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Questa è la Versione finale referata (Post print/Accepted manuscript) della seguente pubblicazione:

Original Citation:

Innovative survey methods for the digital documentation of vernacular architectural Heritage in Syria / G. Tucci; V. Bonora; A. Nobile. - In: THE INTERNATIONAL ARCHIVES OF THE PHOTOGRAMMETRY, REMOTE SENSING AND SPATIAL INFORMATION SCIENCES. - ISSN 1682-1777. - ELETTRONICO. - (2009), pp. 0-0. (Intervento presentato al convegno XXII CIPA International Symposium "Digital Documentation, Interpretation & Presentation of Cultural Heritage" tenutosi a Kyoto nel 11-15 ottobre 2009).

Availability:

This version is available at: 2158/373411 since:

Publisher:

Yutaka Takase

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12 May 2024

INNOVATIVE SURVEY METHODS FOR THE DIGITAL DOCUMENTATION OF VERNACULAR ARCHITECTURAL HERITAGE IN SYRIA

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KEY WORDS: Laser scanning, Cultural Heritage, Photogrammety, Traditional building techniques

ABSTRACT:

In rural villages to the south of Aleppo (Siria), dome-shaped buildings made of adobe were studied in the Culture 2007 European research project *Coupoles et Habitats. Une tradition constructive entre Orient et Occident: les villages de Syrie du Nord*; these buildings represent an exceptionally important historical-architectural heritage. The objectives of this project include the study and understanding of the cultural heritage shared by East and West and attention is also focussed on the preservation and protection of local traditional building techniques.
The basic unit of these buildings is defined by a volume that is almost a cube; the very thick walls of variable height (usually between two and three metres) are covered by a pseudo cone-shaped dome with horizontal courses, constructed entirely in sun-dried bricks.
The spatial continuity of the domes and the consequent lack of sharp edges create difficulties for traditional surveying methods.
To over-come these limits our scientific unit used classical topographical surveying techniques to realize the topographical net, 3D scanning systems for the detailed survey and photogrammetric systems for obtaining rectified images and orthophotos.
The study was carried out on some vernacular dwelling units whose typology, size and layout were considered typical: Er Raheb, Oum Aamoud Seghir, Joub Maadi.

1. THE SURVEY CONTRIBUTION TO A CULTURE 2007 RESEARCH PROJECT

The dwellings that constitute the villages in northern Syria are characterised by the use of domed roofs, realised in adobe, which confer to the agglomerate the skyline of a nomad encampment, evoking images of the tents of Bedouin tribesmen, from whom the local population descend. They are formed by a more or less linear sequence of single or double "cells", positioned in turn around a "court" devoid of any urban planning of the whole, fruit of a process of auto-construction based of the necessities of single family groups. Dome-shaped buildings made of sun-dried earth were studied in the Culture 2007 European research project *Coupoles et Habitats. Une tradition constructive entre Orient et Occident: les villages de Syrie du Nord*. The objectives of this project include the study and understanding of the cultural heritage shared by East and West and attention is also focussed on the preservation and protection of local traditional building techniques.
In our case, the investigation of the locally observable examples has lead to these structures being grouped into two "categories": "simple dome" and "Sultanya dome". A deeper analysis however offers (with the variation in the system of junction between the vertical support structure and circular springer level of the dome), a range of solutions so vast and ambiguous to render far from easy their classification as one or the other.
This attests to the limits of any procedure of taxonomy inclined to undervalue the "differences" considered accidental, or secondary, respect to the presumed "identity" type-morphology.
In the case of spontaneous architecture we find ourselves in front of a situation intermediary between handcrafted objects, in themselves unique, and serial production, as the reference to "types" and technical procedures "codified" by local traditions guides the user-maker to realise dwellings that adhere to an identical paradigm, but that differ between themselves in some "secondary" characteristics.

