3D Digitisation of Icons of European Architectural and Archaeological Heritage

3D ICONS

# D3.1: Interim Report on Data Acquisition

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# Contents

# Executive Summary

Deliverable 3.1 Interim Report on Data Acquisition is a preliminary overview of all the activities related with digitization (WP3), at month 17 of the 24 allocated for WP3 (M6 to M30). This interim report shows how the WP3 activity is proceeding, both globally and at partner level, proving also feedback to the project management for deciding possible corrective actions.

The information for this report was taken from the Progress Monitoring Tool and a short WP3 survey questionnaire completed by all the content providers. The analysis of the questionnaire responses show that a wide range of data acquisition technologies are being used with the most popular one being photogrammetry (used by thirteen partners). Laser scanning for large volumes is also widely used (nine partners), whilst only five are using small volume laser scanning. Only two partners produce 3D content with CAD modelling, starting from pre-existing documentation/surveys. An overview of both the passive and active scanning technologies is provided to aid the understanding of the current work being undertaken in WP3 of 3D-ICONS.

Regarding the progress of WP3, the global situation shows that, although some delays have influenced the activity of a few partners, the project is properly proceeding, having completed the 62% of the digitization work. Actually, 17/24 corresponds approximately to 71%, which would be the amount of work done to be perfectly on time. But we have to consider that in the initial phase of WP3, some of the partners – especially those less technically skilled or experienced with 3D modelling- needed a few months for setting up the most optimized 3D acquisition strategy, tailored to the work each partner is expected to carry out in the WP3 period.

Considering, therefore, from 2 to 5 months initial phase at zero or low productivity due to the start-up of this unprecedented massive 3D acquisition activity, we can see that the operating months at full rate are about 12 to 15, which compared with the duration of the Work Package gives and average of 62%, as actually performed by the project.

Furthermore, considering the last semester, digitization activity appears to have been significantly accelerated by each unit, so the achievement of the targets by M30 seems definitely feasible.

However, if necessary, with six months left beyond M30, small delays in digitization can be absorbed into the remaining schedule without affecting the final delivery of models and metadata at M36.

# D3.1 Interim report on data acquisition

## 1. Introduction

The digitization action expected as output of WP3 is referred to the collection of the three-dimensional data needed for creating, in the framework of WP4, the 3D models that will be then converted in a form suitable for publication (WP5), enriched with both technical and descriptive metadata (WP4), structured as defined in WP6. The 3D models will also be loaded in a project repository, whose creation has been recently started. This repository will allow each partner to store their 3D content and define a Uniform Resource Locator (URL) to be associated with the model. Such a URL, included in the metadata record to be uploaded into EUROPEANA, will allow users to connect the data records accessible through the EUROPEANA portal to the actual 3D content or a simplified representation of it, as shown by the block diagram in Figure 1.

The 3D-ICONS project involves two complementary "channels" for collecting 3D data.

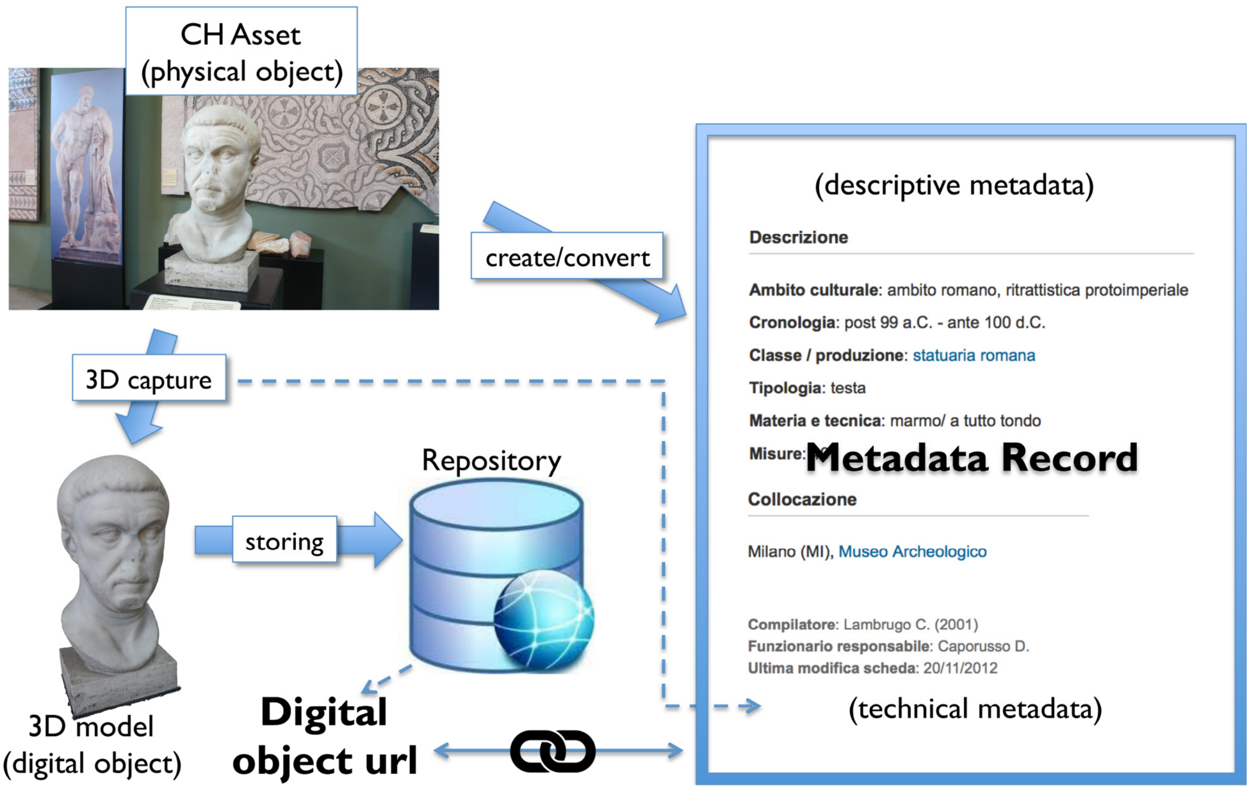



**Figure 1 - Synthetic representation of the whole data collection involved in the 3D-Icons project. The activity of WP3 are part of those involved in the "3D capture" block. The metadata record and an iconic representation of the model (thumbnail image) are ingested into EUROPEANA.**

On the one hand, the project takes account of a set of pre-existing 3D models of significant Cultural Heritage assets originated by both 3D acquisition and CAD modeling in the framework of previous works/projects whose purposes were different from the generation of 3D content for EUROPEANA. In this way, a patrimony of data, otherwise unused, acquired over the years by some of the project partners, can usefully be put at the disposal of the community. The WP3 activity in this case consists in properly checking and converting datasets already existing, in order to have them available for the project.

Finally the project pursues the 3D acquisition of new Cultural Heritage assets that will allow, at the end of the ingestion process planned in the 3DICONS pipeline, to add about 3,000 new 3D items to EUROPEANA.

The main tool that has been used for evaluating the WP3 state of advancement is the Database developed by the CETI unit (http://orpheus.ceti.gr/3d_icons/), available to project partners and the EU commission for checking the progress of the whole project, also by comparing the actual target objectives with what is expected from the project DOW. This was complemented by an on-line questionnaire (https://docs.google.com/forms/d/1ciBxCs3ygbYldTUeyVNlP_9Z5G-y_Dj7FE0EBVUC0Co/viewform) that allowed these figures to be integrated with complementary information related to the 3D technologies employed by the various partners for carrying out the digitization phase.

As shown in Table 1, from such tools it was possible to see that the total number of pre-existing 3D items is 565, while 2,393 new 3D items are expected to be acquired with different 3D technologies, providing a total of 2,958 3D items to be produced within the end of the project. This figure would exactly the same indicated by the DOW.

