Interactive digital representation of Sasspol temples

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Near Alchi, Ladakh region, from Jammu & Kashmir state – India, is Sasspol, a small village - not that well known location that hides beautiful cave- painted- Buddhist – temples. This paper presents activities regarding 3D laser scanning of two of the painted caves, a first temple in a good conservation and a second temple with a residential side in ruins. Except of these two temples, other remains of temples exist, some with remaining paintings, but they are hardly identifiable, even harder to access and badly collapsed. Beside the 3D acquisition where taken samplings from different areas to distinguish the red pigments used. Investigated methods consists in laboratory spectroscopic analysis, methods like laser induced breakdown spectroscopy or laser induced fluorescence. The work presented in this paper is part of a scanning campaign, made in August 2008, at the invitation of Tibet Heritage Fund, with measurements including location like Alchi and Leh.

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1. Introduction

The part of described campaign is dedicated to several investigations and measurements based on photonic techniques specialized to cultural heritage prospection. Preliminary research plan included many other method. Unfortunately due of local regulations and administrative reasons only 3D laser scanning, thermovision, and limited material investigation by LIBS (laser induced breakdown spectroscopy) has been carried out.

The locations were chosen due to their very own particularity. At the complex temples from Alchi – Tsatsapuri a wall – painting cleaning, stabilizing and conserving program were developed. At the Red – Maitreya temple wall - paintings recovering and stabilization intervention were carried out. The activities at these two locations were coordinate by THF officials and their request was regarding digital high accuracy documentation of the temples. Except these two location a third one was proposes, cave – temples from Sasspol with the aim of digital recording of the degrading temples.

Temples investigated in this paper are situated in northern part of India, Jammu & Kashmir, region of Ladakh. The caves are placed in a small village, Sasspol (also known as Saspul, Saspol or Sasspul), less than 10 km from Alchi, and the nearest road at 2 km. Measurements were made in two of the temples, that are in a good conservation state, especially the main one.

Additional investigation, not presented in this paper, thermovision, long time microclimate monitoring, LIBS and LIF investigation were performed in order to associate and overlay the results, to make a complex digital model with information from 3D geometric data, to chemical surface composition, (possibly biological (attack) or structural subsurface defects. Furthermore, the information resulted from the spectral technique which will not be presented in this paper, may offer information regarding the pigments used in the area (the temples were built between 13th and 15th centuries.

The campaign had multiple scopes. It was a way to support the restorers' effort with a fast and accurate documentation that included details not delivered by any other method, like: accurate relative positioning of painting on the wall surface, incision depth, extra-thin layer detaches, mechanical degradations position and depth -– which is the subject of the present paper and an opportunity to test on site the feasibility of a self-proposed 3D digital model.

The developed research was addressed to the methods of acquisition and storage information regarding the nature of the material of the artifacts, and about their shape. Substrates morphology and the physical and chemical structure of the object has been also studied by corroborating the information and using the concept of digitalization. So, the cultural patrimony is viewed by different and understood bringing it closer to the actual meaning.

This work is a very good example of the photonics efficiency and usefulness in the field. Nowadays more and more certified research methods from medical and forensic domains are directly or in association used in complex artworks investigation, characterization and description. All means and methods have been selected for complementary delivered information, as non-contact, none or micro-invasive methods, due to their versatility – possibility to use on many sorts of materials, on various degradations, and on large range of working conditions.

The paper will not insist on the critical situation or on the extreme need of many special monuments in the area, but of the possibility to act fast and to save almost instantly accurate and complex information about the structure and composition of many monuments in high risk of irreversible degradation.

This measurements were developed during a 3 weeks campaign, at the invitation of Tibet Heritage Found. Except Sasspol scanning, recordings were also made in Leh – Red Maitreya Temple, Alchi – Tsatsapuri complex temples which are other papers subject.

At an altitude above 3000 m, with no electricity, reaching the top of the hill was, maybe, the hardest part of the 1 day work. Equipped with an electric generator and kerosene, with a power stabilizer, an uninterrupted power supply (battery backup) and scanning system (3D scanner, laptop and a tripod), climbing to the caves was very hard.