By some it has been proposed to define the survey of historic buildings as an operation that would consent the reconstruction of the project (Migliari, 2004). An assertion that presupposes conditions are not only unfound in the majority of buildings realised from a "project" (to which they almost never correspond, in that they are fruit of a more or less numerous alterations in the course of realisation), and whose present physiognomy is derived from the incessant transformation, over time, of the "original", but which are completely missing in "spontaneous" architecture. The survey operation has since been set up and managed irrespective of this hypothesis, rendered even more disputable by this scenario, in the precise intent to provide the most complete and faithful documentation possible of this architectural heritage, at risk of "extinction", capable of being continually updated and integrated.

Figure 1. Joub Maadi: view during the 3D scanning survey

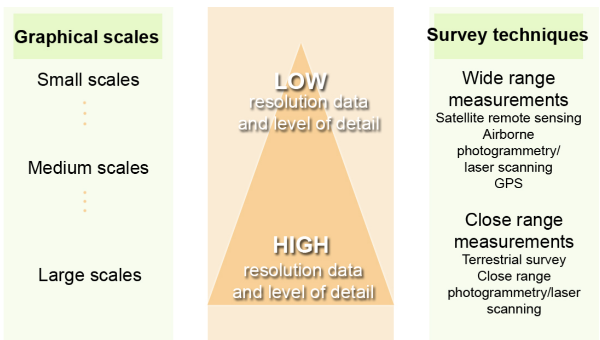
1.1 Metric documentation: the geomatic contribution to the Project

Metric documentation of Cultural Heritage requires a thorough understanding and careful observation of the site and suitable graphic restitution of the data collected as well as dimensional quantification using appropriate instruments.
Documentation projects are particularly important in cases where the heritage is, for whatever reason, in a precarious state. The Syrian villages studied are certainly a valuable heritage but they are also vulnerable, the risks to which they are exposed being mainly related to human activities and environmental factors. It is, therefore, important to collect documentation as thoroughly as possible: geomatic methods can be applied to generate permanent records from which information can be extracted.
We believe that complexity is an inspiring challenge and that contingent difficulties constitute an effective stimulus to finding better solutions, so we have listed some of the factors that made it so interesting to participate in this project.
- our preliminary knowledge of the villages we explored was limited so a certain flexability was required when setting up the on-site survey operations;
- instrument use was constrained by environmental and climatic conditions;
- the presence of experts from diverse fields highlighted the existence of different requirements for spatial data collection.

Recording is a key activity in the conservation management of Cultural Heritage. Conservation-related information is usually obtained (certainly in the case of this project) from multi-disciplinary research activities. In teams with multi-disciplinary expertise geomatic techniques are used to construct a reference base that enables all members to meaningfully participate in both investigative procedures and project development and application.

2. SURVEY ACTIVITY ON THE FIELD

Recording should be undertaken to a level of detail that provides the information required for appropriate and cost-effective planning and development. The need to provide documentation at different scales highlights the usefulness of integrating the various level of detail in the same project.



At the apex of the pyramid-shaped drawing are the inventories, the most basic form of documentation. They require "identification": in our case every village had to be first recognized, then geo-referenced and memorised; sometimes other basic attributes were associated with a given position. At the base of the pyramid drawing are the highly detailed 3D models, where the level of detail is such that even the texture of the constituent materials is described. The various operations undertaken in the Syrian villages occupy the middle area of the pyramid:
- positioning the various villages in the territory, having first confined the study area to the west of the salt lake, close to Hama and to the west of the Euphrates; the borders are obviously flexible and depend on "discoveries" and indications collected on-site;
- documentation of the arrangement of the settlements, i.e. the spatial relations between the habitative units which, despite being quite autonomous, share spaces of which the "pseudo-urban" nature is one of the elements being studied;
- survey of a single dwelling, including the rooms used for living, the central court and the accessory structures (oven, stores, animal shelters);
- documentation of the technological and structural characteristics of a typical cell.

