

ARCHITECTURAL PATRIMONY MANAGEMENT IN YEMEN

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ABSTRACT:

On the initiative of Marylène Barret, archaeologist and art restorer working at the French embassy in Sana'a Yemen, and detached at the SFD (Social Fund for Development) of Yemen, professors of the French ENSG (Ecole Nationale des Sciences Géographiques), together with some of their students went twice to Yemen since October 2004 to survey five historic mosques on the point of being restored. Indeed it is assumed that the complete and precise documentation of a monument is already the first step to its preservation. For each of these mosques, classical topometry techniques were used, at first to set up a network of ground control points. The monument's interior and the exterior were then scanned with a laser scanner Mensi GS100. Besides certain parts of the monuments were photographed in stereoscopy, so that 3D plotting and orthoimages could be produced later. The joint use of the very voluminous laser data and images lead Yves Egels to develop a specific software tool, called Cumulus, with which it became quite simple to produce, among other things, sections and orthoimages, which are traditional products that architects and restorers ask for. Both field operations and post-processing of the collected data were also the subject of a specific training provided to a Yemeni team who should soon be in charge of organizing by themselves similar operations as part of a specific unit at the SFD. Today, according to an agreement between the ENSG and the SFD, trainings should go on to make that unit operational as soon as possible.

RÉSUMÉ :

Sous l'impulsion de Marylène Barret, archéologue restauratrice en poste à l'ambassade de France à Sana'a (Yémen) et détachée au Fonds Social de Développement du Yémen, des professeurs de l'ENSG (Ecole Nationale de Sciences Géographiques), accompagnés des étudiants du mastère Photogrammétrie, Positionnement et Mesures de Déformations, se sont rendus au Yémen pour y effectuer le lever de mosquées historiques sur le point d'être restaurées. En effet, la documentation complète et précise d'un monument représente déjà la première étape de sa conservation. Pour chacune de ces mosquées, des techniques classiques de topométrie ont d'abord été mises en oeuvre, permettant la constitution d'un réseau de points d'appui. L'intérieur et l'extérieur des monuments ont alors été scannés par un scanner laser Mensi GS100. Certaines parties des monuments ont par ailleurs fait l'objet d'une prise de vues stéréoscopique destinée à faire de la saisie 3D et des orthoimages. L'utilisation conjointe des très volumineuses données laser et des images a conduit Yves Egels à développer un outil logiciel spécifique, Cumulus, avec lequel il est aisé de produire, entre autres choses, des coupes et des orthoimages, c'est-à-dire les produits dérivés demandés par les architectes. La préparation des missions, leur mise en oeuvre sur le terrain, et le post-traitement des données ont également fait l'objet d'une formation spécifique à l'attention d'une équipe yéménite chargée, à terme, de gérer elle-même de semblables opérations au sein d'une unité qui devrait être prochainement créée. Aujourd'hui, dans le cadre d'une convention entre le SFD et l'ENSG, les formations devraient continuer pour rendre l'unité autonome le plus rapidement possible.

1. INTRODUCTION

1.1 Context

In the south of the Arabian Peninsula lies Yemen, formerly known as an important stop on the Frankincense Road, well known today for its astonishing mountainous landscape, and much less so for its very rich architectural heritage. This richness is a result of the country's former prosperity, and needs to be transmitted to future generations. Any action of safeguarding this cultural heritage is of course valuable. The first step to preserving a monument is simply to produce a complete and precise documentation of it.

1.2 Partners

Marylène Barret, archaeologist and art restorer working at the French embassy in Sana'a (Barret, 2004), the capital of Yemen, and detached at the Social Fund for Development of Yemen (SFD), was the first to introduce the idea of

traditional techniques of close-range photogrammetry to produce the documentation.

