The digitization of shared cultural built heritage highlighted in "Heritage at Risk in Algeria".

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Abstract. The present paper deals with the technic using the terrestrial laser scanning survey (TLS) in the restoration and conservation of the shared built cultural heritage in Algeria. The cross-section method, that was the skeleton of our surveys, is applied by using directly 3D meshing models.

The project described in this article was motivated by the need to document some of key buildings, that looks very venerable, in the city of Setif in Algeria: The Mosque of El Attik minaret, the mausoleum of Scipion, and the statute of the fountain of Fouara.
This statue which is made of marble was realized by Francis de St Vidal in 1899 that represents a nymph which is a part of the fountain, publically displayed in the center of the city's main plaza. On 18 December 2018, a man has deteriorated the statute. Following the day of the incident, our team has been called to use a previous scanner laser survey of the nymph that was stored in our cultural heritage monument database in order to help the restoration of the missing part of the nymph (the face and the breast). As a matter of fact, the original laser scanning survey provided a helpful and accurate details to support the restoration of the nymph.

If the experience of Ain fouara show all the interest of this technology not only in the digital archiving of 3D models generated; the digitization of The Mosque of El Attik minaret and the mausoleum of Scipion highlights the effective use of 3D meshing models obtained, in the study of the mechanical behaviours. This preventive approach is useful in other studies of shared cultural built heritage.

Keywords: Shared cultural built heritage, Algeria, Digitization, Cross-section.

1. Introduction:

1.1. Heritage at risk in the Middle East and North Africa.

Since the beginning of mankind, Man has created built structures that remain today as the results of an ancient occupation of a place and spaces. Many of these remains help us to understand the history of past cultures and civilizations. Today these remains are considered as the world built cultural heritage.

Built physical structures, as artefacts, are the expression of the history of mankind. With each successive period, people have exchanged and shared their various cultures, skills and experiences.
These artefacts give particular aspect to places, which become the material expression of the social economic, political, territorial and environmental values.

Unfortunately, these shared parts of history and heritage are constantly exposed to natural threat factors (i.e. swarms, floods, landslides, volcanic eruptions and earthquakes) and human activities (i.e. pollution, inappropriate use, war, acts of vandalism and other conflicts). Indeed, the archives recount the troubled history of some of the most emblematic sites of shared built heritage; most of them are located in a country struck by war, a destructive context in which it is extremely difficult to ensure the safeguarding and protection of heritage properties. Examples include the minaret of the Great Umayyad Mosque of Aleppo in Syria, that have been destroyed in the Syrian war; the mausoleum of Askia in northern Mali, the Ninevah Museum in Mosul and Mar Benham 4th century monastery in Iraq, and many others we did not hear about.

In recent years, although there has been a growing interest in the conservation and protection of the built cultural heritage that need to be protected from destruction. This paper deals the role that digital technologies can play in preserving the cultural built heritage and then, will show that there is a need for creating a digitized resource center. After assessing the cultural and historical evaluation, we choose some key buildings in our city that looks very venerable: the minaret of the Setif city’s mosque called El Atik, the statue of Ain Fouara of Setif and the Scipio mausoleum of the city of Setif in Algeria.

1.2. Solving the heritage at risk with the digital data base.

“Understanding the physical fabric of a site is an important first step in finding the right conservation strategy, and documentation is the first step in understanding” (Clark 2007). This sentence highlights the primary role of documentation and the interdependence between knowledge and conservation strategy (Vanlentina B & Grazia T 2014). Indeed, the surveying of the built cultural heritage is a first step of its conservation and restoration. Then, the only possible way to hand over “heritage documentation” to future generations in modern times is through, digital data base.

The LIDAR (light detection and ranging also called laser scan) object of this article, is a technique of Lasergrammetry that allows the digitization of cultural built heritage (Raimondi, 2015a). It is a data acquisition process in point cloud aspect, then in the form of 3D modelling.