2.1 Survey techniques and methods

Survey methods and the resulting documentation have been planned in order to meet project requirements and objectives and to be appropriate for the cultural context and the resources available.
Geomatic techniques are almost always non-intrusive as remote sensing is deployed at a distance from the object being surveyed. This technique has the advantage of completely preserving the object but it can usually only be used on the external surfaces of the object.
In this context the term multi-resolution survey is appropriate because data density is gradually optimised by applying different instruments or by regulating the acquisition parameters: in this way the information density is correlated with the formal complexity of the object to be measured. If we consider a village observed from a long distance, i.e. from a view point that sets it in the context of the surrounding territory, it can be represented as a point on a map or on an aerial photo, or stored in a DB as standard longitude and latitude coordinates. Moving the observation point closer, it may be useful to schematise the structure of the buildings that make up the village. To this end the buildings can be considered modular. The modules are defined with an approximation that highlights only the most relevant dimensional differences of the cells without making the description less effective. It is possible to distinguish larger and smaller modules (the first are generally used for dwellings or as stores, the second as kitchens, ovens or secondary rooms), identify the open areas associated with the modules, ascertain the position of the mastaba and indicate the presence of external dividing walls.
A more detailed observation will focus on just one of the dwellings: at this scale the following factors have to be considered: are the structures aligned or not; how do the dwellings vary with respect to the module; what type of terrain morphology (particularly important for water drainage); how are the dwellings aggregated (isolated, aligned along a road or path, grouped in other ways).
When the observation point is moved even closer the technological elements of the structure are revealed: arches which connect the internal spaces, niches in the brick-work, openings for aeration,

Figure 2. Joub Maadi: plan and elevation of the dwelling studied

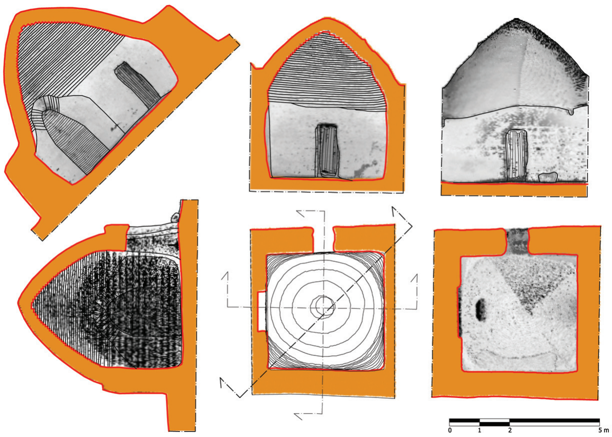


Figure 3. Oum Aamoud Seghir: a large scale drawing of a single habitative unit

window and door frames, the integration of elements in wood and stone in the architraves of the openings, the *tantours* of the cupolas, individual bricks. Manual inspection, sketches and recording of detail are usually indispensable at this analytic scale.

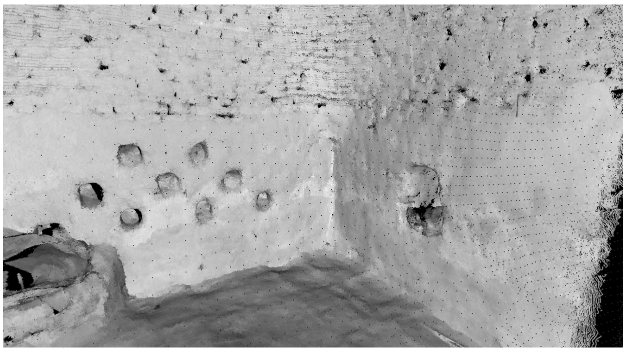


Figure 4. Technological elements are clearly visible in the 3D model: the picture shows a small niche (on the right) and some openings for aeration (on the left)

To obtain such results a possible approach is to combine different sensors, such as GPS, satellite imagery, total station, photocameras, and laser scanners. A data fusion approach involves measurements at different levels: wide-range measurements are based on satellite or topographic systems, while close-range photogrammetry or laser scanning are suitable for small-scale detailed recording.

