3D scanning a hominid fossil excavation site
A preliminary study at Trabuc's cave, France
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Participants:
José Braga[1], Professor, AMIS Laboratory, University of Toulouse, France
Laurent Bruxelles[2], TRACES Laboratory, INRAP, Toulouse, France
Jean-Pierre Jessel[3], IRIT, University of Toulouse, France
Gérard Subsol[4], LIRMM, CNRS, Montpellier, France

1. Introduction

3D scanning a hominid fossil excavation site will be useful for three kinds of application:

- *Archiving*. The excavation process is destructive. The excavation record (as scale map, stratification, description of artifacts and bones, photographs, scale drawings, etc.) is all that remains. 3D laser scanning will record the entire surface geometry of the excavation site at a given time. In particular, such exhaustive data could be analyzed several years after the acquisition, for research topics which were not defined at the time of the excavation.

- *Fossil analysis*. It will allow putting accurate 3D models of the fossils (which will be acquired after the excavation) back in the 3D model of the environment. More specifically, this will allow paleontologists to quantify precisely the orientation and the location of the fossils in relation with the various flowstones and their samples taken for absolute dating. This may also lead to better understand taphonomic deformations and/or fragmentation of the skeleton, or to correlate the positions of the bone with respect to the geologic environment.

- M*useograph*y. A digital 3D model could be presented to the general audience either by using multimedia workstations in the Museum or on a Web site.

We can find description of some very recent research in *[McPherron et al., 2009] and [Rüther et al., 2009]*.

We used a Minolta Vivid 910 scanner which is based on a laser light-stripe method to measure around 300,000 points in 1 second. In addition, a 640×480 color image of the object is also obtained. The technical description of the Minolta Vivid 910 scanner is available in an annex file.

Three lenses are available: TELE, MIDDLE, and WIDE.

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[1] *http://www.anthropobiologie.cict.fr/Personnel/BRAGA_Jose.html*
[2] *http://traces.univ-tlse2.fr/1255534041781/0/fiche___annuaireksup/&RH=annuaire_traces*
[3] *http://www.irit.fr/~Jean-Pierre.Jessel/*
[4] *http://www.lirmm.fr/~subsol/*

- MIDDLE will be used for most of acquisitions. It gives a field of view of around 0.7 × 0.7m at a distance of 2m with an accuracy of about 0.4mm.
- WIDE will be used to or to scan the walls of the cave. It gives a field of view of around 1.7m × 1.7m at a distance of 2m with an accuracy of 1.5mm.
- TELE could be used for detailed scanning of some fossils. But in our application (getting a 3D acquisition of the overall excavation site), it may be not very useful. It would be better to scan these fossils with volumetric and accurate devices as CT-Scan after their excavation.

In the following experiments, the acquisition (in fact, the superimposition of 3 acquisitions with different parameters) takes a couple of seconds and data are sent to a connected computer. Data can be archived in standard format (ex. stl, obj, ply) which makes possible to visualize, interact, analyze and edit with commercial (as RapidForm[5] or Geomagic[6]) or free (as MeshLab[7]) software.

2. Setting-up the scanner



The scanner with its tripod weights about 20 kg. It is quite easy to move.

José Braga (left), Jean-Pierre Jessel (right) and Gérard Subsol (lying) setting-up the scanner.

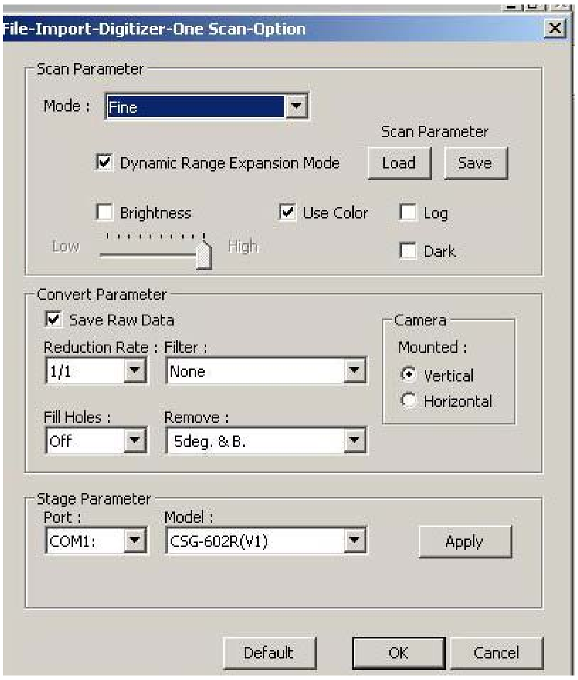
[5] *http://www.rapidform.com/*
[6] *http://www.geomagic.com/en/*
[7] *http://meshlab.sourceforge.net/*

The installation itself- installing the scanner on the tripod, pluging-in, and connecting to a computer - took a couple of minutes:.