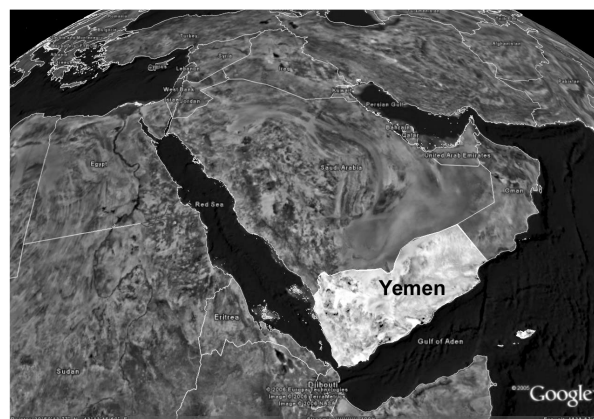


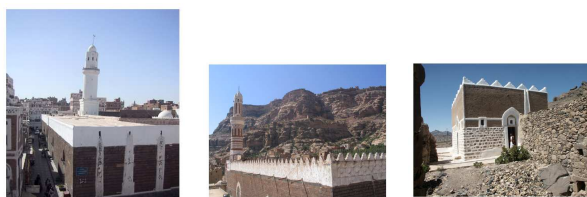
Figure 1: Yemen in the Arabian Peninsula

The SFD is an autonomous agency with financial and administrative independence, governed by a Board of Directors, representing the government, NGOs, and the private sector under the chairmanship of the Yemeni Prime Minister. The SFD seeks to reduce poverty by improving living conditions and providing income generating opportunities for the poor. It should be noted that it already has a department for Cultural Heritage.

Having read about the particular works previously done by French IGN (Institut Géographique National) on prestigious archeological sites, Marylène Barret invited its technical university, the ENSG (Ecole Nationale des Sciences Géographiques), to survey the first monument in order to convince the Yemeni authorities of its interest. In that context, four ENSG teachers, together with six post-graduates (Photogrammetry, Positioning and Measures of Deformations), went to Yemen twice to do a photogrammetric survey of historic mosques on the point of being restored.

1.3 Sites of interest

Five mosques were completely surveyed: at first, in October 2004, the small mosque of Asnaf, the great mosques of Sana'a (7-8th/9th/12th century) and Shibam-Kawkaban (9th/10th century), then, in October 2005, the mosques of Al Ahsrafieh (13th century) and Al Muzzafar (13th century) in Taez.



Great Mosque of Sana'a, size : 75x66m
 Great Mosque of Shibam, size : 35x26m
 Mosque of Asnaf, recently restored, size : 9x8m

Figure 2: First survey operation

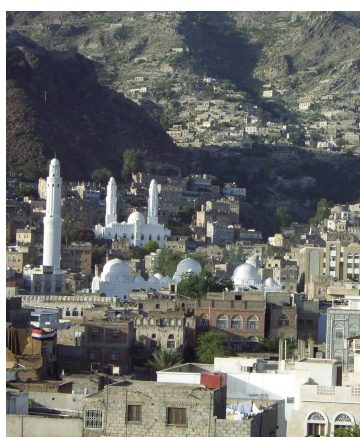


Figure 3: Second survey operation

The two mosques surveyed in Taez, Al Ahsrafieh (size : 35x30m) and Al Muzzafar (size : 54x54m)

2. FIELD WORK USING A COMBINATION OF TOPOMETRY, PHOTOGRAMMETRY AND LASERGRAMMETRY

2.1 Methodology

In order to obtain a reliable and accurate survey, being faithful to the shape and appearance of the monument, it has been decided to use topometry, photogrammetry and 3D laser scanning altogether.

2.2 Setting up a local topometric system

A local network of both flat and spherical targets has been set up and measured to ensure that images and laser scenes could be used later and combined into a common 3D coordinate system. Reference points were located inside (and even in a part of the underground floors) and outside the mosques, links between them being made through the doors (between inner and outer mosque, and also between the inner mosque and the courtyard) and the terrace. A basic network in 3D was thus formed on which all the measurements depend. The team used Trimble 5600 DR, Trimble 3600 DR, and LEICA TCR 803 (Direct Reflex) total stations for the control survey. The total stations' direct reflex capabilities also enabled the team to take measurements of distance without prisms and accurately determine the position of the spherical targets by direct measurement. In total, 450 control points were established at Sana'a, 200 at Shibam and around 200 also in the two mosques in Taez. The 3D coordinates of all the network points were computed with COMP3D, a software program for global bundle adjustment, for micro-geodesy, photogrammetry, and 3D scanning developed by Yves Egels, ENSG' professor. Results were validated on the site and the precision achieved was approx. 5-6 mm (0.2 in) on the Shibam site and approx. 1 cm (0.4 in) on the Sana'a site; these differences being mainly due to the size difference of the surveyed sites (a 75-m-long (246-ft) side for the Sana'a mosque, 35-m-long (115-ft) for Shibam).