A multi-resolution approach requires the application of multi-sensor acquisition techniques.

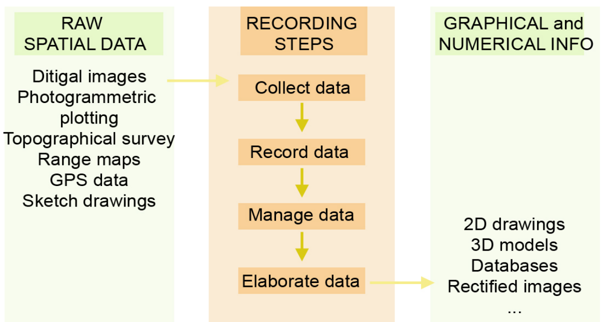


Figure 5. Rapid acquisition on-site is important when distance and inaccessable sites make long survey campains both difficult and expensive. Among the factors influencing the choice of instruments used in Siria were portability and operational autonomy. A GPS receiver, a total station, a digital camera, and a laser scanner were used.

The presence of different scales in the same survey project shows the usefulness of integrating the various levels of detail.

On the technology side we currently have a broad range of recording techniques at our disposal: these need to be combined in order to best match project requirements because of the complexity of some heritage structures and the lack of a single method capable of providing satisfactory results in all measuring conditions.

The principle that can be derived from the above-described approach is the same as that which guides all correct survey procedures: it prescribes starting with general information and then proceeding to more specific detail, i.e. a very small number of points are ascertained with high precision (the number of points has to be kept as low as possible because mensurative operational costs increase proportionally to the degree of accuracy required). A "cascade" procedure utilizing measuring procedures that become increasingly simple is then adopted to determine the detail points that describe the form of the object.

A common reference system, usually defined by topographic parameters makes it possible to acquire different objects and to highlight the relationship between them.

It is important that the data acquired in the various phases be subjected to quality controls; i.e. its usefulness and accuracy should be checked.

3. DETAILED SURVEYING

3.1 Topographic survey

The topographic survey in Syria was divided into the following sequential phases:

- The topographic net;
- Measuring signalised points (required for photogrammetry and/or laser scanning);
- Detailed surveying.

A total station topographic survey was carried out in the Arbaia and Rasm al bugher villages using celerimetric measurements: the process was quite fast because no redundant measurements were taken. The celerimetric measurements were used to ascertain the size and the shape of the units being analysed: this information was obtained by considering the objects being surveyed as composed of a series of connected straight lines, with each line being determined by two points. When total station is used the point to be determined has to be collimated prior to the topographic measurement (collimation is the accurate identification of a point using the telescope attached to the instrument). Each point has to be highlighted simultaneously on a sketch or on a photo that then becomes a vital part of the graphic

Figure 6. Oum Aamoud Seghir: a closed transverse was defined around each dwelling, spurs of one or maximum two lines branched off to ensure that all internal and external spaces were included

Figure 7. Oum Aamoud Seghir : view of the point model of a dwelling

documentation. The points measured should be those of most significance for the description of the object so that the survey can be completed in as short a time as possible and with optimum results in terms of the approximation of the shape considered. The formal and material characteristics of the dwellings being studied have significantly limited the usefulness of this kind of survey technique. The soft outlines of the domed dwellings, the corners of the building rounded by a thick layer of plaster and the surface irregularities increased the difficulty of recognizing which points were the most significant for synthesising the shape of the dwelling units.