As shown in Table 1, this actualization of data also involved some adjustments with respect to the figures reported in the DOW. The reason for such changes are due to several aspects related with the actual acquisition rate possible on the field, specially for those units involved in the 3D acquisition of large historical or archaeological sites (ARCHEOTRANSFERT, CMC, MAP-CNRS, MNIR, UJA-CAAI), or, in one case, for having indicated as suitable for the 3D acquisition some sites included in a UN controlled territory in Cyprus for which the authorization, initially given, has been finally denied (CYI-STARC). Excluding the partners already making major contributions (KMKG, POLIMI and UJA-CAAI), the remaining partners have decided to increase their contribution (CETI, CISA, CNR-ISTI, CNR-ITABC, DISC, FBK, VisDim), nearly compensating the otherwise significant contraction in terms of 3D items provided by the project, and therefore in terms of digitizations planned within WP3. The already mentioned additional effort will finally allow achievement of the DOW target numbers.

| Partner | Number of 3D models declared in DOW | Change respect to DOW | | Number of 3D models declared in the Orpheus DB | Of which | |
|---|---|---|---|---|---|---|
| | | + | - | | Pre-existing | New |
| ARCHEOTR. | 258 | | 54 | 204 | 62 | 142 |
| CETI | 30 | 6 | | 36 | 0 | 36 |
| CISA | 33 | 50 | | 83 | 50 | 33 |
| CMC | 53 | | 33 | 20 | 0 | 20 |
| CNR-ISTI | 42 | 143 | | 185 | 81 | 104 |
| CNR-ITABC | 143 | 11 | | 154 | 92 | 62 |
| CYI-STARC | 71 | | 30 | 41 | 20 | 21 |
| DISC | 85 | 24 | | 109 | 4 | 105 |
| FBK | 57 | 2 | | 59 | 13 | 46 |
| KMKG | 450 | 5 | | 455 | 0 | 455 |
| MAP-CNRS | 366 | | 17 | 349 | 133 | 216 |
| MNIR | 80 | 20 | | 100 | 0 | 100 |
| POLIMI | 527 | | | 527 | 55 | 472 |
| UJA-CAAI | 763 | | 177 | 586 | 5 | 581 |
| VisDim | 0 | 50 | | 50 | 50 | 0 |
| **Total** | **2958** | **0** | | **2958** | **565** | **2393** |

**Table 1 – Overview of the numbers of digitizations expected by partner, as specified in the DOW in the planning phase and as actualized in a more advanced phase of the project, evidencing pre-existing and new 3D models.**

## 2. 3D capturing technologies actually employed for 3DICONS

The technologies actually employed in the framework of the WP3 lie in the taxonomy already shown in D 2.1, section 7, where a first broad distinction has been made between technologies based on passive or active measurement methods. Both principles fall in the category of non-contact measurement methods, very appropriate for Cultural Heritage objects, being generally delicate and not always suitable to be touched.

The absence of contact between the measurement device and Cultural Heritage artifact is obtained because the probing element, instead of a physical tip touching the surface to be measured for collecting its 3D coordinates at the contact point (as, for example, in the so-called Coordinate Measurement Machines or CMMs), is a beam of radiating energy projected onto the surface to be probed. This beam interacts with the surface and is deflected and measured by the scanning device, enabling the relative position of the current scanned point to be calculated. In this way, a complete set of co-ordinates or "point cloud" is built up which detects the geometrical structure of the scanned object. When the form of energy employed is light (including non-visible radiation like Infra Red), we talk of optical 3D methods, where the main difference between active and passive lies in the way such light is provided.

### 2.1 Passive technologies

In a passive device, light is used just for making clear the details of the scene. These details have to be clearly visible elements contrasting with the background and richly present on all the points of the surface of interest for capture. This is a characteristic, for example, of photogrammetry, a typical passive method based on multiple images of the same scene, taken from different positions. Here the measurement process requires, first of all, to recognize the same points in different shots of a scene, and this is possible only if the measured object is provided with a contrasted texture, or - when the object is uniformly colored with no salient points - if the operator has added a reference target over the surface of interest in a number of points sufficient for estimating its 3D shape.

The typical pipeline for creating a 3D model with photogrammetric methods involves the following steps:

1. **Calibration** – The camera distortions (radial, tangential and affine) are estimated through a proper calibration procedure. If the camera has interchangeable lenses like a reflex or a last generation mirrorless camera, each camera-lens combination needs to be calibrated.

2. **Image acquisition** – A suitable set of images of the object to be surveyed are taken with the same setting that has been calibrated, considering that for collecting the 3D information of a point at least two images must contain that point. The number of images needed to carry out the complete 3D measurement

of a CH object is highly influenced by its size, the resolution needed, and the way resection, the next step, is implemented.

3. **Resection** - This phase calculates the orientation in the 3D space of the camera while taking the images acquired in the step 2. The means for estimating such orientation is identifying a suitable number of correspondence points in adjacent images using their coordinates as input to a non-linear optimization process (bundle adjustment), minimizing the re-projection error on the actual image points of their corresponding 3D estimates. In traditional photogrammetry, this phase is quite lengthy because, unless coded targets are used, the identification of correspondences is a manual operation. In the last few years a more modern approach has been developed, allowing automatically identification of correspondence points by analyzing the image content (Structure From Motion or SFM). This requires that adjacent images cannot differ too much, so the level of superposition of such shots has to be high (at least 60%), and consequently the number of shots to be taken is much higher than in traditional photogrammetry. However, the need to find correspondences generally discourages the use of passive methods for objects with little or no texture.

4. **Intersection** – This phase calculates the 3D coordinates of corresponding points by the intersection of two rays associated with the same point seen on two different images (triangulation). Also, in this case, the process can be extremely time consuming if the end-user has to manually identify the points of interest, generating in this way a specific selection of 3D points taken in suitable positions (sparse 3D cloud). A more modern process implemented in recent years, and usually associated with SFM, is the so-called "dense image matching", that – given a certain orientation - automatically finds a regular set of correspondences between two or more images, thereby calculating a dense cloud of evenly spaced 3D points. The interesting aspect of this approach is that each group of 3D points, is "naturally" oriented in a single coordinate system;

5. **Scaling** – The cloud of 3D points generated by steps 1-4 is a relative estimation of coordinates. There is no metric correspondence with the physical reality they are representing. In order to obtain a set of metric 3D points, one or more reference measurements from the scene have to be provided and the 3D points have to be scaled accordingly;

6. **Modeling** – This phase involves the generation of the 3D model starting from the measured points. Again, its implementation can be done manually on sparse 3D clouds, or automatically on dense cloud of 3D points. In this latter case, a topological revision and an editing phase is usually needed.

The quality of the result – like for photography - greatly depends on the optical quality of the equipment used. Good digital reflex cameras with high quality lenses, used by skilled operators, provide the best image quality for the following 3D processing.

The two implementations of this method used in 3D-CONS are as follows.

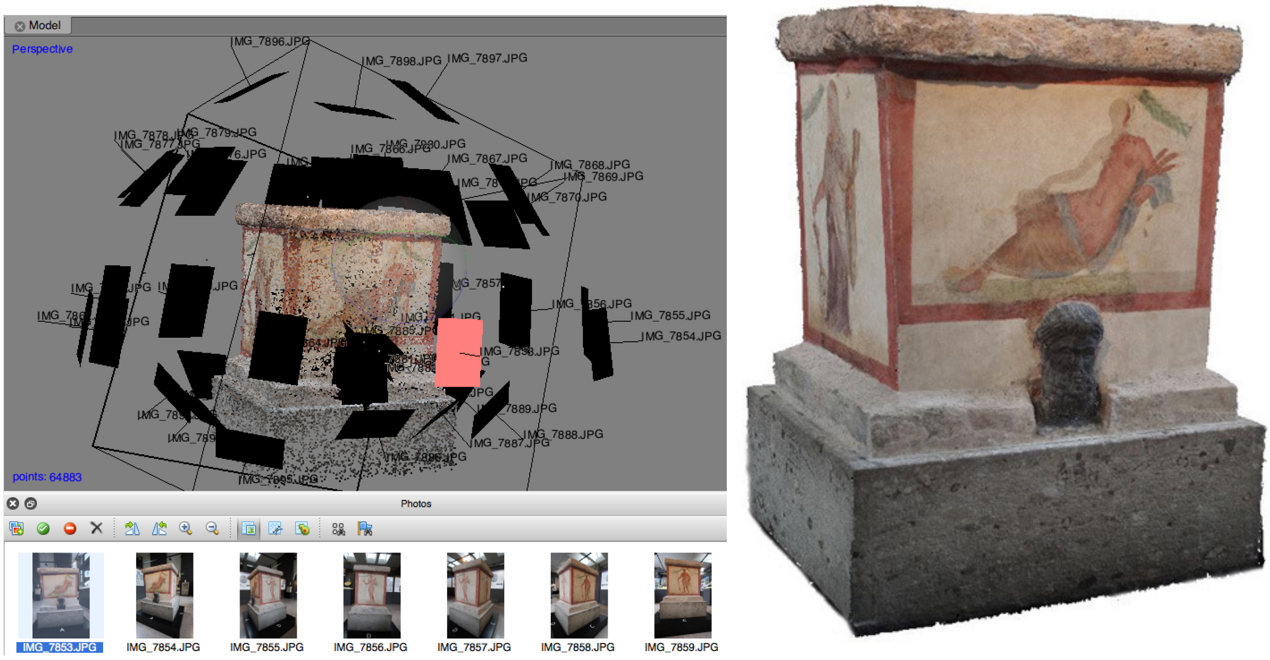
### 2.1.1 Traditional Photogrammetry

All the 6 steps listed previously for the photogrammetric pipeline are done separately by an operator that has to: a) calibrate the camera by photographing a specific certified target (e.g. a 3D grid of some tens of known points) and processing the images with a software capable of providing the distortion parameters from them; b) take photos of the subject, taking into consideration a proper distance between shots in order to have a large base for triangulation (the rule of the thumb is to use a distance between shooting positions approximately equal to 1/3 of the camera-target distance); c) orient all images in the set identifying a suitable number of correspondence points (at least 8-10) for each of the images involved, finally applying bundle adjustment; d) identify some points of the object needed for reconstructing its shape over the oriented images, and collect their 3D coordinates; e) scale the obtained 3D data set and export to 3D modeling software; f) draw a 3D model over the measured 3D points.