2.3 Image shooting

Although a terrestrial 3D laser scanner was available (Trimble GS100), traditional photogrammetry was considered for at least two reasons. For one thing, some nicely decorated details obviously required high resolution images that the scanner could not ensure. Secondly, the configuration of the mosque itself, like the wooden steep sided ceilings (e.g. figure 4a and 4b), was so complex that a complete 3D laser scanning would have been much more tedious than a regular stereoplotting.

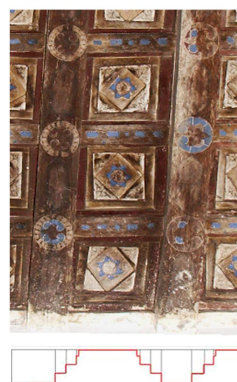


Figure 4.a: Extract of the wooden steep sided ceilings (real and schematic views), seen from below

Figure 4.b: schematic view of the ceilings, cross-section

Thus, traditional stereoscopic image coverage has been made on the ceilings, as well as the facade walls, and the particular details, such as the “mihrab”. A Minolta Dimage previously calibrated at the ENSG, equipped with an outer flash was used, producing approximately 400 images on the site of Sana’a, and 200 in Shibam. In order to be as productive as possible, images have been taken from ground level, which resulted in an average ceilings pixel size of 3mm.

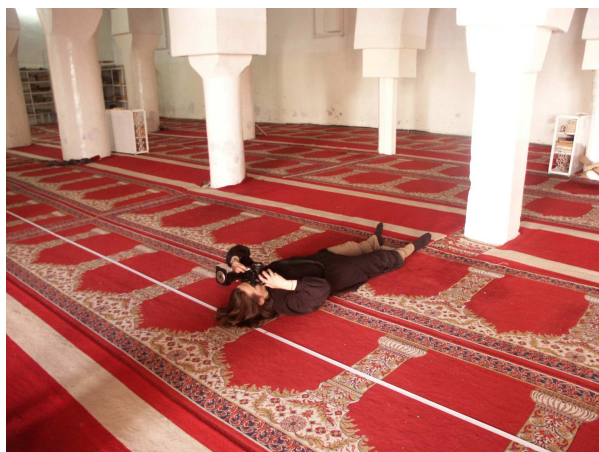


Figure 5: Image shooting of the ceilings

2.4 3D laser scanning

A Trimble 3D Scanner was used to survey the general architecture of the buildings (columns, arches, interior and exterior walls, and terraces) shaped without decoration but with lots of hidden parts. The measurement interval was approx. 15 mm (0.6 in). 3D scanning is well suited to the walls as well as terraces and pillars in which detail density is fairly low, enabling rapid scanning at a low resolution. In contrast to photogrammetry techniques, the scanner’s acquisition time is proportional to the detail desired. However, it is also less sensitive to hidden areas (no need for stereoscopy, precision independent of distance). Its main advantage is its ability to rapidly supply large amounts of data without major processing. For instance, the team completed 100 hours of scanning over two weeks to acquire the necessary data for the mosques of Sana’a and Shibam.

3. DATA PROCESSING IN FRANCE

3.1 Vertigeo

A tacit agreement between the SFD and the ENSG first stipulated that five mosques be surveyed by ENSG’ students, their expenses such as plane tickets and local accommodation being paid by SFD. Further data processing was subject to another contract signed in 2005 by Vertigeo, the ENSG company managed by students. Since that time, ENSG’ students helped by their professors have worked in their free time to produce and deliver the expected results.

3.2 Products to deliver

The list of results to be produced was vague at the beginning, as the SFD as a sponsor knew little about the possible results of topometry, photogrammetry and lasergrammetry, and as the ENSG itself was making its first life-size field survey

with a laser scanner. Traditional outputs of an architectural survey were however required : horizontal plane at ground level, vertical elevations, main cross-sections, and orthoimage for the wooden ceilings and for the façades. Results had to be delivered digitally and in hardcopy according to graphical rules that Vertigeo was free to design (e.g. figure. 6).