3.2 Laser scanning survey

The study was carried out on some vernacular dwelling units whose typology, size and layout were considered typical: Er Raheb, Oum Aamoud Seghir, Joub Maadi.
Er Raheb: open dwelling unit made up of two pseudo cone-shaped domes connected by an arch. Used as a dwelling.
Oum Aamoud Seghir: dwelling unit closed-in by surrounding buildings. A system of pseudo cone-shaped domes, some single and others connected by an arch, used as a dwelling, as a shelter for animals, for storage and for agricultural purposes.
Joub Maadi: dwelling unit closed-in by surrounding buildings. A series of single truncated cone-shaped domes, used as a dwelling, as a shelter for animals, for storage and for agricultural purposes.

Unlike celerimetric surveying (where the point to be measured is selected, collimated through a telescope, and then measured), scanning systems use entirely automatic procedures to enable the rapid acquisition of a huge number of points. Once the instrument has been set and positioned, it performs a "scan" of all the surrounding space by sending a laser spot with high frequencies and a very small angular step. In this way, all visible surfaces are sampled, similarly to what happens when a paper document is scanned with a flatbed scanner. A laser scanner survey provides a digital model of the object, consisting of all the points measured on the surface of the object: it is therefore three-dimensional. It is obvious that the correspondence between the object and its model is proportional to the resolution used and to the density of the points. Adequate documentation of the Syrian dwelling units was produced using a laser scanner: the distance never exceeded a few tens of meters in order to obtain an average resolution of about a centimetre.
These procedures enabled a great deal of information to be obtained from the cloud of points: the way the various cells aggregate to form a dwelling unit; the internal lay-out; the pattern of the brick-work used in the construction of the different dome typologies; technological details such as ventilation openings, door frames and niches. The automatism that characterizes the measurement phase means that "everything" that is visible from the scanning position is surveyed: in the final model not only the walls of the dwellings are recognizable but also all the objects found inside: rugs, cushions, shelves and a few pieces of furniture. These objects were not moved prior to the survey to reduce the invasiveness of the team's presence and to allow the documentation of socio-cultural and anthropological aspects as well.
An HDS 6000 (Leica Geosystems) laser scanner, characterized by a rapid rate of acquisition (up to 50.000 points a second) was used: in the survey conditions here described between 3 and 10 minutes were required for each scan. The rapidity of this surveying technique meant that the extreme sensitivity of the laser scanner to environmental conditions and especially to high temperatures did not have a significant impact. During the two weeks of surveying on-site (from 26th May till 13th June 2008) 3D scans were taken only in the early hours of the morning before the temperature exceeded the maximum limits for effective operation of the instrument.

Scan alignment

Each scan is initially acquired in a local system whose origin lies in the centre where the instrument is stationed. The importance of expressing all the metric data in a single reference system, determined by the topographic frame of reference, has already been emphasised. The transformation of the data acquired from the individual local systems to adapt it to the fundamental topographic system takes the name of "scanning alignment"; this process is carried out using signals placed on the scene and surveyed, as described above, as control points. The coordinates of these signals are therefore known in both the local scanning system and in the topographic system; this makes it possible to

determine the roto-translation that has to be applied to all the points of each scan to "align" them" to the topographic system. Signal recognition can take place automatically, thereby speeding up the alignment phase and limiting operator intervention to the verification of the results obtained. If a scan does not have at least three clearly recognizable signals then natural points can be identified manually.
After the scans have all been aligned it is possible to carry out global compensation: an ICP type algorithm is applied to further reduce any residual distance between corresponding surfaces in adjacent scans.

3.3 The photogrammetic survey

For one of the dwelling units surveyed in the village of Er Raheb it was considered advisable to integrate the detailed geometric information obtained from the 3D scans with other information of a photographic nature. So photogrammetric shoots were realised and then oriented in order to obtain highly accurate ortho-photos of all the elevations of the dwelling. Ortho-photos are photographic documents in which perspective deformation and local variations of scale, characteristic of central projection (and of photography), are corrected zone by zone. It is possible to read dimensions and evaluate surfaces from these ortho-photos in a similar way to an elevation represented in orthogonal projection. Another benefit comes from the complete documentation of the objects being studied which is not confined to the corners or the lines of discontinuity typical of conventional representation; the surfaces of the objects are thus described with photographic quality representing the details of materials, brick-work patterns and the state of conservation.