We installed also one standard 500W projector. It appears that this is sufficient to obtain precise 3D information but the color images are not good quality (very low contrast and only orange color range). Moreover, it was not very convenient as we have to move the projector according to the area to scan. Using only one projector created also a lot of shadows.

The best acquisition angle is about 30 to 45 degrees with respect to the area to scan. This limits the shadows (and then the occlusions) while maximizing the field of view.

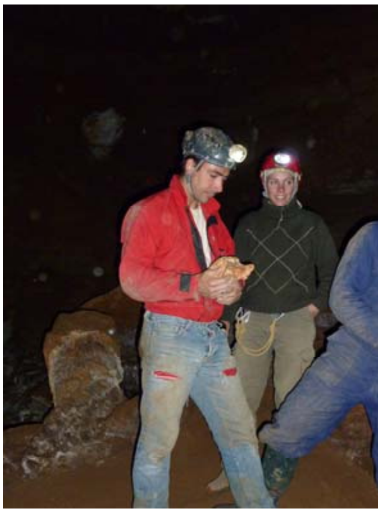
We tested several sets of parameters and we found that the following ones gave good results.



With these parameters, one acquisition shot results in a file of 3,605Ko (in .cdm which is the native format of the Minolta system) or around 35,000Ko (in .vvd which is the 3D mesh reconstruction Minolta format .vvd) or around 15,900Ko (in .obj which is a standard 3D mesh format and in .bmp which stores the texture of the 3D mesh).

⇒ There should be no problem to transport and set-up the equipment in Little Foot's cave.
The requirements are electrical supplying for the scanner (power: 60W) and the computers and lighting.
For lighting, the best would be to have indirect (to avoid shadows), uniform lighting all over the Little Foot's area. Moreover, "natural lighting" bulbs could improve the quality of color acquisition.

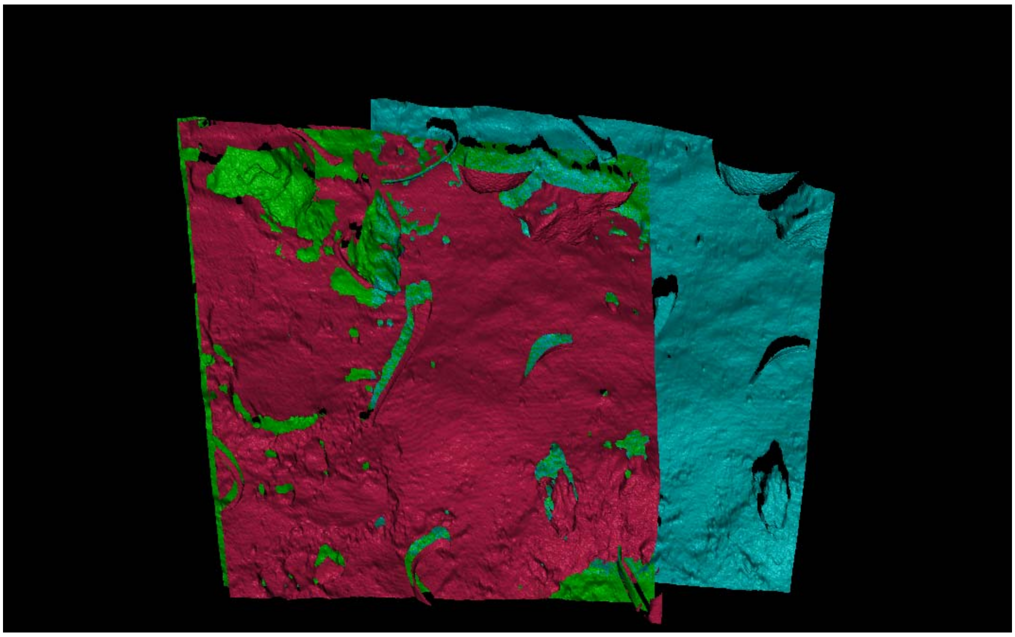
3. Scanning the excavation area


Laurent Bruxelles prepares the fossils for the simulated excavation area….