This method is implemented in both open source and commercial photogrammetry software packages. It is rather fairly but the associated process is quite cumbersome and needs a considerable amount of time and skilled operators. The required time is further increased if the object has no salient reference points and its surface need to be prepared with specific targets attached to it (not always possible on Cultural Heritage assets).

### 2.1.2 SFM/Image matching

This process has been greatly developed in the last ten years and is now a standard operating tool. It implements the six step photogrammetric pipeline using a high level of automation, reducing significantly the time needed for generating a 3D model from a set of images. It is based on the automatic identification of image elements in photographs, possible if the images have a short base of triangulation (i.e. they are very similar each other). The process can be implemented through an on-line service (Autodesk 123D Catch, Microsoft Photosynth, etc.) taking as input a set of images and providing as output a texturized 3D model, with no user control.




a) b)

**Figure 2 – SFM digitization made by the POLIMI unit of a Roman altar conserved at the Archaeological Museum of Milan through AGISOFT Photoscan: a) images automatically oriented in 3D; b) rendering of the 3D model originated by this method.**

But within the 3DICONS project an alternative commercial solution has been widely adopted by many of the partners (AGISOFT Photoscan). Although this works in a similar way, it is a piece of software installed locally by the end-user that allows a certain level of user control over the process.

The operator only needs: a) to acquire a number of images all around the object with a sufficient overlap (suggested 60%) between adjacent shots as indicated in step 2; b) launch the process that automatically identifies many (in the order of some thousands) corresponding points and automatically performs the steps 1 and 3 of the photogrammetric pipeline, generating a first quality feedback about image orientations; c) if the orientations are acceptable, a second process can be launched, performing steps 4 and 6 of the photogrammetric pipeline. The set of points obtained is a dense cloud of 3D points including colour information that the software can mesh automatically. The last point (step 5.) has to be done afterwards in order to provide a metric 3D model. The result obtained at this step – with the exception of a few editing operations – represents the final 3D result (Figure 2).

This method produces particularly effective results and has been used by many of the 3DICONS project partners, as shown in detail in section 3.

### 2.2 Active technologies

In an active device, light is not uniformly distributed like a passive device, but is coded in such a way to contribute to the 3D measurement process. The light used for this purpose might be both white, as a pattern of light generated with a common LCD projector, or single wavelength as in a laser. Active systems, particularly those based on laser light, make the measurement result almost independent of the texture of the object being photographed, projecting references onto its surface through a suitably coded light. Such light is characterized by an intrinsic information content recognizable by an electronic sensor, unlike the environmental diffuse light, which has no particularly identifiable elements. For example, an array of dots or a series of coloured bands are all forms of coded light. Thanks to such coding, active 3D sensors can acquire in digital form the spatial behavior of an object surface. At present, 3D active methods are quite popular because they are the only ones capable of metrically acquiring the geometry of a surface in a totally automatic way, with no need to resize according to one or more given measurements taken from the field. In the 3D-ICONS project such devices have been largely used in the different implementations described in the following sections.

#### 2.2.1 Triangulation based range devices

For measuring small volumes, indicatively below a cubic meter, scanners are based on the principle of triangulation. Exceptional use of these devices have been made in Cultural Heritage (CH) applications on large artifacts like, for example, the Portalada 3D scanning performed within this project by the CNR-ISTI unit. In such cases, these are typically integrated with other types of devices.

The kind of light that was first used to create a 3D scanner is the laser light. Due to its physical properties, it allows generation of extremely focused spots at relatively long ranges from the light source, relative to what can be done, for example, with a halogen lamp. The reason for this is related to the intimate structure of light, which is made by photons, short packets of electromagnetic energy characterized by their own wavelength and phase. Lasers generate light which is monochromatic (i.e. consisting of photons all at the same wavelength), and coherent (i.e. such that all its photons are generated in different time instants but with the same phase). The practical consequence of mono-chromaticity is that the lenses used for focusing a laser can be much more effective, being designed for a single wavelength rather than the wide spectrum of wavelengths typical of white light. In other words, with a laser it is easier to concentrate energy in space. On the other hand, the second property of coherence allows all the photons to generate a constructive wave interference whose consequence is a concentration of energy in time. Both these factors contribute to making the laser an effective illumination source for selecting specific points of a scene with high contrast respect to the background, allowing measurement of their spatial positions as described below.

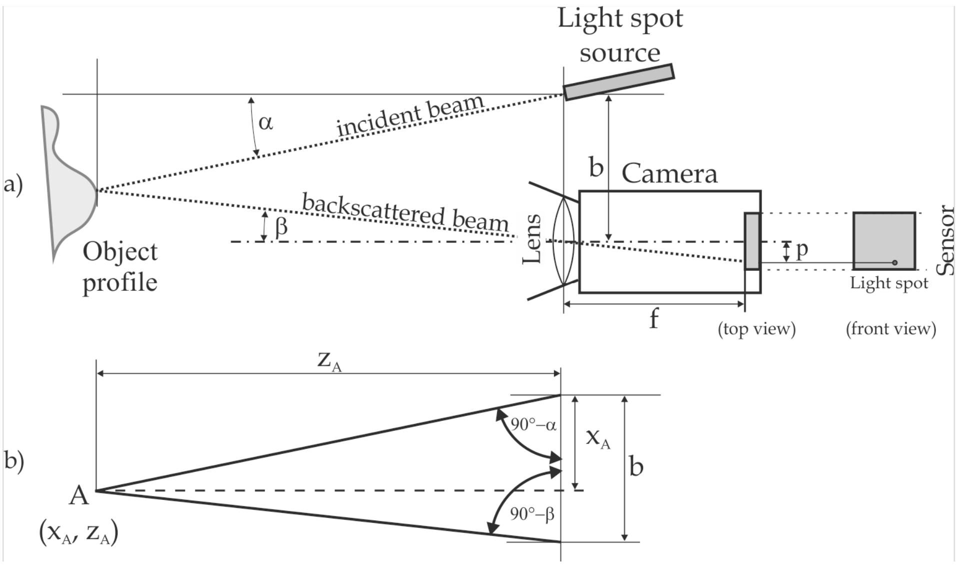



**Figure 3 – Block diagram of a range measurement device based on triangulation: a) a laser beam inclined with angle α respect to the reference system, impinging on the surface to be measured. The light source is at distance b from the optical center of a camera equipped with a lens with focal length f. Evaluating the parallax p from the captured image it is possible to evaluate β; b) combining α and b (known for calibration) and β, the distance $Z_A$ can be easily evaluated as the height of this triangle.**

A triangulation 3D sensor is a range device made by the composition of a light source and a planar sensor, rigidly bounded to each other. In the example of Figure 3, the laser source generates a thin ray producing a small light dot on the surface to be measured. If we put a digital camera displaced with respect to the light source and the surface is diffusive enough to reflect some light also towards the camera pupil, an image containing the light spot can be picked up. In this opto-geometric set-up, the light source emitting aperture, the projection centre and light spot on the object, form a triangle as the one shown in Fig. 3b, where the distance between the image capturing device and light source is indicated as baseline b. In such conditions, the sensor-to-object distance ($Z_A$) can be easily evaluated, and from this the other value $X_A$ calculated.

The principle described above can be extended by a single point of light to a set of aligned points forming a segment. Systems of this kind use a sheet of light generated by a laser reflected by a rotating mirror or a cylindrical lens. Once projected onto a flat surface, such a light plane produces a straight line which becomes a curved profile on complex surfaces. Each profile point responds to the rule already seen for the single spot system, with the only difference being that the sensor has to be 2D, so that both horizontal and vertical parallaxes can be estimated for each profile point. These parallaxes are used for estimating the corresponding horizontal and vertical angles, from which, together with the knowledge on the baseline b and the optical focal length f, the three coordinates of each profile point can be calculated with a high degree of accuracy. This process therefore allows to the calculation of an array of 3D coordinates corresponding to the illuminated profile for a given light-object relative positioning. The described set of the laser sheet generator and camera represent the scanner head. By moving the sheet of light according to a rotational or translation geometry, the whole set of 3D profiles collected represent a 3D view of the scene.