Several important works in the field of digitization of cultural built heritage, using the LIDAR technique, has already been done. We would like to mention some of the most recent projects:

- **Laser scanning and Palazzo d’Accursio’s project**: the analysis of residual maps, obtained by computing the differences between the pointcoordinates of the façade, and reference fit planes. The obtained results, based on both radiometric and geometrical analysis, re used to provide a reasonable hypothesis as to the original configuration of the studied building, while taking into account the available historical information about the constructive phases of the building.

- **Studio 727’s Project**: Established during 2013-2016, a specialist team (Studio 727) develop an experiment to digitize the most important Slovak monuments, using a combined-based survey of Lidar Data and Photogrammetry. They create a virtual representation by Leica Scan Station P20 laser scanner technology, the AIBOT X9 V2 type drone in combination with a Nikon D810 camera.

This project highlights the limit of Terrestrial Laser Scanning method and the necessity of Photogrammetry as a solution for typical application such as parts of buildings that were otherwise inaccessible with former methods.

- **Classification of 3D digital research project**: published in “Classification of 3D Digital Heritage” [...] the project explores the applicability of supervised machine learning approaches on four different archaeological/architectural scenarios, proposing a reliable and efficient pipeline that can be standardized for different case study. the proposed solution works on 2D data (“texture-based” approach) or directly on the 3D data (“geometry-based approach) with supervised or unsupervised machine learning strategies.

The digitized works described in this paper, led by a local teams is the first of its kind in Algeria and it is in line with the current trend of important international projects using LIDAR technique. Our project is distinguished by its approach based on cross section method. The proposed solution works directly
on 3D data. For this purpose, the LAM laboratory researchers use a single method of data collection directly on site, which offer a reduced timeframe (table 1), by using Leica ScanStation P16. This type of new laser scanner integrate the best in class features of the one used by Studio 727 (Scan Station P20) and expand on it in two important areas: 1) the LIDAR system itself, and (2) the scanner’s built-in digital imaging system. This property allow us to take pictures of a scene automatically, using different exposures; then, images are automatically processed to properly colour the point cloud. That, in turn, enables faster office processing for creating deliverables and better looking marketing images. Also, this technology can record 1 million points/sec at a maximum target range of 40 m[^9]. The aim of this project is in order to reconstruct and expertise shared built heritage of the city of Setif in Algeria, using 3D and thus show all the interest of this technology not only in the digital archiving of 3D models generated but also, all the possibilities of use of these models in the study of the mechanical behaviours and studies of the construction of the patrimonial objects.

| Monuments | Scan positions | Volume | Processing time |
|-----------|----------------|--------|-----------------|
| The statue of Ain Fouara of Setif and its minaret of Setif’s mosque called El Atik, | 7 (State1) 7 (State2) 39 | 4060Mb (State1) 4049Mb (State2) 9928 Mb | 2 months 1 month |
| The Scipio mausoleum of the city of Setif in Algeria. | 11 | 16412Mb | 2 weeks |

Table 1. Data volume and processing time for three differently sized monuments in the project.

According to the new development of the technologies; the former way of operating the survey has been replaced by a digital process of modelling (Varady,1997a). However, these new technologies have given us as architects an opportunity such as the automatic orientation as well as measuring process based on the new generation of 3D data on cloud points and it is applied to the digital modelling surfaces and the Web representation of the built cultural heritage. All these actions were used in the digital expertise on objects that which undergo or undergoing deteriorations.

The workflow based on Laser Scanning in Cultural Heritage has three steps in order to initialize the digitalization work.

1. The first step is acquiring the 3D data using the Terrestrial laser scanner 3D restitution of the surfaces of the object through many stations.
2. The second step is the 3D modelization through engineering software for the data processing of the cloud points of the object. This step is based on the transformation of the data and the 3D geometry restitution of the object.
3. The last step is the representation based on the process of digitalization to integrate the 3D data and other multimedia such as text, image…. to visualize and the specific use of the rendering of the model. (Ali Khodja. N et al., 2019)

For the approach presented here, careful attention has been paid to the suitable role that geomatics should play to implement a thorough prevention policy, in compliance with the recent scientific approach adopted for heritage obsolescence, which aims at optimizing preventive (rather than corrective) maintenance on buildings. This method has apparently higher investment costs, but they will be amortized over the long term. This is briefly the logic at the basis of the strategy and methods of “Building maintenance management” (Lee 1993). This kind of activity is based untimely detection of deterioration phenomena (as well as their mechanisms and possible causes) in order to limit their development and assess their incidence on the artefact’s life cycle.