The caves are not that well known for touristic routes; also the history of the caves is missing (some dates the caves in 13th century (Ref. 1), and THF's staff place them in 15-16th century (Ref. 2)). Due to time exposure some of the caves are collapsing, due to the geological structure, making the documentation of the ensemble an urgent matter.

On the surface several measurements were performed, including planarity and cracks inspection. The second one was preferred to give an idea about the surface degradation. Ideally, to have a better evaluation of this collapsing, a second scan it's needed, with a time differences between the measurements at least of several months. After that a mesh compare to be computed to check the differences between the two surfaces. So far the most efficient tool in surface comparison proved to be METRO (Ref 3), but in this case several items need to be considered like mesh alignment error of the two surfaces, same points to be measured and scanner limits, including measurements repeatability and accuracy (Ref 4).

Fig. 1. Cave placement.

2. In Situ activities

A complex and accurate documentation is a compulsory research for a correct and effective intervention. On one hand it is a unique instrument of representation, but as 3D digital reconstruction it is a perfect form of urgent rescue of the content information. On the other hand it increases monuments visibility all over the world via digital representation on Internet or on digital media (like CD's), and significantly shorts the real rescue time for each monument. Detailed research and intervention projects elaboration can be done with remote support also during (even harder) accessible months (like winter time).

The photonic techniques has already demonstrated that they can provide extremely rigorous information about the external shape of the object (e.g. the 3D laser scanning) and about the morphology of some "hidden" structures (e.g. the Doppler Laser Vibrometry, holographic interferometry, GPR, etc), about the physical properties of the investigated material (e.g. thermo emission, chromatic value, etc) to which implicitly information is digitalized by the method of investigation/ data collecting and processing. The entire volume of information is thought to be precisely placed in 3D model. (Ref. 5)

The 3D digital model could be considered as a skeleton that helps relative positioning of other information about the surface layer and hidden substrates. All together data are creating a better understanding digital replica from the authors' point of view.

For recording the 3D shape of the caves was used a commercial amplitude modulated phase shifting panoramic 3D laser scanner, using a continuum wave laser, well suited and ideal for this kind of in situ activities.

Laser output power is 15 mW, class 3R, with a λ= 690 nm. It may be scanned objects at a distance between 1.5 and 22.5 m, with 2 freedom degrees, 360^0 on azimuth (horizontal) and 270^0 on elevation (vertical) and with maximum scanning rate of 190 kHz. Information that may be exported either in points or (mapped) mesh format.

Scanner it is PC's controlled, was preferred a laptop, offers a higher mobility, and used 1394 acquisition protocol. In situ activity was concentrate only in data recording, later on, it was processed, photo colouring, meshing, mesh editing and optimisation (Ref. 6). One of the goals was to make all the scans in one day, in this way all the attention was given to acquisition, the processing being made on dedicated 3D processing stations.

In order to obtain the minimum error due to information overlapping an important item to consider was to minimize the number of the measurements, sine the meshes were aligned using pick points ICP algorithm, followed by a finer alignment.

First temple was digitally reconstructed by 3 recordings. The shape of cave permitted that a first general scan to record more than 80 % of the details, the rest of the details being recorded with dedicated measurements.

Minimum distance of recording of 1.5 meters was enough to make a general scanning of the temple, completed with another two scans, to record the feature of the cave, a right wall of the entrance and another wall difference in front of the entrance.

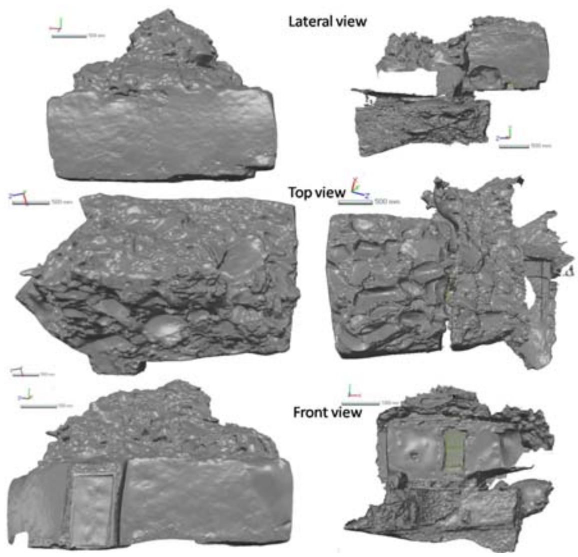

Fig. 2. Views of the two temples, please note the different scales.