A similar result is obtained if, instead of moving a single profile over the surface, several profiles are projected at once. This is in the method used by pattern projection sensors, where multiple sheets of light are simultaneously produced by a special projector generating halogen light patterns of horizontal or vertical black and white stripes. An image of the area illuminated by the pattern is captured with a digital camera and each Black-to-White (B-W) transition is used as geometrical profile, similar to those produced by a sheet of laser light impinging on an unknown surface. Even if the triangulating principle used is exactly the same as for the two laser devices, the main difference is that here no moving parts are required since no actual scan action is performed. The range map is computed through digital post-processing of the acquired image.

The output attainable from both kind of triangulation devices can be seen as an image having in each pixel the spatial coordinates (x, y, z) expressed in millimeters, optionally enriched with color information (R, G, B) or by the laser reflectance (Y). This set of 3D data, called “range image” or “range map”, is generally a 2.5D entity (i.e. at each couple of x, y values, only one z is defined).

In metrological terms these kind of devices provide low uncertainty (below 0.1 mm), but can only work in a limited range of distances, generally between 0.5 to 2 metres. So they are very suitable for small objects with little or no texture, and not too shiny or transparent.

### 2.2.2 Direct distance measurement devices based on Time of Flight (TOF)

With active range sensing methods based on triangulation, the size of volumes that can be easily acquired ranges from a shoe box to a full size statue. For a precise sensor response, the ratio between camera-target distance and camera-source distance (baseline), has to be maintained between 1 and 5. Therefore, framing areas very far from the camera would involve a very large baseline, that above 1m becomes difficult to be practically implemented. For larger objects like buildings, bridges or castles, a different working principle is used. It is based on optically measuring the sensor-to-target distance, having the *a priori* knowledge of angles through the controlled orientation of the range measurement device.

TOF range sensing is logically derived from the so-called “total station”. This is made by a theodolite, namely an optical targeting device for aiming at a specific point in space, coupled with a goniometer for precisely measuring horizontal and vertical orientations, integrated with an electronic distance meter. TOF, or time of flight, refers to the method used for estimating the sensor-to-target distance that is usually done by measuring the time needed by a pulse of light for travelling from the light source to the target surface and back to the light detector integrated in the electronic distance meter.

A 3D laser scanner is different from a total station in that it does not need a human operator to aim at a specific point in space and therefore it does not have such a sophisticate crosshair. On the other hand, it has the capability to automatically re-orient the laser on a predefined range of horizontal and vertical angles with an assigned angular resolution, in order to select a specific area in front of the instrument. The precise angular estimations are then returned by a set of digital encoders, while the laser TOF gives the distance. By combining this information representing the polar representation of each point coordinate, the corresponding Cartesian coordinates can be easily calculated.

For ground-based range sensors, the angular movement can be 360° horizontally and close to 150° vertically, with an operating range from less that one meter to several hundred meters or more (depending on the actual implementation), allowing a huge spherical volume to be captured from a fixed position. As for triangulation based range sensors, the output of such devices is again a cloud of 3D points originated by a high resolution spatial sampling of an object. The difference with triangulation devices is often in the data structure. In TOF devices, data is collected by sampling an angular sector of a sphere, with a step that is not always fixed. As a result, the data set can be formed by scan lines that are not necessarily all of the same size. Therefore, the device output may be a simple list of 3D coordinates not structured in a matrix.

In term of performances, contributions to measurement errors may be made by both angular estimation accuracy and distance measurements. However, due to the very high speed of light, the TOF is very short, and this means that the major source of randomness is due to its estimation that becomes a geometrical uncertainty once time is converted in distance. Generally, a strength of this kind of device is that the only distance limiting factor is the laser power, so that the principle can be used also for very long range devices, like those used in Airborne Laser Scanning (ALS), capable of collecting 3D data from thousands of metres.

### 2.2.3 Direct distance measurement devices based on Phase Shift (PS)

In this technique distance is estimated with a laser light whose intensity is sinusoidally modulated at a known frequency, generating a continuous wave of light energy directed toward the target. The backscattering on the target surface returns a sinusoidal light wave delayed with respect to the transmitted one, and therefore characterized by a phase difference from it.

Since the phase is directly proportional to the distance, from this value the range can be evaluated similarly as in the previous case. This indirect estimation of distance allows a better performance in term of uncertainty for two main reasons: a) since the light sent to the target is continuous, much more energy can be transmitted respect to the TOF case, and the consequent signal-to-noise ratio of the received signal is higher; b) the low-pass filtering required for extracting the useful signal component involves an attenuation of the high frequency noise, resulting in a further decrease of noise with respect to signal.

A peculiar aspect of this range measurement technique is the possibility of ambiguous information if the sensor-to-target distance is longer than the equivalent length of a full wave of modulated light, given by the ambiguity range $r_{amb}=\pi c/\omega_0$, due to the periodical repetition of phase. Such ambiguity involves a maximum operating distance that is in general smaller for PS devices rather than TOF. For this reason PS are generally used for medium range operating distances, while TOF are used for long range.

However, the scanning mechanism remains the same as TOF devices, allowing an horizontal angular scan of 360° and a vertical one around 150°, covering almost a whole spherical view.

### 2.3 Relationship between technology and applicative scenarios

The different working principles allow implementation of 3D capturing solutions for various applicative situations. Figure 4 provides an overview of the device-to-target distance that is implicitly related to the device's field of view.

As shown in Figure 4, the low range devices are those based on triangulation, like laser scanners based on a sheet of light (e.g. Minolta Vivid 910), or on pattern projection (e.g. Breuckmann Smartscan HE). All these are generally used on a tripod and require a significant post-processing effort for aligning the various range maps required to cover the whole surface of an object. As an alternative for fast 3D capture, recent triangulation-based devices offer on-the-flight evaluation of their position and orientation with respect to the scene. Therefore, they can be handheld and used more easily for fairly larger scanning volumes (e.g. Artec EVA; Z-Corp Z-Scanner 800). Consequently, these are commonly used for small archaeological artifacts, object museums, etc.

For medium range applications, PS laser scanners work well for interiors or small/medium architectural structures and archaeological sites. Their speed, in the range of 1 million of points per second, allows them to be used in complex structures where several scanner positioning are needed.

For long range applications, TOF laser scanners are the most suitable. Even if usually slower that PS devices, they can be used as terrestrial devices, in the same way as PS laser scanners, for capturing large structures or even natural landmarks (e.g. the FBK unit used this device for capturing a famous rocky mountain in the Dolomites). But since they have no intrinsic range limitations, they can also be mounted on flying vehicles for capturing large sites from above with the so-called Airborne Laser Scanner (ALS).

Finally Photogrammetry, both in its traditional implementation and in the more recent SFM/image matching version, covers the widest range of applicative situations. In principle, there are no intrinsic range limitations. The only parameter to be taken into account is the required resolution (or GSD – Ground Sampling Distance), which is influenced by the lens used (wide-angular vs. teleobjective), and by the camera-to-target distance. This flexibility probably explains why this method is the most widely used among the 3DICONS partners, as shown in section 3.

