RECONSTRUCTION OF ALEPPO UMAYYAD MOSQUE MINARET:
A DIFFERENT APPROACH

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ABSTRACT

Aleppo, a world heritage site since 1986, one of the oldest inhabited cities in the world, have been suffering a disruptive war for the last six years causing the destruction of many important and unique monuments of the city, one of them is the minaret of Aleppo Umayyad mosque (the great mosque) which was destroyed on April 25th 2013.

Fortunately, a metric photographic documentation was prepared for many important monuments inside World heritage sites in Syria, and this minaret is one of them, which enables the future planned reconstruction of the minaret. This paper is discussing an alternative approach of future reconstruction by using augmented virtual reality techniques using Auto generated 3D models with spherical photogrammetry techniques by using the mentioned image documentation, in order to virtually reconstruct the minaret (in-situ) as a solution that achieves the reversibility and authentication until the real physical reconstruction is conducted.

The opportunities and threats to merge these two techniques are investigated, and the application on a monument considered an icon of Aleppo city for more than a thousand year seeks to analyze the possibility of widening this practice to cover other affected minarets, solely documented by tourists’ photos, in order to implement this methodology on all the damaged heritage of Aleppo in the future.

INTRODUCTION

Minaret, or (Mi’dhana) in Arabic, is an important element in mosques’ design, although it was not built in the time of the Prophet Muhammed (PBUH) (M.Bloom, 2012); it was originally used for Adhan, calling to prayers in Islam. Across centuries it was developed structurally and morphologically in time to play another role as a symbolic architectural element (M/Bloom, 1991). From the earliest Umayyad square tower to pencil shape Ottoman minarets; it is possible now to define the style and history of the mosque by looking at its minarets.

Aleppo, one of the oldest continuously inhabited cities, a world heritage site and the capital of Islamic culture in 2006 (Ismail, Morezzi, 2014), was a home for different Islamic civilizations that were reflected on architecture of mosques’ minarets, presenting a unique collection reflecting different architectural styles of Islamic eras.

Although the sound and acoustic technology development has decreased the importance of Adhan function for minarets (Alzaed, 2015), their functions as symbolic built heritage and architectural value were increased across history. The minaret of Aleppo’s great mosque is an example of a minaret that represented the identity of a city. Aleppo was remarked with its citadel, the great Umayyad mosque, and its minaret; one of the oldest known minarets over the world. Its destruction represents a big loss for humanity and absolutely to Aleppo people as well (Rahim, 2014).
After six years of destructive war in Syria, and with the immense destruction in the old city of Aleppo, accidentally or deliberately, the need for intervention studies for restoration, conservation, and reconstruction of the remains of high value monuments have emerged (Ismail, 2012). The dilemma of those studies was how to achieve fast and reliable reconstruction, which should accomplish the international charters recommendation of authenticity, reversibility and sustainability together with national laws at the same time. (ICOMOS, 1982)

Taking in consideration the technological and economic challenges, a different approach for reconstruction is proposed in this paper, using the augmented reality (AR) technologies to virtually reconstruct the minaret of Aleppo's Umayyad mosque, the challenges and the opportunities were investigated for realizing an In-situ reconstruction accomplishing the previously mentioned goals, that enable Aleppo people to participate effectively with their opinion about future actual physical reconstruction of the minaret and the other monuments of the city.

METHODOLOGY:

In order to analyze different probabilities, challenges and opportunities, the study was conducted by comparing the minaret of Aleppo with another case study from turkey, which is the Ince Minaret Madrasah in Konya, Turkey.

It was built before 1265 as one of the original architectural examples of the Anatolian Seljuk time (Karabacak, 1981), which means it returns to the same time period when the Umayyad minaret was rebuild in Seljuk period in Aleppo. While the Umayyad minaret was destroyed in 2013 because of war bombing, which caused its total collapse, Ince Minaret in 1901 was hit by a lightning and destroyed until the first balcony (Uğur and Koman 1939). During the restorations of the Madrasah complex (1936-1956), while the mosque was rebuilt, the minaret was restored until the first balcony (Yavaş and Çobanoğlu 2000), while the Umayyad minaret was restored in 2003 under the project of mosque restoration.

Augmented Reality (AR) was developed rapidly in the last decade, it has its applications in many sectors from construction to games and education, (Elsevier, 2013), it was applied initially with 3D image aquisition for the purpose of documentation, for example using spherical photogrammetry as a metric documentation technique applied to recreate a 3D model of the Umayyad minaret which enables obtaining dimensions and shapes of the architectural geometry (Fangi and Wahbeh, 2013). Personal mobile devices, like the mobile phones, using the GPS, the gyroscope and the standard web-cam hosted in the mobile devices, created the optimal conditions for the geo-reference of the information, comparing them with the maps and the satellite orthophotos available by the most common geo-browser enabled the indoor restoration projects for small heritage elements and objects (Saggio and Borra, 2011) which facilitated many applications in museums and art galleries like Augment application for mobile phones¹, and other interior design applications. Implementing the same technology for bigger projects is not easy with the size of details especially when applying it outdoor due the need to high