This other two scans where made to respect this minimum distance, at an angular resolution of 100 lines per degree, spatial resolution, determined after processing estimation, in this case taking values less than 3mm (comparable with laser beams waist at the scanner exit).

Fig. 3. Corner temple's scan.

Angular resolution of the general scan, a parameter controlled by software was 80 lines per degree. The distance between the interested areas was between 1.6 and 2.3 meters (as seen in table 1), resulting a planar resolution comparable with a digital photo camera from 7 up to 20 MP.

Table 1 Original data scan of main temple

Model	Scan dist [m]	Ang res. [lines*deg^{-1}]	No of points	Scanned area height * width [m*m]
Temple corner	2.5	100	738824	1.7*0.86
North wall	1.8	80	20665403	1.4*6.2
West wall	2.3	80	7675376	1.8*2.4
East wall	2.4	80	14802092	1.5*3.3
South wall	1.6	80	20027952	1.7*4.4
Door scan	1.6	100	7636304	1.4*0.41

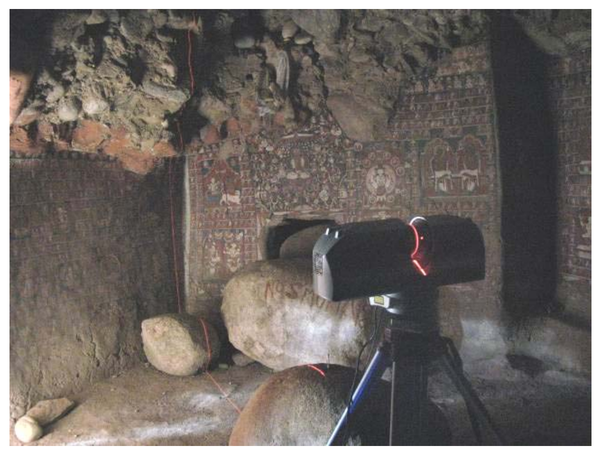

Fig. 4. Main temple general scan - right entrance wall, it may be seen how the laser line crossing the wall

3. Processing

For the available data posted on internet, http://www.tibetheritagefund.org, the model had to be simplified, even thou it may be found some original models with the high resolution available.

The workflow for obtaining this models 3D colour consists in filter applying for the raw data (like insufficient data, gaps, small areas or export mask) (Ref. 7) . After that the information was (x,y,z,I_{red}) ASCII exported. The point's information was then noisy filtered and then photo merged to obtain point of clouds' colour model. This 3D colour points where then triangulate, using 2D algorithm, mostly because of the flat surfaces that where preferred to work.

After obtaining the 3D mesh model, where made some mesh editing and gap filling (if it was needed), colour smoothing or mesh merging (is some cases).

In order to generate the 3D panoramic images the UV maps were generated and exported, maps equivalent with photo images 7200*2500 pixels. These maps are stored in the 4th column of the ASCII matrix. It represents the radiation recorded back to scanner that depends by the scanner – object distance, angular incidence, and surface reflection properties and also by the physical properties of object (reflectivity that also depends by wavelength, conductivity, magnetic permittivity). (Ref. 8)

Texturing the model was only interesting in 1.5 meters, except 20 cm above the floor, as it may be seen in figure 5, also with representation of Vajrapani Bodhisattva. In this representation it may be seen a missing area, that correspond the entrance, that needed a dedicated measurement was made to cover it. (Ref. 9)

Fig. 5. Right entrance wall and figurine of the Vajrapani, Unimaginable Strength

Another task was to identify and measure the walls defects.

Fig. 6. Representation of Avalokiteśvara, the compassion of all Buddha's.