Orthoimages were computed at the closest resolution to the ground resolution of raw images, that is to say 3mm for the ceilings of the mosques of Sana’a and Shibam, and 5mm for the façades. Ceilings were printed at the scale of 1/10 (e.g. figure 7), and façades at the scale of 1/50.

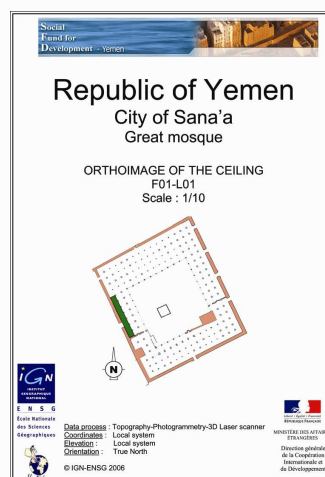


Figure 6: Box out of the graphical rules retained by Vertigeo



Figure 7: One row being printed at the scale of 1/10...

3.3 Tools

Aerotriangulation

An IGN software, Topaéro, normally designed to compute georeferencement of aerial images with the bundle adjustment method, has been successfully used for computing the aerotriangulation of the wooden ceilings and of the façades. Tie points had been previously measured in a semi-automatic way, using LPS.

Orthorectification

Automatic correlation was tested on the wooden ceilings to produce DSM, which is necessary to compute a true orthoimage. As a matter of fact, the ceilings look very much like a dense urban area, although it is seen from below rather from the top. But because of the repetitive aspect of the ceilings, both in shape and drawing, the correlation results were so poor that the interactive editing task would probably have been longer than direct manual stereoplotting ! Nevertheless the volume of traditional stereoplotting would have lead to unacceptable delivery time. Thus, a simplified method was adopted : only the lowest wooden beams have been recorded into the DSM, while in Adobe Photoshop, the central area of the images were defined, limited at both extremities by the lowest beams, and saved into alpha layers (e.g. figure 8), that the software later used to compute the orthoimage, was able to understand as such. Taking only the central part of the images easily allowed the orthoimage to

look like a “true” one, while limiting the area of interest to the lowest beam avoided possible ghosting effects or any wrong edge matching artifacts.

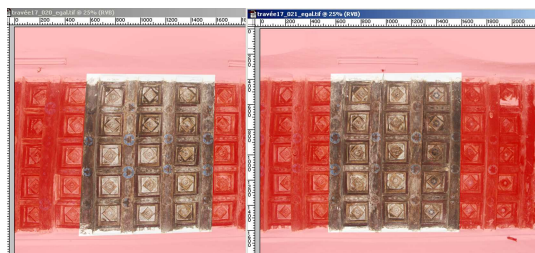


Figure 8: alpha layers

This simplified methodology was only applied for the ceilings, because it was acceptable regarding the cost and the geometric accuracy, satisfying the architects at the same time. As a matter of fact, even if the delivered orthoimage was not 1cm accurate as it was first expected, it gave the restorers a precious overview document, e.g Figure 9. Of course for the façades and other more usual areas, rigorous orthorectification was normally used at a reasonable cost.



Figure 9: Orthoimage of the ceilings of the Great Mosque of Sana'a

Cumulus by Y. Egels

Furthermore, even if a huge potential of the dense laser scanning was assumed since the beginning, no efficient and user friendly tool was available yet on the market. Yves Egels, at that time head of the DIAS (photogrammetry department at the ENSG), already familiar with software development, decided to write a new one, mainly dedicated to terrestrial 3D laser data processing. Rapidly operational, Cumulus was able to visualize laser data using any color, or scanning intensity, or color from the scanner low resolution camera, or even color from outer high resolution images whenever georeferenced in the same topometric system as the laser data. Cumulus was also able to georeference laser scenes using the spherical target of the topometric network, to compute sections through the laser data in any specified direction, and eventually to compute true orthoimages, taking into account both occlusions in the laser data and in

georeferenced outer images. Y. Egels made his software also usable for 3D data captured by traditional stereoplotting, which, as mentioned above was helpful in producing orthoimages on the wooden ceilings.