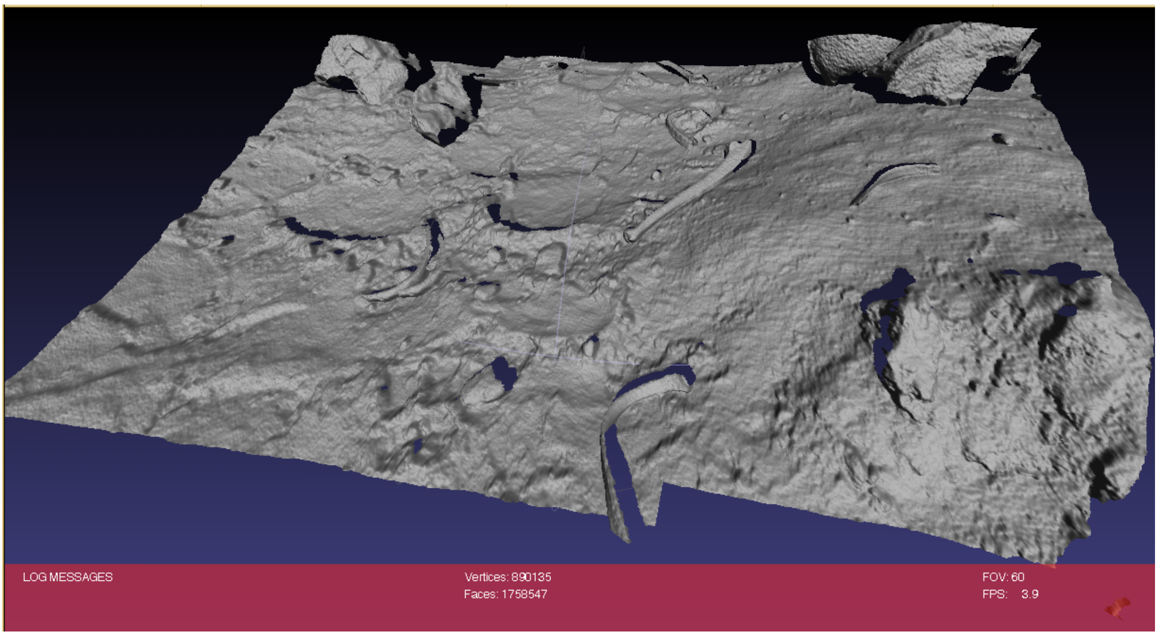
We created a fossil excavation area by dispersing some bones (skull, hand, rib, and a long bone) on a 3×2m area and we scanned it with the MIDDLE lens. We took 3 different views which overlap of about 20-50% between 2 views..

The dimensions acquired by the scanner are real ones; there is no need of any metric calibration.
The orientation of the views (given by the vertical axis in the views) depends on the tripod orientation which is roughly measured by a level.