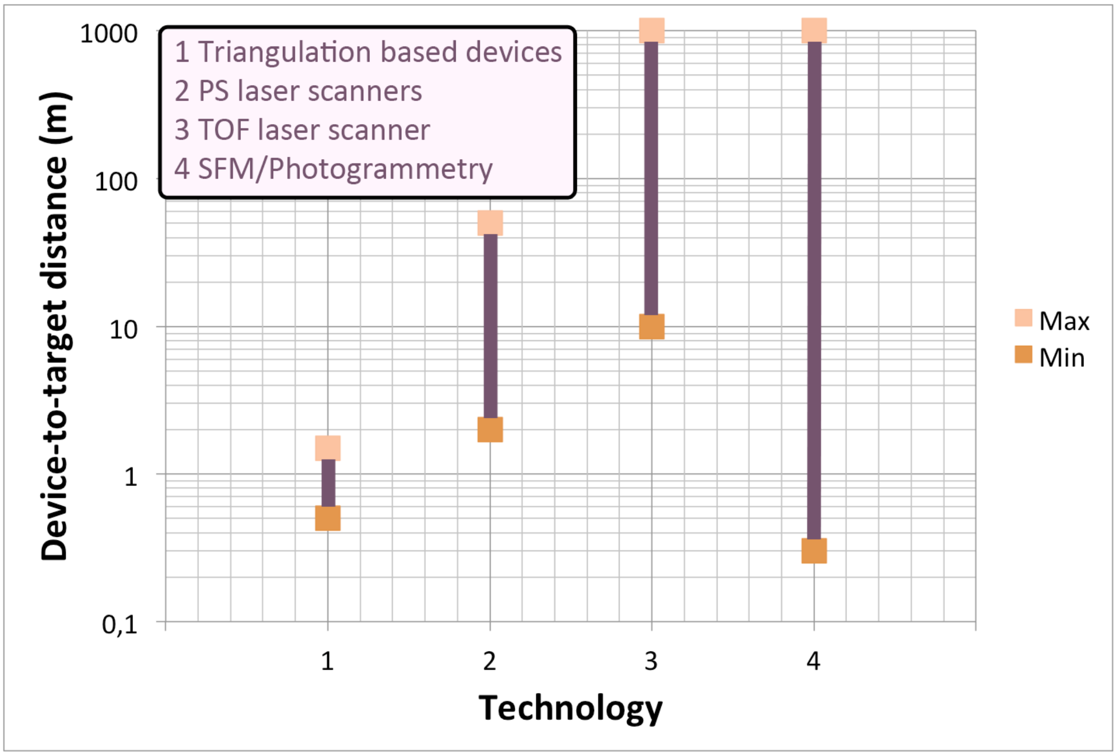



**Figure 4 – Field of applicability of the various 3D technologies used in the 3DICONS project. The upper limit of 1000 meters is just indicative of a long range, since TOF LS and Photogrammetry can work even from longer distances.**

## 3. Distribution of 3D capturing technologies among the partners

According to the questionnaire completed by the partners, a survey about the 3D technologies employed by the various partners has been conducted, revealing a diffusion of many different approaches, with a predominance of SFM/Photogrammetry for its ease of use and speed. All the partners answered the questionnaire, showing an interesting coverage of the whole 3D digitization area. The results are reported as follows.

### 3.1 ARCHEOTRANFERT

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Traditional photogrammetry (sparse 3D cloud)

*Which of them you used more?*

SFM/Photogrammetry (dense 3D cloud)

*Which Camera/Lens did you use?*

Nikon D800E

### 3.2 CETI

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), TOF/PS laser scanner

*Which of them you used more?*

SFM/Photogrammetry (dense 3D cloud)

*Which Camera/Lens did you use?*

DSLR Nikon D40 at 6.1MP with an 18–55 mm lens; Canon EOS350d at 8.1MP with an 18–55 mm lens; Samsung NX1000 at 20MP with an 20-50 mm; Nikon D320 at 24MP with an 10-20mm

*Which range sensing which devices did you use?*

Optec Ilris 36D

### 3.3 CISA

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), TOF/PS laser scanner, CAD Modeling

*Which of them you used more?*

We use a bit of everything

*Which Camera/Lens did you use?*

Nikon D90/ 18-55 mm

*Which range sensing which devices did you use?*

Zoller & Froilich Imager 5003

### 3.4 CMC

*Which 3D acquisition technology have you used in WP3?*

TOF/PS laser scanner

*Which range sensing which devices did you use?*

We are using data acquired by 3rd parties, who primarily used Leica hardware.

### 3.5 CNR-ISTI

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Triangulation range sensor, TOF/PS laser scanner

*Which of them you used more?*

Triangulation range sensors

*Which Camera/Lens did you use?*

Nikon D 5200, Nikon D70, various compact cameras

*Which range sensing which devices did you use?*

long range: Leica Scan Station / Leica 2500 / Leica 3000, RIEGL LMS-Z, FARO Photon 120

triangulation: Minolta Vivid Vi 910, Breuckman Smartscan-HE, NextEngine Desktop Scanner"

### 3.6 CNR-ITABC

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), TOF/PS laser scanner

*Which of them you used more?*

SFM/Photogrammetry

*Which Camera/Lens did you use?*

Canon 60D 17mm; Canon 650D 18-50 mm; Nikon D200 (fullframe) 15mm

*Which range sensing which devices did you use?*

Faro focus 3D

*Other technologies?*

Spherical Photogrammetry (Canon 60D 17 mm)

### 3.7 CYI-STARC

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Traditional photogrammetry (sparse 3D cloud)

*Which of them you used more?*

We use a bit of everything

### 3.8 DISC

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Triangulation range sensor, TOF/PS laser scanner, Airborne Laser Scanner (ALS)

*Which of them you used more?*

TOF/PS Laser scanners

*Which Camera/Lens did you use?*

Canon 5D MK II/ 24mm - 105mm/ 20mm

*Which range sensing which devices did you use?*

Faro Focus 3D, Fli MAP-400 ALS, Artec EVA

## 3.9 FBK

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Traditional photogrammetry (sparse 3D cloud), Triangulation range sensor, TOF/PS laser scanner

*Which of them you used more?*

SFM/Photogrammetry

*Which Camera/Lens did you use?*

Nikon D3X/ 50mm; Nikon D3100/ 18 mm; Nikon D3100/ 35mm

*Which range sensing which devices did you use?*

Leica HDS7000; ShapeGrabber SG101: Leica ScanStation2; FARO Focus3D

## 3.10 KMKG

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud)

*Which Camera/Lens did you use?*

Canon, different cameras and lenses

## 3.11 MAP-CNRS

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Traditional photogrammetry (sparse 3D cloud), Triangulation range sensor, TOF/PS laser scanner

*Which of them you used more?*

We use a bit of everything

*Which Camera/Lens did you use?*

Nikon D1x, D2x and D3x with 20mm, 35mm, 50mm, 105mm, 180mm

*Which range sensing which devices did you use?*

Faro Focus 3D, Faro Photon 80, Konica Minolta Vivid 910, Trimble Gx, Mensi GS200

## 3.12 MNIR

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Traditional photogrammetry (sparse 3D cloud)

*Which of them you used more?*

SFM/Photogrammetry

*Which Camera/Lens did you use?*

Canon EOS 40D, 17-40mm; Nikon D3100, 18-105mm

## 3.13 POLIMI

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Triangulation range sensor, TOF/PS laser scanner

*Which of them you used more?*

SFM/Photogrammetry

*Which Camera/Lens did you use?*

Canon 5D Mark II/20 mm and 50 mm; Canon 60D/20 mm, 50 mm and 60 mm; Canon 20D/ 20 mm; Sony Nex-6/Zeiss 24 mm

*Which range sensing which devices did you use?*

Minolta Vivid 910; Faro Focus 3D; Leica HDS3100

## 3.14 UJA-CAAI

*Which 3D acquisition technology have you used in WP3?*

SFM/Photogrammetry (dense 3D cloud), Traditional photogrammetry (sparse 3D cloud), Self positioning handheld 3D scanner

*Which of them you used more?*

SFM/Photogrammetry

*Which Camera/Lens did you use?*

Canon EOS 40D/SIGMA DC 18-200mm and EOS APO MACRO 350mm

*Which range sensing which devices did you use?*

Z-Scanner 800

## 3.15 VisDim

*Which 3D acquisition technology have you used in WP3?*

Virtual Reconstruction

*Other technologies?*

3D virtual reconstruction based upon archaeological plans, publications, measurements and observations on site, interpretation by experts.

The 3D models were built in ArchCAD, improved and retextured in Blender. The terrain and vegetation is done in Vue.