2. Modern survey system within three experience projects from LAM lab.

2.1. Picking up pieces using 3d modelling: the Ain Fouara of Setif in Algeria, a French colonial statue.
In December 2017, vandalism struck the Ain Fouara of Setif, a French colonial statue which was severely damaged, broken into many pieces, leading to raise the resident population. This accident had a fluctuating impact at the local level but also at the European one. In fact, it has been used as a part of the European election campaign of an Italian political party and their supporters (BBC News, 2019). This demonstrates not only the people's relationship to build cultural heritage, but also, the role it plays in the European political context.

The researchers from our laboratory were called by the authorities to provide help in order to restore the statue. Fortunately, the laboratory has in its database the original survey digitized model of the statue that was done before the incident (state 1). The accuracy of 3D scanning and the processing and visualization tools developed by the project allowed the many broken remains to be virtually pieced together like a jigsaw puzzle: this reduced the need to handle them physically, preventing further potential damage and making it easier to evaluate different reassembly options. Conservators could then undertake the difficult task of rebuilding the statue of Setif’s Ain Fouara and repairing its surfaces.

The technique that has been used is based on the comparative study of the side section by focusing on the deterioration parts of the object.

2.1.1. The first step of the workflow. The first work is shifting the textured object of the original statue, obtained before deterioration (state 1) to the textured object obtained after the deterioration of the statue (state 2) (Figure1). This step is very important because the good accuracy of the result depends on it. By shifting the two states of the object we obtain the fusion of the two as the third state.

[Figure 1. Process of merging pre-and post-incident situations. (Ali Khodja. N et. al, 2019)]

2.1.2. Choosing sections control. The second step of the workflow is to choose the geometry 2D control sections within the three axes (X, Y, Z) by putting a plan section on the cloud points obtained from the fusion of the two objects of the statue obtained before and after its deterioration (figure2).

This work this depends, of course, on the nature of the heritage object being processed, but also on the precision required, particularly for the restoration operation. It is also possible to extract 2D section geometry from a point cloud, by a section plane object, except that in this case the edge accuracy and contour accuracy are not useful for a restoration work.
2.1.3. Merging 2d representation: Third step once the 2D geometry of section plans have been made on the object: the next step would be to isolate them to use them within a 2D representation CAD (Computer Aid Design) then after the section will be distinguishable coloured in order to merge them with each other (figure3).

![Figure 2. Sections following the axis (Ali Khodja. N et al., 2019)](image)

2.2. Documenting and study of mechanical behaviour using 3D modelling.

The digital documentation is organized in two stages: the first concerns the collection of data in the field; the second stage is carried out in the laboratory and consists of processing the data acquired in the field.

2.2.1. Data collection: The collection of data is done by a 3D laser scanner system, which calculates the distance of the point from the focal point and between the other points of the objects (the minaret of mosque El Atik and the Scipio mausoleum of the city of Setif in Algeria). The scanner thus registers the real space as a cloud of points (Cloud points). It provides a comprehensive overview by means of a measurement without contact, secure, precise and extremely fast.

From the areas scanned in a "cloud of points" obtained on several stations, a computer processing will recreate a real digital skin which then reconstitutes the geometry of the digitized surface.

At this stage, two methods are used the first one is automatic the second is manual reconstitution.

2.2.1.1. Automatic alignment of Scan Word by using targets within the software process: the Scipio mausoleum of the city of Setif in Algeria. Recent events (Kamel, B 2018) highlighted the lamentable state of the great Roman mausoleum in the city of Setif in Algeria, known as the Tomb of Scipio, dating from the end of the 3rd and beginning of the 4th centuries AD.