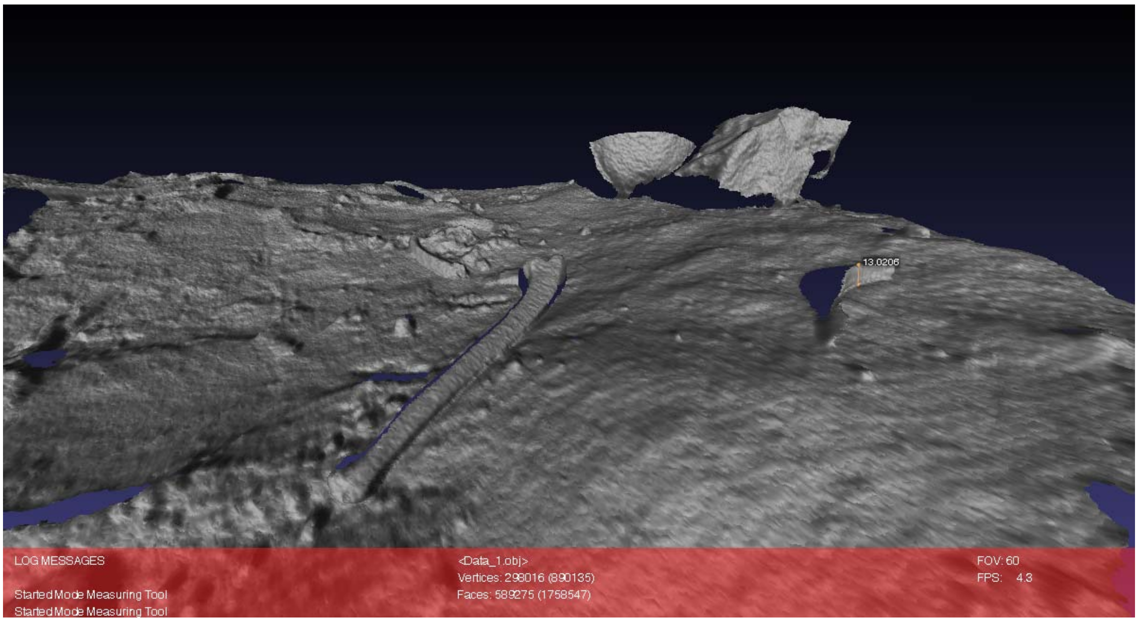


Acquisition 1: the 3 different views before registration.

The automatic registration of the 3 views was successfully performed, leading to a 3D reconstruction of the excavation area with pretty good details. The length of the long bone is around 22cm and the height of the right rib is 13mm only.

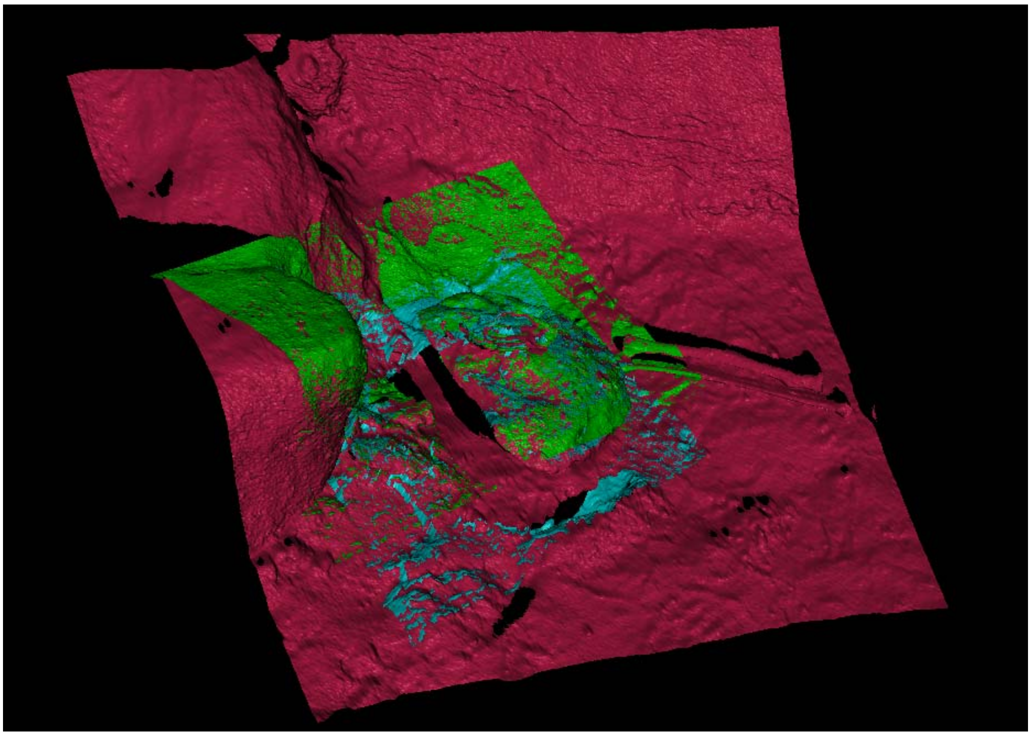


Acquisition 1: registration of the 3 different views.