## 3.16 Considerations about the 3D technologies employed

A wide range of technologies are used within the project due to the type of objects to be digitized which range from entire archeological sites to buildings, sculptures and smaller museum artifacts as shown in Table 2.

| | Traditional photogrammetry | SFM with Image matching | Triangulation range sensors | TOF/PS laser scanners | CAD + old 3D data |
|---|---|---|---|---|---|
| ARCHEOTR. | ✔ | ✔ | | | |
| CETI | | ✔ | | ✔ | |
| CISA | | ✔ | | ✔ | ✔ |
| CMC | | | | ✔ | |
| CNR-ISTI | | ✔ | ✔ | ✔ | |
| CNR-ITABC | | ✔ | | ✔ | |
| CYI-STARC | ✔ | ✔ | | | |
| DISC | | ✔ | ✔ | ✔ | |
| FBK | ✔ | ✔ | ✔ | ✔ | |
| KMKG | | ✔ | | | |
| MAP-CNRS | ✔ | ✔ | | ✔ | |
| MNIR | | ✔ | | | |
| POLIMI | | ✔ | ✔ | ✔ | |
| UJA-CAAI | ✔ | ✔ | ✔ | | |
| VisDim | | | | | ✔ |
| *Total* | 5 | 13 | 5 | 9 | 2 |

**Table 2 - Overview of 3D acquisition technologies used by partners**

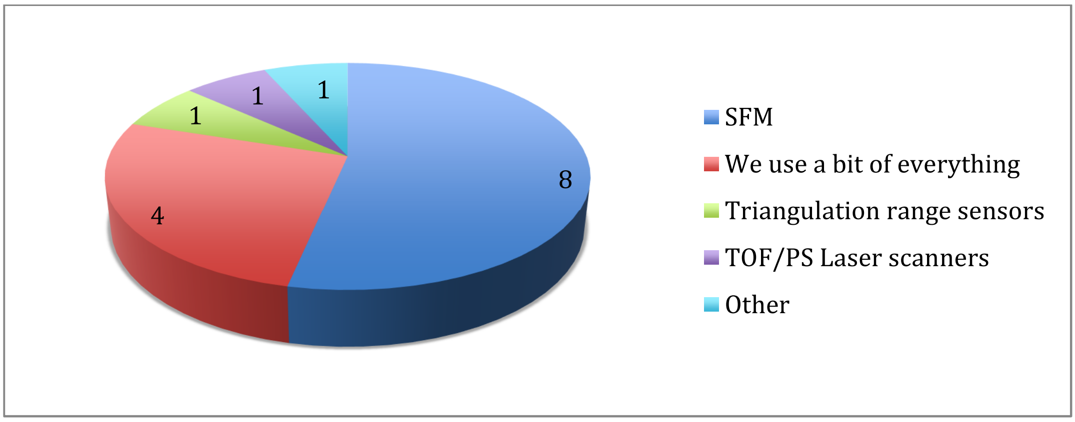



**Figure 5 - Most commonly used data acquisition methods for the various 3DICONS units.**

As shown in Table 2, nearly everyone is using SFM/Photogrammetry (dense cloud) with no partners using Traditional Photogrammetry (sparse cloud) alone. Nine partners are using TOF/PS laser scanners, eight in conjunction with photogrammetry and one as a sole technology (for a large archaeological site). A further five partners use triangulation range sensors in addition to the two other technologies. The exceptions are VisDim who creating virtual reconstructions (so no actual digitization of a real object), and UJA-CAAI and DISC who are also using a hand-held scanners, and CISA, using CAD in addition to Photogrammetry.

| Partner | Digital Single Lens Reflex (SLR) cameras | Lens | Mirrorless/Compact cameras | Lens |
|---|---|---|---|---|
| ARCHEOTR. | Nikon D800E | 18-55mm | | |
| CETI | Nikon D40,D320<br>Canon 350D | 18-55mm, 10-20mm<br>18-55mm | Samsung NX1000 | 20-50mm |
| CISA | Nikon D90 | 18-55mm | | |
| CMC | | | | |
| CNR-ISTI | Nikon D5200, D70 | | Various models | |
| CNR-ITABC | Canon 60D, 650D<br>Nikon D200 | 17mm, 18-50mm<br>15mm | | |
| CYI-STARC | | | | |
| DISC | Canon 5D MkII | 24-105mm, 20mm | | |
| FBK | Nikon D3x, D3100 | 50mm, 18mm, 35mm | | |
| KMKG | Canon, various models | Various lenses | | |
| MAP-CNRS | Nikon D1x, D2x, D3x | 20mm, 35mm, 50mm, 105mm, 180mm | | |
| MNIR | Canon 40D; Nikon D3100 | 17-40mm; 18-105mm | | |
| POLIMI | Canon 5D MkII, D60, D20 | 20mm, 50mm macro, 60mm macro | Sony Nex-6 | 35mm |
| UJA-CAAI | Canon 40D | Sigma 18-200mm,<br>APO macro 350mm | | |
| VisDim | | | | |

**Table 3 - The range of digital cameras used by partners for image-based 3D acquisition.**

From Figure 5 it's interesting to notice that eight units out of the fifteen in total actually involved in 3D digitization indicated SFM/Photogrammetry as the most commonly used technique, four make use of multiple approaches with no special preferences, one is mostly involved with triangulation range devices, and one – DISC, the most active on large sites – indicated TOF/PS Laser scanners as their main tool, including Airborne Laser Scanning. In addition, two units indicated the use of a triangulation-based self-positioning range device, suitable for reducing the post processing effort needed for aligning the acquired range maps.

With regard to the cameras shown in Table 3, many different models were used with a large majority of digital Single Lens Reflex (SLR) belonging to the professional segment with full frame sensor (Nikon D800E, D3x; Canon 5D Mark II), to the semi-professional segment with APS-C sensor (Nikon D90, D70, D1x, D2x; Canon 60D, 40D and 20D), and a few consumer SLRs also with APS-C sensor (Nikon D3100, D5200; Canon 350D). Canon and Nikon were, therefore, by far the most dominant brands in this area – twelve of the partners used one or both of these makes. A few smaller cameras have also been used, belonging to the Mirrorless and Compact segment, like Samsung NX1000 and Sony Nex-6. Several types of lens have been used, with a majority of zoom lenses ranging from 10 to 350mm by most of the partners, but with a rigorous use of fixed length lenses by the groups most traditionally involved with photogrammetry, mostly with focal length ranging from very short (15mm, 18mm and 20mm), to medium (35mm, 50mm, 50mm macro and 60mm macro), with a couple of tele lenses (105mm and 180mm).

| Partner | Triangulation range sensors | PS lasers scanners | TOF laser scanners |
|---|---|---|---|
| ARCHEOTR. | | | |
| CETI | | | Optec ILRIS-36D |
| CISA | | Zoller & Froelich Imager 5003 | |
| CMC | | Leica HW from 3rd parties | Leica HW from 3rd parties |
| CNR-ISTI | Minolta Vivid Vi 910, Breuckman Smartscan-HE, NextEngine | Faro Photon 120 | Leica Scan Station, HDS2500, HDS3000; RIEGL LMS-Z |
| CNR-ITABC | | Faro Focus 3D | |
| CYI-STARC | | | |
| DISC | Artec EVA (handheld) | Faro Focus 3D | FLI-MAP400 |
| FBK | ShapeGrabber SG101 | Leica HDS7000; Faro Focus 3D | Leica ScanStation2 |
| KMKG | | | |
| MAP-CNRS | Minolta Vivid 910 | Faro Photon 80, Focus 3D | Trimble Gx; Mensi GS200 |
| MNIR | | | |
| POLIMI | Minolta Vivid 910 | Faro Focus 3D | Leica HDS3100 |
| UJA-CAAI | Z-Scanner 800 (handheld) | | |
| VisDim | | | |

**Table 4 - The range of active range sensors used in WP3 by the 3DICONS partners, in order of operating distance.**

The 3D active devices used by the partners are listed in Table 4. Among these, the Faro Focus 3D was used by five different partners, and other Phase Shift devices by Faro and other manufacturers (Z+F and Leica) by a total of 8 partners. Long range TOF devices have been used by 7 partners. Six partners used short range active devices, two of which handheld (Artec EVA and Z-Scanner 800).

## 4. State of advancement of WP3

The work analyzed here is related exclusively to the 3D digitization activity within the framework of the whole 3D model generation. Considering the various technologies mentioned above, this means, for each object to be modeled:

- with **Traditional Photogrammetry**, the shooting of images, their orientation, the selection and collection of 3D coordinates on interest;
- with **SFM/image matching**, the shooting of images, their automatic orientation, the automatic identification of a dense cloud of 3D points up to the final mesh model (being – in the SFM software more widely used in the project - mixed in the same process the 3D data collection and the mesh generation);
- with **Triangulation range devices** (both laser and pattern projection), the collection of the necessary range images around the objects of interest;
- with **TOF and PS range devices** (both terrestrial and aerial), the collection of laser scans on the field and possible complementary information (GPS, 2D/3D alignment targets, etc.).

WP3 is now at month 17 of the 24 allocated within the project (M6 to M30). The inspection made on the current state of progress of this work package demonstrates how the WP3 activity is proceeding both globally and at partner level, albeit with some discrepancy between the various partners about the state of the work.

The individual and global situation is shown in Table 5, where we see a global performance of 1,838 items acquired (62%) against 1,120 to be completed (38%) to reach the total of 2,958 3D digitizations. The difference in work required to produce new models or to adjust existing ones is not taken into account in the table. The status of pre-existing models is difficult to analyze: in some cases they were ready for delivery, in others some work was still required, for example validating 3D and sometimes re-processing it. As it is impossible to exactly quantify the amount of work dedicated to this task, the table is necessarily approximate.