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¹ http://www.augment.com/
level of accuracy in positioning and referencing. (Behzadan and Kamat, 2013)

One significant aspect of this study is the virtual 3D reconstruction of the architecture. While it is possible to generate the 3D models manually by using 3D modelling tools such as Blender and Autodesk 3ds Max, this is a time consuming and labor intensive way. In the literature, there are studies proposing automated and semi-automated 3D reconstruction. In case of the presence of numerous pictures of the same area taken from different view-points, a method known as structure from motion (SfM) finds out the camera locations and builds 3D point clouds (Snavely, Seitz, & Szeliski, 2008) (Furukawa & Jean, 2010) which can be converted to 3D mesh models using surface generation methods such as Poisson reconstruction (Kazhdan, Bolitho, & Hoppe, 2006) and Fuhrmann et al’s recent study (Fuhrmann & Gosele, 2014). These methods depend on the availability and quality of lots of input images and perform well for popular touristic areas (Agarwal, et al., 2011). In case of known rough geometry of the architecture, less number of photos could be used by back-projecting them onto the 3D structure (Bulbul & Dahyot, 2017). There are also interactive methods which uses parallel lines and their vanishing points in the images to suggest possible planes of the structure and generates 3D building upon the user’s depiction of the correct planes (Sinha, Steedly, Szeliski, Agrawala, & Pollefeys, 2008). Given, time stamped images another relevant study reconstructs a region and at the same time detects the applied modifications over time (Martin-Brualla, Gallup, & Seitz, 2015).

THE PROJECT:

Due to previous restoration project by using available excellent documentation in the archive; such as drawings, images, and elevation plans; we can create a 3D model of different historical eras of the monument, then with any mobile device which includes a camera and GPS, could install the application on his device; running the application it will connect to the server if internet connection is available, otherwise an offline mode will be activated, on the server where the models were uploaded, and defining the position and the angle of the camera the application will give the possibility to drop the chosen model on the real site background of the mosque. The project aims to provide different appearances of the minaret through the history and the user will be able to travel to the different periods of history which will also simulate the aging of the materials. Additional features as zooming and historical comments will be available, even adding an animated image of the Muezzin climbing the minaret and calling for the prayer is an available option.

FIGURE 5: Diagram of the process of virtual reconstruction and using it in AR to show it on mobile devices (Authors)

USED TECHNOLOGY:

In order to provide a virtual reconstruction, which would be visible through the screens of mobile devices, first necessity is to obtain the 3D model of the missing regions. For that purpose, there are several options. One of them is automatic 3D reconstruction using SfM based techniques with many images of the structure that is reconstructed. Figure 6 shows a sample reconstruction result using available photos from Flickr and Google. The quantity and the quality of the images affect reconstruction significantly. One property of this method is that the most popular parts of a structure, which are usually visible in the images, are reconstructed better; while the non-visible, occluded, or less popular parts cannot be reconstructed as well. This property can be supported by the idea that people are interested in the popular views, which are reconstructed better. However, the regions that are not photographed sufficiently will be missing in the final 3D model, which is not acceptable in many cases. Another disadvantage of automatic reconstruction is that, it produces a point cloud and if it is not dense enough the reconstructed surface over that point cloud may have apparent deficiencies.

FIGURE 6: 3D Reconstruction of Umayyad Mosque using VisualSfM (Wu, 2013) with images acquired from Flickr4 and Google5 image search.

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2 https://www.blender.org/
3 http://www.autodesk.com/products/3ds-max/overview
4 https://www.flickr.com/
5 https://www.google.com/imghp
If there is less number of images of the area of interest, there are semi-automatic methods, which work in an interactive manner. Similar to automatic reconstruction, a sparse reconstruction is performed using SFM and the possible planes are suggested to the user. Then according to the user’s selection, planar surfaces are generated which are texture mapped using the input images.

Finally, if there are not sufficient images for image processing methods to find corresponding features and build a 3D structure, according to the written and visual descriptions; a user can generate the 3D model using available 3D modeling softwares. Employing each of these methods or a mixture of them may be necessary depending on the available documentation; e.g., presence of photos, quality of the visuals, textual descriptions.

While Ince Minaret shares several characteristics with Umayyad Mosque’s Minaret, there are additional limitations for the latter one. In Ince Minaret case, GPS service is available which provides location information accurate within approximately 10 meters (Zandbergen, 2009), also 4th generation Internet connection is available, and the wide square in front of the Madrasa gives more flexibility to use many solutions to show the missing part of the minaret. For the Aleppo case, however, devices including GPS were not allowed due to security prohibition, and the total demolition of the minaret causes another important limitation for applicable technologies. Additionally, narrow streets around the mosque made it difficult in normal conditions to see the whole minaret from different points of the city. As an advantage, minaret of Umayyad mosque has more photos, which enables automatic reconstruction as shown in Figure 6. As stated before, the common view of the minaret from the inner area of the mosque can be reconstructed as opposed to the roofs and backsides, which are not present in the images. For these regions, it is better to use a semi-automatic or manual modeling method.