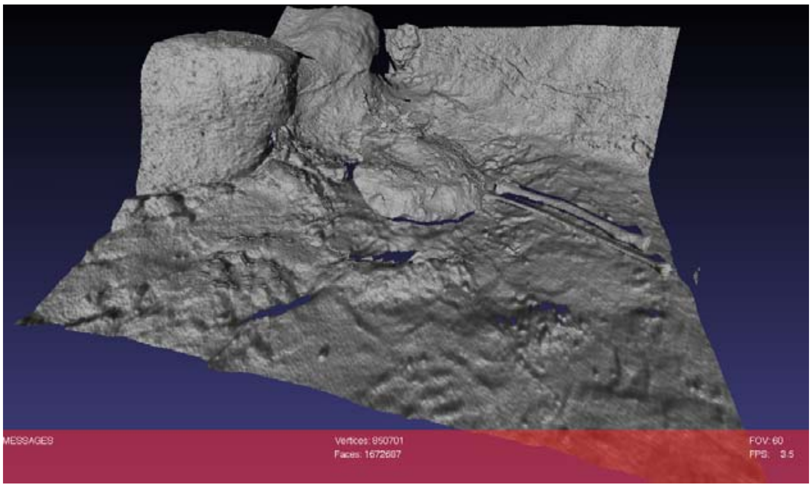
Zoom on Acquisition 1 showing details around the long bone.
Its measured length on the screen is around 22cm

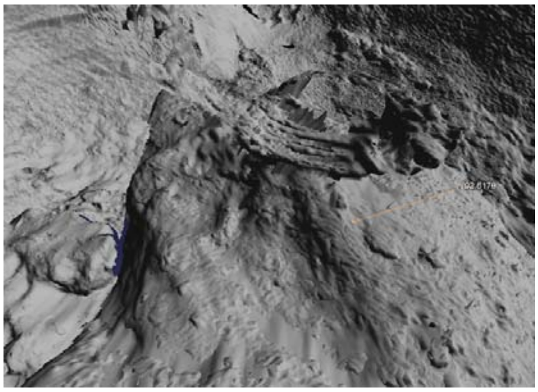
We did a second acquisition of an other area centred on bones of a hand. Three acquisitions were performed at different distances as we can see on the following Figure.



Acquisition 2: the 3 different views were taken at very different distances (and then with different field of views)

The different bones of the hand are not very accurate as we used the MIDDLE lens but the 3D reconstruction of its environment is very good. The length of the orange line is 9.2cm.





Acquisition 2: registration of the 3 different views.
Zoom on the bones of the hand: the length of the orange line is 9.2cm.

It is fundamental to plan carefully the points of views in the acquisition process. The views must overlap in order that the automatic registration algorithms perform well and must be taken from at least two opposite directions in order to reduce the occlusions.

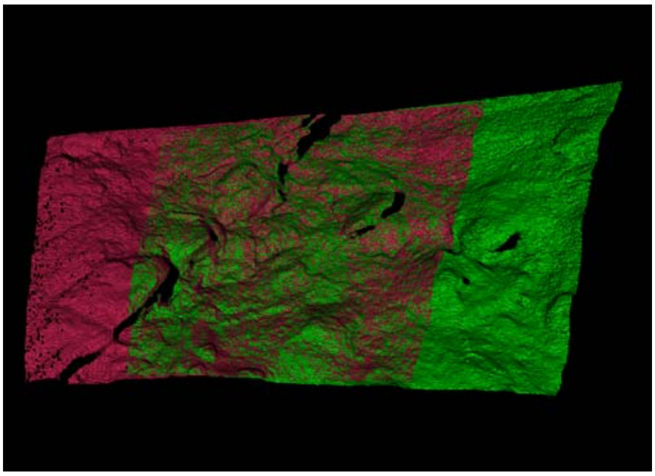
⇒ It is possible to scan the excavation area around Little Foot with an accuracy of at least 1 to 2mm.
At the beginning, some time (half day?) must be devoted to the planning of the acquisitions in order to scan the whole excavation area (around 10-15m^2) as precisely and exhaustively as possible.
We can estimate that around 25-75 scans should be required, which is feasible in 3 to 4 days.
Registration (a least a rough one) must be performed just after an acquisition to be sure that data are correct and may be used in the future. The software delivered with the scanner features a registration algorithm which is fast and very easy to use.
A vertical (or horizontal) axis should be scanned in order to orient all the views.