This global value, at project level, might be interpreted as evidence of a delay in the progress in the first 17 months of the 24 available, corresponding approximately to 71% elapsed time, which would be the amount of work done to be perfectly on schedule. Such percentages do not however keep into account differences among partners and their respective tasks that are difficult to quantify. Therefore, the table must be accompanied by a qualitative explanation.

It should be considered that in the initial phase of WP3, some of the units – especially those less technically skilled or experienced - needed time for setting up the most optimized 3D acquisition strategy, tailored to the work each unit is expected to carry out in the WP3 period. This will be analyzed in detail below.

At project level, let us consider, therefore, an average of 2 months' initial phase, with very low productivity due to the start-up of this unprecedented massive 3D acquisition activity. Thus the operating months at full rate are about 15, which compared with the duration of the Work Package gives about 62%, as actually performed by the project. This is relevant for the next months, when the activity will proceed at the steady level achieved by now.

As regards individual partners, there is a significant difference from each other.

For a first group of partners, the "seniors", i.e. ARCHAEOTRANSFER, CNR (both teams), MAP-CNRS and POLIMI, content to be provided included about one third of already available models. This witnesses their previous experience in 3D acquisition and in defining a mass digitization strategy. This enabled them to start quickly the preparation of new models. Thus they have a very high production rate, as they could use almost all the time since the start of WP3, with a very short 'warm-up'.

FBK and VisDim also belong to the "senior" group. Their production rate is only apparently low: this is because they had less models to produce, as shown by the fact that they already achieved the target completely.

A second grouping, the "sprinters", includes MNIR, which was able to escape from an administrative impasse and proceeded at good pace since then, and DISC, which managed to start quickly, perhaps supported by a very effective national strategy on digitization.

There is then a group of two rather experienced partners, the "trapped" ones, CYI and CMC, hampered by external problems. For example, as regards CYI, the use of some already made models was forbidden because of an unforeseen change of policy of the local antiquity authority, which all of a sudden stopped also the acquisition of other models, and by political difficulties in the data acquisition in the UN controlled area, which could be completed only partially. Both partners are actively searching for substitutes, and they are expected to recover, at least partially, the time lost in useless negotiations. For these partners the relatively low scanning rate in the first period of activity is due to the external difficulties: they did not operate at full speed for several months; actually in these months they could not operate at all.

Finally there are the "newbies": CETI, CISA, KMKG, and UJA-CAAI. All these partners had previous sporadic experience in digitization: they all have zero or few pre-existing models, with the exception of CISA. They all needed some initial time to get acquainted with the tools and to establish an appropriate digitization pipeline for mass acquisition. Their contents differ: KMKG and UJA-CAAI will digitize small objects such as museum artifacts and archaeological finds, a simpler task than CETI and CISA, which will work on more complex monuments. For all of them, and more sensibly for KMKG and UJA-CAAI, the rate of improvement of the last few months shows that they are now able to perform much better, increasing substantially their digitization rate.

| Partner | WP3 target | WP3 completed | Outstanding digitizations | Monthly digitization rate from WP3 start, actual work | Monthly digitization rate to complete until WP3 end |
|---|---|---|---|---|---|
| *Seniors* | | | | | |
| ARCHEOTR. | 204 | 144 | 60 | 9.6 | 8.6 |
| CNR-ISTI | 185 | 185 | 0 | 12.3 | 0.0 |
| CNR-ITABC | 154 | 110 | 44 | 7.4 | 6.1 |
| MAP-CNRS | 349 | 312 | 37 | 20.8 | 5.3 |
| POLIMI | 527 | 380 | 147 | 25.3 | 21.0 |
| FBK | 59 | 59 | 0 | 3.9 | 0.0 |
| VisDim | 50 | 50 | 0 | 3.3 | 0.0 |
| *Sprinters* | | | | | |
| DISC | 109 | 80 | 29 | 6.7 | 4.1 |
| MNIR | 100 | 64 | 36 | 5.3 | 5.1 |
| *Trapped* | | | | | |
| CMC | 20 | 16 | 4 | 1.3 | 0.6 |
| CYI-STARC | 41 | 31 | 10 | 2.6 | 1.4 |
| *Newbies* | | | | | |
| CETI | 36 | 10 | 26 | 0.8 | 3.7 |
| CISA | 83 | 60 | 23 | 3.5 | 3.3 |
| KMKG | 455 | 70 | 385 | 5.8 | 55.0 |
| UJA-CAAI | 586 | 248 | 338 | 20.8 | 48.1 |
| **Total** | **2958** | **1838** | **1120** | **137.2** | **160.0** |
| **%** | **100%** | **62%** | **38%** | | |

**Table 5 – Overview of the progress in WP3 as collected by the Orpheus data base on Jan 31st, integrated for one partner (KMKG) by the data collected with the on-line questionnaire (from Jan 13th to 16th).**

In order to check the actual state of the art of each partner, the monthly digitization rate has been evaluated for the first period dividing the number of models produced by of months effectively dedicated to acquisition, i.e. 15 months for the first group (Seniors) and 12 for the others, on the assumptions that "seniors" needed two months to start and the others needed three more for the reasons explained above. It must be underlined that this is an average value that does not take into account the substantial improvements recently achieved by some partners.

The rates to complete are calculated dividing the number of outstanding models by 7, i.e. the number of months left until WP3 ends.

As evidenced by the column "Outstanding digitizations" of Table 5, the global situation shows some partners that have already finished or are close to the end of their WP3 work with ten or less remaining digitizations, e.g. CNR-ISTI, FBK, VisDim and CYI-STARC, some still needing a certain amount of work, but running smoothly at a regular rhythm

(ARCHEOTR., CNR-ITABC, MAP-CNRS, POLIMI, DISC, MNIR), whose digitization rate does not need to increase. In fact, some of these partners will be available to support the delayed ones if necessary.

Other partners, the "newbies", will need to increase their efficiency, as they have already started doing recently:

- CETI and CISA (whose monthly digitization rate would be close to that of CETI without taking into account his preexisting models) should arrive at a rate close to the one MNIR and DISC have already achieved to finish their work by M30. A rate of less than 5 models/month sounds reasonable for both of them, keeping into account that their outstanding work is a mixture of small and large monuments.
- KMKG and UJA-CAAI should much improve their performance, this seems feasible (although perhaps not easy) when considering that their content consists of small objects for which the digitization is fast when an optimized production pipeline is adopted. Experience shows that an average of 4-5 objects per day may be maintained. In any case, limited delays may be absorbed with little impact by the remaining 6 months after WP3 completion.

It must be underlined that the WP3 questionnaire mentioned above, regarding this particular point contained the question "Are you confident to reach WP3 goal?" and all partners answered "yes", expressing their commitment for obtaining the planned results.

Regarding the final project goal, some partners have added new models to their original lists, others had made substitutions mainly due to problems with IPR. This will be covered in more detail in the Year 2 Management Report where the changes will be summarized. These adjustments generated a zero balance with respect to the target reported in the DOW, but the analysis reported above shows that some of the partners have the capability to possibly exceed the DOW limit, becoming a possible backup resource in case of difficulties of the "newbies".

In conclusion, with the exception of a very few potentially critical cases, we can state that if the project will globally accelerate, increasing of the 20% (x1,2) the average rate of digitization/month provided in the first 17 month of activity - that given the previous considerations seems definitely feasible - the WP3 activity can be properly concluded as planned within M30. Since some flexibility was built into the original schedule with a further six months before 3D-ICONS finishes, any minor delays can be easily absorbed enabling the delivery of metadata and 3D models to complete on time at M36.