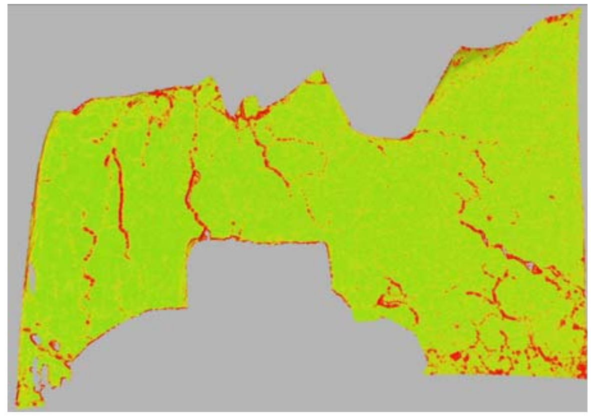

Fig. 7. First temple right entrance wall

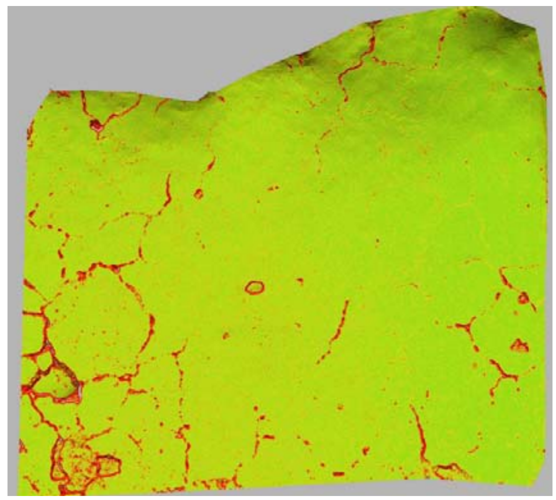

Fig. 8. Second temple right entrance wall.

The model was exported under a mesh format - .obj, that could contain besides the vertex information also the UV map. In order to measure the induced defects no gaps filling was performed. After a first visual inspection of the models, significantly cracks were found on the left entrance wall. On the rest of the walls only detachments can be seen. On this walls plane projections were performed to inspect the non-planarity. The mean deviation is less than 3 mm, for both of the temples, comparable with the model mesh resolution.

For cracks inspection distance measurements between the edges of the defects were arried out. The maximum distance is up to 2 cm in the first temple, respectively 2.1 in the case of the second temple. A vertical distribution was mainly observed, with direction of the propagation from bottom to up. This conclusion comes from the predominant number of chinks at the bottom of the wall and from the distribution of edges distance, lower values of the distance, of the same crack, as it is inspected from bottom to up.

4. Conclusions

Because of various reasons of history and geography, many temples are not well-known, or their conservation been ignored. In the same time they are important themselves because they are magnificent examples of Buddhist paintings of several different styles and, also, because so little works of equivalent quality has survived in the area. So these are surviving exemplars of that culture and period of art that could be restored and conserved just in years (annually, just 3 – 4 months could be allocated for onsite interventions).

Similar texturing algorithm, as the one used form 3D color mapping, will be used to obtain the more complex digital model, with information from structural or subsurface defects, to microbiological attacks or even chemical composition. This kind of work will be performed at the other temples. A first problem may rise from the different kind of imagistic information that are delivered from these techniques so probably a parametric texturing algorithm instead of a projecting one would be more efficient.

The first steps that we suggested and proved are:

- to elaborate digital reconstruction of the 3D form (artwork, historical remain, or building) – a most accurate model of the form, also a common frame of the information delivered by complementary methods;

- to select properly investigation methods for efficient decisions regarding restoration plan.

Moreover, the presented case study, part of the larger campaign, proves efficiency of the photonic techniques' and unvalued possibility to collect in real-time huge amount of information by remote, non-contact, non invasive or micro-invasive methods - standards for increasing the application level and for improving the decision and the scientific and technical efficiency of strategies in restoration work.

A first approach is to make a worldwide accessible digital instrument, in this case models of the two temples from Sasspol caves, that can be visualised on the internet: models consisting in a low resolution one, of the entire temple and in some interesting cases, with a better resolution, detachments or interesting paintings.

An important advantage of proposed working way consists in the determination of the area with high risk of degradation by repeated scanning, and also very important it is the unique technical solution for complex digital replica. Such a digital product allows us to have complex and correct reconstructions in case of hazard.

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