After obtaining a 3D model of the particular area, second step is to accurately register this 3D model over the camera input. The geographic coordinates of the structures are already known and we need to localize the camera image. Rough camera localization is achieved directly by GPS based location where applicable, which is not the case for Aleppo. To overcome the lack of GPS based location information, several common locations are predetermined and the image features coming through the camera of a mobile device can be used to depict the one that is the closest to the user’s actual location. This strategy is employed to obtain the accuracy of GPS based information with an additional cost of finding out the location by image comparisons.

Accurate rendering of the virtual 3D model over the camera image requires finer localization, which constitutes the next step of camera localization and aims to decrease the localization error from meters to centimeters. In other words, we need to register the 3D model or its image over the input camera image. To automatically register an image over another, we need visual similarities. These similarities can be searched in image features. One widely used image feature detector is SIFT (Scale-invariant feature transform) (Lowe, 1999) which is also employed for 3D reconstruction. SIFT based image matching requires common unique features in both images. In our case, as a significant portion of the structure is destroyed only the remaining features can be used which would make it harder to register the 3D model to the current condition of the area.

Another approach that is useful for registration is to utilize the straight lines present in the region of interest. In perspective view, parallel lines converge at a point, which is called a vanishing point. Despite the decrease in visible features, remaining lines and vanishing points can be used to refine the registration step. Applying those available technologies enables a new possibility for intervention projects in built heritage sites suffered any kind of demolition, instead of implementing complex, difficult and expensive real physical reconstruction, saving time and cost could be achieved by applying a VR reconstruction and using it to augment the reality. This gives the choice to analyze, modify and safeguard the intervention projects before its real application.

Figure 7 Using mobile phone to show Aleppo minaret before its last destruction.(Authors)
Figure 8: Using mobile phone to show Aleppo minaret during its restoration project in 2005. (Authors)

Figure 9: Using mobile phone to show Aleppo minaret in older historical era. Challenges of Ince Minaret are different; mainly the lack of images, thus a 3D modelling program is needed. Moreover 3D of historical description could be generated for older historical periods. Figure 10 showing on mobile device a 3D is shown using the historical images in black and white to complete the missing part. Having the main body of the minaret enables easier and more accurate positioning of the element.

Figure 10: Using mobile device to view Ince minaret complete 3D with the application options (Author)

RESULTS AND DISCUSSION

The project presents Virtual reconstruction is a valid possible alternative for high value monuments reconstruction projects. Many different challenges are facing the application of technology according to special conditions and physical situation of each case study.

It is possible to apply variety of technologies to achieve the objective of each phase of the project, starting from 3D regeneration according to available information and documentation (images, drawings, 2D…etc), then accurate positioning of the camera of mobile devices, to the last phase of projecting the saved 3D in our database over the real background taken by the camera of the device. In order to achieve real experience for the end user (tourist, designer, constructor, decision maker…etc) thorough and deep studies should be conducted by experts to overcome the challenges and limitations of each case separately.

According to the experience acquired in this project and the different difficulty levels of Aleppo and Ince minarets, it will be easier to apply the same flowchart to monuments or elements with partially missing parts, and wider spaces to in front of the building and more images in the archive. Figure 11 shows a possible case study in Aleppo of Alrumi mosque’s minaret where the application could be easier due to partial loss of the structure and its features similar to Ince minaret since they return to the same era and style of minarets, and the limited locations from which photos could be taken.

Figure 11: Minaret of Alrumi Mosque in Aleppo, before (left) and after (right)

Monuments with few images and complete destruction are more challenging cases, especially in monuments where vertical factor is dominant. Horizontal elements and buildings will generate different challenges and limitations going to be investigated in the future.

CONCLUSION

A virtual reconstruction on actual site was released achieving charters recommendations and guidelines as a temporary solution till the detailed documentation and analysis of the minaret stones and remains are conducted, it is also a flexible solution which enables us to modify the 3D reconstruction due to new gathered information, plus the possibility to show different historical eras of a monument, which could be widely used for a many monuments and heritage sites where the actual reconstruction is complex, expensive and provocative.

It is a method to revive many sites, enables the private public participation by developing another application to upload personal archive documents and images in order to enhance the quality of the virtual 3D model, and facilitate the decision making process by providing experimental temporary reconstruction projects on the actual site virtually before the actual construction occurs.
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NOMENCLATURE (MANDATORY HEADER)

Aleppo Minaret: The minaret of Aleppo Umayyad great mosque.
AR: Augmented Reality.
Ince Minaret: The minaret of Ince Madrasah School and Mosque.
In-Situ: Intervention in cultural heritage performed onsite.
Muezzin: A man calls to prayers using Adhan.
SIFT: Scale-invariant feature transform.
SFM: Structure from motion.
VR: Virtual Reality.

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