## Appendix - Detailed state of digitization by unit

| ARCHEOTRANSFERT | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Blaye Citadel | 17 | 17 |
| La Sauve-Majeure Abbey | 24 | 1 |
| Abbadia Castle in Biarritz | 9 | 3 |
| Historic Centre of Rome (UNESCO WH site): Piazza Navona. | 30 | 1 |
| Non-prehistorical heritage of the V | 19 | 19 |
| Historic Centre of Rome : Circus Maximus. | 13 | 11 |
| Tipasa | 30 | 30 |
| Gallien Amphitheater | 2 | 2 |
| Pey Berland Cathedral | 4 | 4 |
| Saint Emilion | 4 | 4 |
| Delos | 35 | 35 |
| Sphinx of Naxos | 1 | 1 |
| Xanthos | 15 | 15 |
| Karnak | 1 | 1 |
| Total | 204 | 144 |

| CETI | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Monastery of Kosmosotira | 12 | 1 |
| Monastery of Panagia Kalamou | 4 | 0 |
| Church of Acheiropoietos | 3 | 1 |
| Church of Agioi Apostoloi | 6 | 6 |
| Rotunda | 9 | 0 |
| Kioutouklou Baba, Bekctashic Tekke | 2 | 2 |
| Total | 36 | 10 |

| CISA | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Historical Center of Naples: Roman Theatre | 2 | 1 |
| Historical Center of Naples: Statue of Herakles Farnese | 1 | 1 |
| Historical Center of Naples: Necropolis | 4 | 0 |
| Historical Center of Naples: Walls | 1 | 1 |
| Historical Center of Naples. Thermae | 4 | 0 |
| Pompeii: Necropolis | 4 | 0 |
| Pompeii: Villa of Misteri | 3 | 0 |
| Pompeii: Casa del Fauno | 3 | 0 |
| Hercolaneum: Theater | 3 | 0 |
| Hercolaneum: Shrine of Augustali House | 7 | 7 |
| Hercolaneum: Roman Boat | 1 | 0 |
| Etruscan artifacts | 50 | 50 |
| Total | 83 | 60 |

| CMC | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Skara Brae E1 | 11 | 11 |
| Skara Brae E2 | 2 | 1 |
| Skara Brae E3 | 3 | 2 |
| Skara Brae E4 | 2 | 1 |
| Skara Brae E5 | 2 | 1 |
| Skara Brae Artefacts | 0 | 0 |
| Total | 20 | 16 |

| CNR-ISTI | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Loggia dei Lanzi | 8 | 8 |
| Piazza della Signoria | 12 | 12 |
| Tempio di Luni | 20 | 20 |
| Piazza dei Cavalieri | 4 | 4 |
| San Gimignano | 10 | 10 |
| Certosa di Calci | 2 | 2 |
| Badia Camaldolese | 4 | 4 |
| Ara Pacis | 5 | 5 |
| Duomo di Pisa | 26 | 26 |
| Portalada | 4 | 4 |
| Ipogeo dei Tetina | 24 | 24 |
| David Donatello (marble version) | 4 | 4 |
| Sarcofago degli Sposi | 6 | 6 |
| Ruthwell Cross | 14 | 14 |
| Pompeii | 16 | 16 |
| Villa Medicea Montelupo | 3 | 3 |
| San Leonardo in Arcetri | 14 | 14 |
| Capsella Samagher | 4 | 4 |
| DELOS statues (new since targets set) | 5 | 5 |
| Total | 185 | 185 |

| CNR-ITABC | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Historical Centre of Rome | 27 | 15 |
| Cerveteri necropolis | 17 | 1 |
| Appia Archaeological Park | 29 | 22 |
| Villa of Livia | 52 | 52 |
| Sarmizegetusa | 9 | 0 |
| Via Flaminia | 11 | 11 |
| Villa of Volusii | 4 | 4 |
| Lucus Feroniae | 1 | 1 |
| Estense Castle | 4 | 4 |
| Total | 154 | 110 |

| CYI-STARC | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Hellenistic-Roman Paphos Theatre | 21 | 20 |
| Ayia Marina church in Derynia, Famagusta District (Buffer Zone) | 11 | 11 |
| CYI-STARC - The Santa Cristina archaeological area, Paulilatino | 4 | 0 |
| CYI-STARC - The Cenacle (room of last supper), Israel | 5 | 0 |
| Total | 41 | 31 |

| DISC | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| BNB_LANDSCAPE | 3 | 3 |
| TARA | 10 | 10 |
| DA_ROYAL | 1 | 1 |
| NAVAN_ROYAL | 1 | 1 |
| RATH_ROYAL | 1 | 0 |
| SKELLIG | 13 | 12 |
| POULNABRONE | 1 | 1 |
| BNB_KNW | 16 | 14 |
| DUN_AONGHASA | 4 | 4 |
| BNB_NG | 5 | 0 |
| DUN_EOCHLA | 1 | 0 |
| DUN_EOGHANACHTA | 1 | 0 |
| DUCATHAIR | 1 | 0 |
| STAIGUE | 1 | 1 |
| AN_GRIANAN | 1 | 0 |
| CAHERGAL | 1 | 1 |
| CLONMACNOISE | 16 | 11 |
| DERRY_WALLS | 8 | 3 |
| GLENDALOUGH | 16 | 16 |
| GALLARUS_ORATORY | 1 | 1 |
| DROMBEG | 1 | 1 |
| - | 1 | 0 |
| - | 1 | 0 |
| - | 1 | 0 |
| - | 3 | 0 |
| Total | 109 | 80 |

## FBK

| FBK | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Three Peaks of Lavaredo | 1 | 1 |
| Buonconsiglio Castle | 3 | 3 |
| Buonconsiglio Castle Museum | 8 | 8 |
| Drena Castle | 1 | 1 |
| Etruscan Tombs | 12 | 12 |
| Valer Castle | 3 | 3 |
| Stenico Castle | 1 | 1 |
| Paestum Archeological Site | 6 | 6 |
| Paestum Archeological Museum | 6 | 6 |
| Etruscan Museum - Roma Villa Giulia | 2 | 2 |
| Etruscan Museum - Vulci | 4 | 4 |
| Etruscan Museum - Chianciano | 10 | 10 |
| Ventimiglia Theatre | 1 | 1 |
| Austro-Hungarian Forts | 1 | 1 |
| Total | 59 | 59 |

## KMKG

| KMKG | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Almeria Necropolis | 450 | 70 |
| Cabezo del Ofício, grave 12 | 1 | 0 |
| Cabezo del Ofício, grave 1 | 1 | 0 |
| Zapata, grave 15 | 1 | 0 |
| Cabezo del Ofício, grave 1 | 1 | 0 |
| Cabezo del Oficio, grave 18 | 1 | 0 |
| Total | 455 | 70 |

| MAP-CNRS | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Chateau Comtal de Carcassonne | 15 | 14 |
| Saint-Guilhem-le-Desert | 52 | 52 |
| Trophee des Alpes | 7 | 5 |
| Chartreuse de Villeneuve-lez-Avignon | 29 | 16 |
| Petit Trianon | 92 | 88 |
| Saint Michel de Cuxa | 80 | 72 |
| Centre Pompidou | 12 | 6 |
| Amphiteatre Arles | 1 | 1 |
| Saint-Trophime Gate | 2 | 1 |
| Fontains-Church | 2 | 1 |
| StJean-Fountain | 1 | 1 |
| Vieille-Charite | 1 | 1 |
| Chapelle-imp | 1 | 1 |
| TPLB | 6 | 5 |
| Pont_Avignon | 12 | 12 |
| Fort Saint Jean | 13 | 13 |
| Pompei - theaters area | 3 | 3 |
| Tholos - Delphi | 7 | 7 |
| Treasury of Marseille - Delphi | 13 | 13 |
| Total | 349 | 312 |

| MNIR | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Saint Michael`s Cathedral | 10 | 10 |
| Objects from St. Michael`s Cathedral Museum | 14 | 14 |
| Sarmizegetusa (UNESCO WH site) | 0 | 0 |
| Lapidarium | 15 | 15 |
| Romanian National History Museum's Collections | 61 | 25 |
| Total | 100 | 64 |

| POLIMI | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Chartreuse of Pavia (6 separate monuments) | 46 | 46 |
| The roman church of San Giovanni in Conca (Milan) | 9 | 9 |
| Civico Museo Archeologico di Milano | 472 | 325 |
| Total | 527 | 380 |

| UJA-CAAI | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Oppidum Puente Tablas | 28 | 28 |
| Cemetery of La Noria (Fuente de Piedra, Málaga) | 52 | 52 |
| Cemetery of Piquias (Arjona, Jaén) | 47 | 47 |
| Sculptoric group of Porcuna | 81 | 40 |
| Burial Chamber of Toya (Jaén) | 3 | 0 |
| Rockshelter of Engarbo I and II (Santiago-Pontones, Jaén) | 4 | 2 |
| Cemetery and site of Tutugi (Galera, Granada) | 29 | 7 |
| Burial Chamber of Hornos de Peal (Peal de Becerro, Jaén) | 5 | 5 |
| Sculptoric group of El Pajarillo | 9 | 0 |
| Sanctuary of Castellar | 64 | 27 |
| The Provincial Museum of Jaén | 150 | 16 |
| The archaeological site and the museum of Castulo | 60 | 0 |
| Hill of Albahacas | 52 | 22 |
| Wall of Ibros | 1 | 1 |
| Wall of Cerro Miguelico | 1 | 1 |
| Total | 586 | 248 |

| VisDim | No. of 3D Models | WP3 Completion of Digitization |
|---|---|---|
| Historical reconstruction of Ename village, Belgium | 50 | 50 |
| Total | 50 | 50 |