Although Article 17 of Law 04/98 of 15 June 1998 clearly states that no building may be constructed within 200 m of each historic monument, the Roman tomb is surrounded, not to say "attacked", by several residential buildings. The situation of this witness of a thousand-year-old history offends both insiders and ordinary citizens.

The neglect of this precious resource has prompted us to document the monument and study its mechanical behaviour with a view to preventing any further alterations in the future.

The monument was scanned by the laser scanner using serial numbered targets and placed to ensure at least one common target between two successive stations. This made possible to gather the clouds points obtained automatically and more accurately.

2.2.1.2. Manual alignment of Scan Word by using orientation and measurement of the accuracy precision within software process: the Mosque of El Attik of Setif in Algeria. Built in 1838 by the French military engineers, the first mosque in Setif named El Atik, is located in the downtown city, a
few meters from the mythical fountain of Ain El Fouara, in the Frantz Fanon street. It is a place of worship, culture and Koranic teaching. Confronted with the risks of climate change, its minaret has been damaged. As a result visible cracks are recognized on its walls. Actually, it is closed to access.

Therefore, the laboratory team decide in October 2019 to document the minaret and learn more about the type of stresses to which these structural elements are subjected. This action is both preventive and educational (figure 4).

2.2.2 From clouds points to meshing. The assembly of the various Scan Word obtained from different setups allows us to obtain the 3D models which were streamlined to follow into a reduced database. Thereafter the streamlined 3D models were refined by a meshing process using the technic of triangulation (noise reduction and filling of the missing parts).

Figure 4. Alignment of stations by manual reconstruction.

Figure 5. Example of Meshing by CAD.
Case study of the Minaret of the Scipio mausoleum of the city of Setif in Algeria.

Figure 6. Example of meshing by triangulation.
Case study of the Minaret of the Mosque El Atik of Setif in Algeria.
2.2.3 Result of section comparison. Once the 3D model has been refined, we analysed the mechanical behaviour of the object based on the superposition of the horizontal and vertical sections of the generated model.

2.2.3.1. The case study of the Scipio mausoleum of the city of Setif in Algeria. As a result, an outstanding shift is raised at the level of the keystone of the arch (figure 7). Considered as an essential element of the structure, the keystone removal affects considerably the stability of the monument.

![Figure 7. Example of horizontal sections.](image)

2.2.3.2. The case study of the minaret of the mosque El Atik of Setif in Algeria. Based on this technique of "cross section", we were able to observe a shift between the base and the gallery, this shift is mainly located at the level of the central core of the minaret. We therefore, hypothesize that the object in question is in perpetual motion due to an inverted pendulum effect (figure 8).

Our assessment of the risks to the stability and durability of the structure in question makes it possible to recommend treatment solutions.

![Figure 8. Example of horizontal and vertical section meshes.](image)

3. Sharing built heritage within virtual reconstitution.

Beyond a traditional vision of monumental heritage, we use the digital support obtained not only for the diagnosis of the mechanical behaviour and the study of procedural techniques of old buildings, but also and above all for the digital mediation of the heritage through the implementation of remote visits allowing access to the heritage and its interpretation to new audiences (figure 9). This system can be approached through a cultural approach with an educational aim, as well as serving as a catalyst for the country's tourism economy by stimulating the affective, emotional and experimental dimensions of the built heritage.
4. Conclusion
At the time of assessment, there is no doubt that the built cultural heritage, as a shared history and culture, remains in danger because of the natural and human risks to which it is exposed on a daily basis. The problems of management and strategies for its conservation, in particular, are still critical. Cultural heritage is therefore, not without challenges.

This paper has focused on shared built heritage in situations of conflict and war, particularly in the countries of the Middle East and North Africa, and more particularly in Algeria. These dangers mean there is also an urgent need to make the most of digital technologies to record, document and preserve Middle East and North Africa’s cultural heritage and make it accessible online to citizens.

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