Figure 8. Orthophoto of the mail elevation - habitative unit in Er Raheb

4. GRAPHIC OUTPUT

The three-dimensional points model obtained after aligning all the 3D scans constitutes a real data base: it is an extremely dense and sufficiently accurate "information depot" from which all the required graphic output can be successively derived.
The wealth of information contained in these models is valorised by the possibility of visualising and exploring them interactively with the appropriate software. The model acquires in fact the role of significant referent of the object, and it is possible to observe the model as if it were the object itself: the model rather than the building itself can be deployed for dimensional evaluation, analysis of constructive details and anthropological considerations, with all the advantages that derive from the possibility of operating at different times and in different places.
A first approximate technical classification of the graphic output that was obtained from the points cloud distinguishes the bi-dimensional documentation from the tri-dimensional and the raster documentation (composed of images) from the vectorial. A standard "from the general to the detail" approach was adopted for determining the information presented in the various documents proceeding, for example, from the realisation of environmental sections which insert an entire dwelling unit in its context, to representations of the details of characterising typological elements, such as the profile of the dome, the wainscoting of the walls, the base of the pendentive, the brickwork structure and the openings.

4.1 Section profiles and contour lines

Aeffective way of synthesising the three-dimensional conformation of the dwelling units in vectorial and bi-dimensional output is to extract section profiles from the points model: a very thin layer of the points cloud, delimited by a couple of parallel planes which can be either horizontal or vertical, is isolated and then exported and vectorialised using CAD software. Environmental sections for dwelling units in Oum Aamoud Seghir and Joub Maadi were created using this method. Other units were investigated at the scale of the cell, realising one horizontal section (about 1 m from the floor and vertical sections (longitudinal, transversal and diagonal). While the longitudinal and transversal sections, associated with the plan, reflect the standard bi-dimensional documentation that is capable of completely describing the three-dimensional space of the dwelling units, the addition of the diagonal section takes into consideration the requirements of structuralists to obtain precise information on the corners of the square box at the base.
Representations that are less synthetic that those obtained from sections following coordinated planes were realised using contour lines, These representations proved necessary because it was particularly difficult to highlight the lines of discontinuity on the objects examined in any other way. The equidistance of the contours was differentiated as a function of the morphological complexity of the building portions analysed: profiles were extracted every 50 cm starting from the impost of the dome and finishing with the closing element (tantour), integrated by profiles every 10 cm for the entire pendentive. Structural research has in fact been concentrated on this element which unites the square perimeter and the circle of the impost of the dome.

