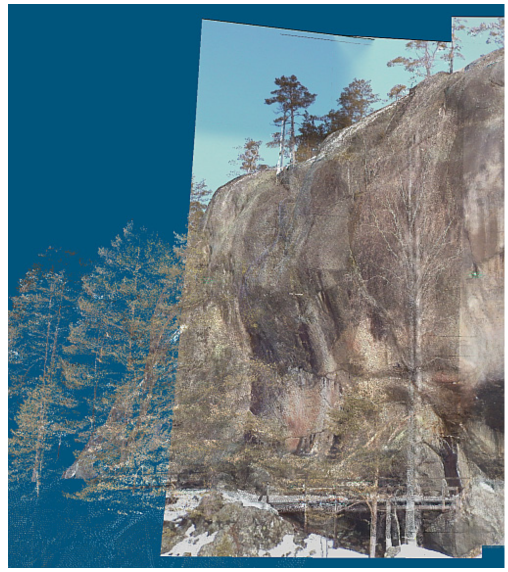

***Figure 5**. Right part: images taken by terrestrial laser scanner. Left part: point cloud from scanner colored with scanner's images (E. Hannus/Viva3)*

***Figure 6**. Optical hand-held scanner which produces the 3D model mesh with texture instantly (E. Hannus/Viva3)*

quality, it depends on the imaging device and indented model usage, is it good enough.

One remarkable thing is that the texture is in the correct place on the surface. It can then be used as a guide to projecting better quality images on the model if needed.

### Images and optical scanners

As optical scanners are technically based on sensing information from images, they always include a camera device. However, the camera of this kind of equipment is not often capable of producing photographic images because it is indented to work as a measuring instrument. Some instruments have an optional camera for capturing photographic images to be used as texture in the resulting 3D model. Some optical scanners even produce the 3D surface with texture instantly during the scanning procedure (Figure 6). Quality issues are similar to the laser scanning case mentioned before, but due to often shorter distance, some errors might be smaller.

### Photograph based methods

In photograph based methods, photographs are used as only data source for capturing the geometry of the subject. Methods are technically based on Photogrammetry, which is the science and art of obtaining measurements from photographs, and thus it can be used to produce 3D information. In a field of photogrammetry, the photographic images have been used by a technique called stereophotogrammetry for a long time. This is done by a quite complex procedure, and special arrangements and hardware is needed. Maybe the most well-known field of usage is topographic mapping by using aerial images, or terrestial stereo imaging formerly used to measure building facades.

The photographic images can also be used for 3D modeling in a more modern and simpler way, while still accurate enough and useful for many purposes. The main techniques are convergent photogrammetry and photo-based 3D scanning which both can be done by quite simple and cost-effective software packages and normal cameras. Also a combination of both techniques can be used. Images to be used must be digital or digitized and taken by certain methods from certain angles. The quality and accuracy of the results depends heavily on image set and image quality. When using digital cameras, the better the camera and the lens are, the better results can be achieved. However, even the camera of mobile phone etc. can be used if the highest accuracy is not needed.

In convergent photogrammetry, images are taken from different non-parallel angles around the subject (Figure 7/top left). Individual images are then referenced together and the software can build up a 3D space. 3D modeling can be done by drawing objects and lines etc. based on visible features on photographs. Photo-based 3D scanning is used to produce a dense 3D point cloud which is then used to reconstruct even complex surfaces in 3D. In this case a pair of images is taken near-parallel (aka “near stereo”) and overlapping each other and then referenced together in software. The surface of the subject should have a natural or random texture or some texture should otherwise be applied on the subject in order to produce point cloud (Figure 7) [4].

The resulting model can be textured by the same photographs which produced the geometry of the model. A good point is also that texture is in the correct place on the surface. Texturing could also be done intelligently so, that each polygon of the model gets it texture from the image which is at the best position to that polygon. Projection errors can then be minimized. The visual quality is as good as used photographs are, and it can be enhanced e.g. by lighting up the target object or by using advanced photographic methods such as high-dynamic-range imaging (HDRI or HDR).

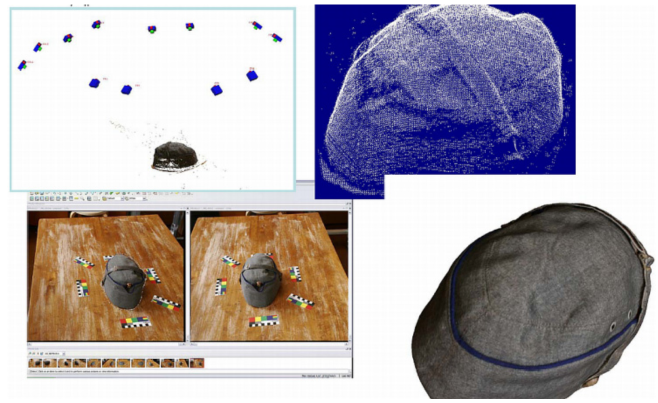

***Figure 7**. Photo-based 3D scanning. Bottom left: one “near stereo” pair of images. Top left: convergent camera constellation of 6 pair of images. Top right: un-textured point cloud made from images. Bottom right: resulting 3D model textured automatically by the same images (E. Hannus/Viva3)*

## Conclusion

Images are important in 3D digitizing. In visually demanding modeling purposes images are absolutely needed at least as textures for the model. Images are also used technically in some digitizing methods and some techniques are even entirely based on images. Use of photo-based 3D digitizing may provide good and realistic visual appearance for a digital object in the same process which produces the 3D geometry of a subject object. The method is also quite cost-efficient while expensive scanning devices are not needed. Even more cost-efficiency is gained in cases where taking photographs of objects is already a part of the operating processes e.g. in museums.

## References


[1] G. Pavlidis et al., “Methods for 3D digitization of Cultural Heritage,” Jour. of Cultural Heritage 8, 93-98 (2007).

[2] Renju Li et al., 3D Digitization and Its Applications in Cultural Heritage, EuroMed 2010 LNCS 6436, pgs. 381–388. (2010).

[3] A. Kesseli, "3D digitizing," B.Sc Thesis. Lahti UAS, Fac. of Tech. (2006).

[4] A. Walford, A New Way to 3D Scan Photo-based Scanning Saves Time and Money, Eos Systems Inc.

[5] J. Lehtinen, “3D modelling of the Sacristy of Mikkeli," B.Sc Thesis. Mikkeli UAS, Dept. of Information and Media Tech. (Viva3) (2009).


## Author Biography


*Esa Hannus (B.Eng) works as a GIS Expert and Project Specialist in Mikkeli University of Applied Sciences, Department of Information and Media Technology. He is recently focusing on 3D data capturing techniques, 3D modeling based on measured information and geographic information systems (GIS).*

*Osmo Palonen (B.A.) works as a Project Manager for digital archiving related projects in Mikkeli University of Applied Sciences, Department of Information and Media Technology.*