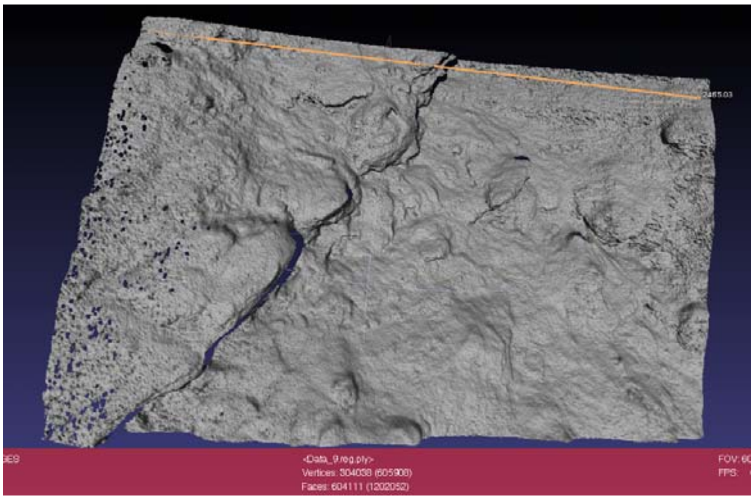
4. Scanning the cave (walls and floor)

In this experiment, we wanted to test the possibility of scanning larger areas of the cave (walls or floor) in order to get an overall 3D survey of the excavation site. In particular, this would allow the location of the fossil area in relation with some reference landmarks which are defined all over the cave (e.g., the datum point).

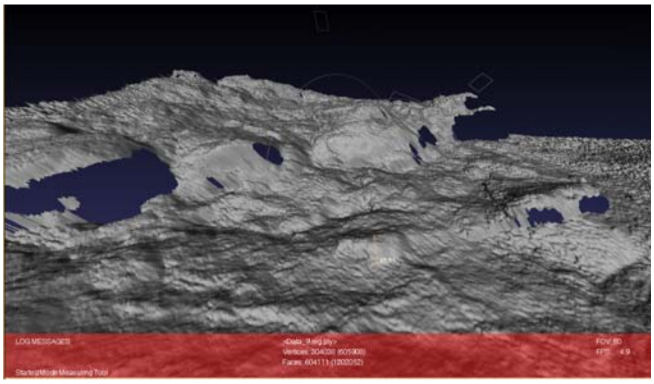
We use the WIDE lens which gives a field of view of around 1m $\times$ 2m at a distance of 2-3m with an accuracy of 1 to 5mm.

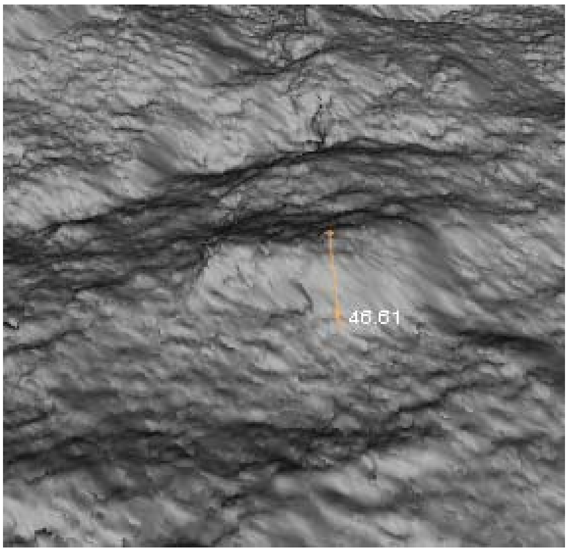
The automatic registration of 2 views was performed successfully leading to a 3D reconstruction with good details. The length which is measured in the right Figure (orange line) is 2.4m.





In the following right Figure, we zoom on a small bump in the middle of the 3D reconstruction. Its height is 46.61mm and this reference scale allows one to evaluate the accuracy of the scan.





⇒ It is possible to scan the areas around the Little Foot fossils in order to have an overall 3D model of the site with some parts of the walls.
It will allow us to scan the datum point and to make the connection with the Little Foot area.
Details are also sufficient to be able to distinguish (at least some quite thick) geological layers.

5. Some recent references

[McPherron et al., 2009] S. McPherron, T. Gernat, J.J. Hublin. "Structured light scanning for high-resolution documentation of in situ archeological finds". Journal of Archeological Science, 36, 19-24, 2009.

[Ruther et al., 2009] H. Rüther, M. Chazan, R. Schroeder, R. Neeser, C. Held, S.J. Walker, A. Matmon, L.K. Horwitz. "Laser scanning for conservation and research of African cultural heritage sites: the case study of Wonderwerk Cave, South Africa". Journal of Archeological Science, 36, 1847-1856, 2009.

Thank you to all the staff of the Trabuc's cave for their help and their kindness!