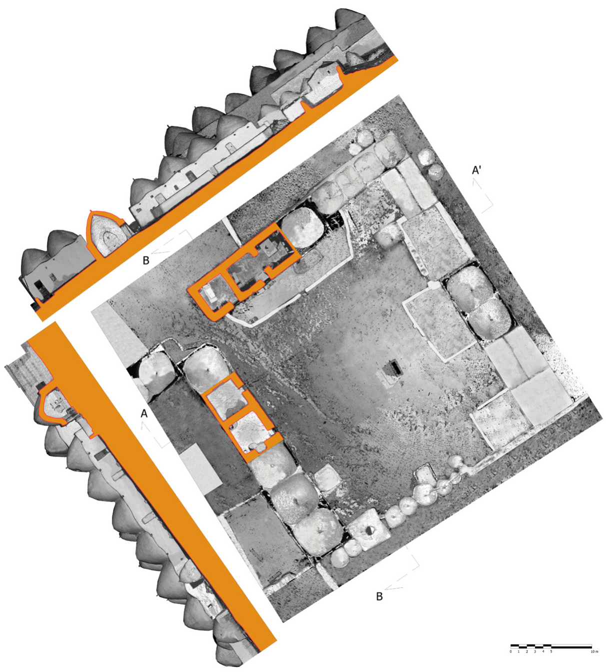


Figure 9. Section profile of a dwelling in Oum Aamoud Seghir

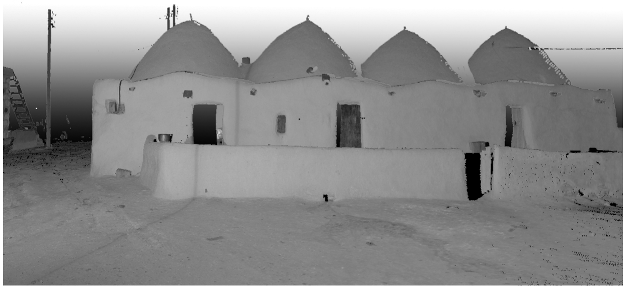


Figure 10. Orthogonal image of the 3D model

4.2 Orthogonal images from points cloud

To complete the geometric-dimensional information provided by the section profiles, all the documentation was integrated with orthogonal images of the points model; although these images are not really photographic images they manage to effectively evoke the material and chromatic characteristics of all the elements that appear in these representations.

4.3 Surface models

Al model acquired using 3D scanning is inevitably discrete because it is made up of points but it can be made continuous by using "triangulation" to create a surface model. Triangulation generates a "mesh" and the minimum elements of this mesh are no longer undifferentiated; but are organised following a definite topological structure. The minimum element of the model is made up of triangular-shaped portions that describe the object with a level of detail inversely proportional to their size (the smaller these elements are the more of them there are). The geometric simplification of a model means that superficial details are obliterated thereby making the model more manageable.
Surface models were prepared for both the dwelling units surveyed at Er Raheb.

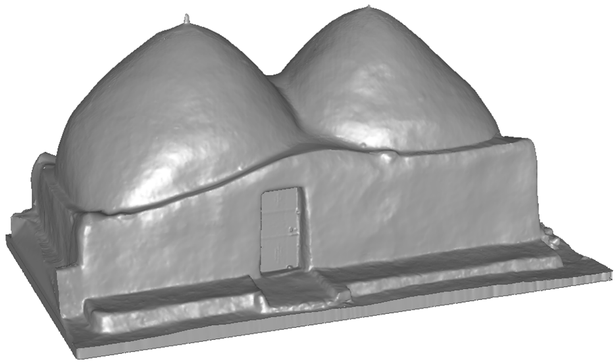


Figure 11. Er Raheb: surface model of a double habitative unit

4.4 Solid models

Finally, reduced-scale solid models are an effective support for projects involving communication and divulgation: they can be understood without the intermediation of data processing systems which increases the number of potential users.
A 1:20 scale was used for the models of the dwelling units of the village of Er Raheb: this ensures that the final model, made up of a series of thin layers, retains a high degree of detail, making it possible, for example, to distinguish the different types of wall texture or to recognize minute details.

Figure 12. Solid model

The Culture 2007 European research project *Coupoles et Habitats. Une tradition constructive entre Orient et Occident: les villages de Syrie du Nord* is coordinated by Prof. Saverio Mecca, University of Florence (UNIFI e INN-LINK-S Research Center on Innovation and Local and Indigenous Knowledge Systems).

Prof. Grazia Tucci, University of Florence, is the scientific supervisor of the team involved in Geomatic researches.

Research units:
- Università degli Studi di Firenze (Italy, Coordination)
- Hellenic Society (Greece, Co-organization)
- Université de Liège (Belgique, Co-organization)
- CNR - ICVBC (Italy, Co-organization)
- Ecole d'Avignon (France, Co-organization)
- Universidad de Valencia (Spain, Co-organization)
- Direction Géneral des Monuments et des Antiquitès (Syria, Partner)

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