3.4 New products for architects and restorers

Since it became, thanks to Cumulus, rather simple to produce, among other things, sections and orthoimages, which are the traditional results that architects and restorers ask for, some of the people in charge of the restoration operations asked for more than was initially required, like more cross-sections (fourteen cross-sections were asked for the Great Mosque of Sana'a), and horizontal planes at different levels (ground level of course, but also pillar capital level). The raw output from Cumulus is unfortunately a bit rough, because of the unexpected objects which have been scanned together with the intended objects (the mosques were usually full of bookshelves which were too cumbersome to move), and also because of the intrinsic noise of the scanning.



Figure 10: One raw cross-section in the Mosque of Sana'a

Moreover, there always remain occlusions that produce holes in the final products. All this makes it inevitable to clean the raw output from Cumulus, for use by most architects apparently not prepared to deal with such data. This step has been very little tried out so far at ENSG, mainly through lack of time and manpower. However, a student is expected to work on that specific subject at SFD during the summer 2007, to produce real cartographic data out of the raw output from Cumulus, and also to work out its methodology. However, one may expect that architects will slowly come to appreciate the very rich content of raw data, in spite of the above mentioned defects.

4. TRANSFER OF TECHNOLOGY

4.1 Yemeni pool of experts

Besides proving to Yemeni authorities the validity of 3D modelling techniques, Marylène Barret also intended to set up in Yemen, and first in SFD, a specific unit specialized in advanced documentation techniques for the historical architectural heritage of Yemen. For that purpose, ENSG teachers have identified four Yemeni experts from among various specialists (architects, surveyors, engineers) as being sensitive to the urgent need to produce complete and accurate documentation of the rich Yemeni architectural heritage and able to understand the methods to produce this documentation.

4.2 Training sessions

In order to have that team operational as soon as possible, training sessions have been organized. Trainees first attended the two week field operation in Taz, where each of them

worked together with one French student. This organization, apart from leading to friendships, gave the opportunity to Yemeni trainees to efficiently learn the basics of a field survey and to French students to clarify the knowledge they had to teach. After that, two more training sessions were given in Sana'a by ENSG teachers, during which basic theory required to use the photogrammetric tools for the whole process were taught. Most of these tools, like Cumulus, were translated into Arabic for the occasion. Finally the trainees came to France for one month, where they surveyed almost alone a part of the Chartreuse of Villeneuve-Lez-Avignon. This included field survey and data processing.

4.3 Agreement of cooperation between the SFD and the ENSG

An agreement between the SFD and the ENSG should be signed very soon, making the already very good relationships between these two institutions official. Training sessions will be regularly given in Yemen for at least two years, by ENSG professors and professionals. Some engineers or high level students could take part in implementing the documentation unit in SFD in their ENSG practical training (possible duration from two to six months). For instance, two ENSG students make their practical training in SFD during the summer of 2007, one to help organize the newly funded unit, the other to redraw some rough cross-sections and to write its methodology.

4.4 SFD unit specialized in advanced documentation techniques for the historical architectural heritage of Yemen

Although the documentation unit was first set up in SFD, it may well be transferred later on to other organizations. This will of course require the current Yemeni trainees to have a good knowledge of all steps in the production process, so that

they can become trainers themselves. It seems to be safe to keep the documentation in SFD in its early stages, since SFD already invested in training sessions, and provided the first necessary basic equipment, that is to say, besides existing printers and computers, a semi-professional camera –Canon EOS 5D-, a total station –Leica TCR 803- and topometric accessories. Purchasing a 3D terrestrial laser scanner will be considered only when the documentation unit works smoothly.

5. CONCLUSION

Although the idea of creating in Yemen an autonomous documentation unit was first looked on with some doubt, Marylène Barret worked hard and finally succeeded in having SFD support this project actively. Today, thanks to the SFD's sincere involvement combined with great enthusiasm and long-term involvement of ENSG's professors to see that unit work, tangible results may already be seen: on the one hand documents essential for the preservation of a still little-known heritage have been produced, and authorities are beginning to see its importance. On the other hand, the Yemeni team has received most of the equipment, and is starting already to work properly. Once the documentation unit is fully operational, which is expected to happen within two years, the next stage will be to see that unit itself becoming expert in the field of 3D documentation for Yemen and for the neighboring Middle-Eastern countries...

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