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Integration of 2D mapping, photogrammetry and virtual reality in documentation of material deterioration of stone buildings: Case of Mardin Şeyh Çabuk Mosque

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Abstract

Today, various methods are used in documenting the cultural heritage with the development of technology. However, it is seen that 3-dimensional (3D) documentation technologies have some disadvantages. For instance, ground laser scanning techniques are not used widely due to their high costs and the expertise required. Although photogrammetry can create point clouds with lower costs, it has large data files, which require allocating more time for data management. Within this context, the aim of this study is to present a method, which integrates the photogrammetry and virtual reality technologies in order to obtain 3D model of a stone building with a reasonable cost and in a short time; and to research the stone material deteriorations over the 3D model obtained. The study is significant in terms of systematically presenting the methods how the material deterioration maps are obtained over the 3D model of a stone building in a virtual environment. Mardin Şeyh Çabuk Mosque, which shall be investigated as case analysis under the study, was investigated on-site, and 360 degree panoramic images were taken related with the building. 3D virtual environment was created from the panoramic images on Mozilla Hubs programme, which is an open web-sourced platform. Stone material deteriorations were determined over the model in the virtual environment, and determinations regarding the stone building deterioration types were entered into the schedules prepared. As a result of the study, it was concluded that the virtual 3D environment regarding the building can be created from the global panoramic photographs with the suggested method on Mozilla Hubs platform, which is an open-sourced website, with a reasonable cost and in a very short time; and stone material deteriorations regarding the building can be determined easily on this virtual environment.

1. Introduction

Stone buildings are the works of art that occupy the largest ratio in cultural heritage field in the world. However, the stone buildings are defaced by being exposed to various impacts [1-4]. The types of stone material deteriorations are classified and mapped under various names from past to present in literature. For this purpose, documents were presented in order to establish standard methods for investigating the stone material changes and tracking the interventions carried out in stone material conservation field in also various countries, primarily in Italy.

The most important of these documents is the Italian Standard Normal 1/88, which was published in Italy in 1990 and is called "Alterazioni macroscopiche dei materyali lapidei: lessico" that may be used in mapping the stone deteriorations. Each of 27 terms provided in this dictionary was shown with photographs and a graphical schedule [5]. Another document is a document written by Jose Delgado Rodrigues, which is consisted of 26 terms, intended for the terminology of stone deterioration forms on monuments, and was created within the framework of ICOMOS Stone Committee's Petrography Group. This suggestion, was used as a base to publish a dictionary in Portuguese in 2004, which includes short definitions, including the terms related with stone, masonry and plaster deteriorations and each term is linked with a graphical table [6]. Another illustrated document, which was written by Fitzner et al. [7] and updated by Fitzner & Heinrichs in 2002, classifies the deterioration models per type and intensity. "Verein Deutscher Ingenieure" is a list of German terms comprised of 14 terms together with the definitions and drawings meaning Union of German Engineers [8]. As in the Italian Standard and in Fitzner's system, it has presented a suggestion for the graphical representation of deterioration models. Another document is an illustrated dictionary drawn up by Queen's University of Belfast (England), which is consisted of 30 terms. On its website (http://www.qub.ac.uk), comprehensive segregation characteristics, which both include the deterioration models of the monuments and refer to the anthropogenic damages, are presented. In 2008, with the 'ICOMOS-ISCS: Illustrated glossary on stone deterioration patterns', which was published by ICOMOS, ICOMOS International Scientific Committee of Stone (ISCS) has created a scientific language on stone deterioration incidents and processes [9].

Various countries, institutions, and authors made various classifications on the types of deteriorations over the years in order to ease the determination of stone material deteriorations as explained. Based on these documents, the method of material deterioration mapping on the buildings has been used in many studies in literature over the years, and its positive contribution into the determination of material problems is known [7, 10, 11, 12-17]. However, many of these studies emphasize that the studies, which document the stone material deteriorations as 3-dimensional (3D), are needed to diagnose the stone material deteriorations, which vary in geographic areas [12, 18-19]. Franković et al. [12], which is a significant example, have compared the stone material damage maps carried out on Belgrade Castle, and demonstrated that deterioration type damage maps, which are prepared in detail, are important diagnosis instruments in restoration projects, and it was suggested that the maps, which are created utilizing these classifications, must be carried to the 3D environments in future studies. Napolitano et al. [19] emphasized that while two-dimensional (2D) mapping is reasonable in terms of time and cost, at the same time it has various disadvantages when compared with 3D methods. They have mentioned that the surface contamination, which is among the stone material deteriorations seen on a historical building, may be caused by erroneous drainage system on the roof of the building or by various factors such as air pollution; it causes failing to document the diagnosis of the problem completely, since it fails to demonstrate the link between the damages on more than one sides of the building in the determinations made by considering the samplings at standards; and the material deteriorations of the buildings must absolutely be documented as 3D, since the 2D documentations enable only the treatment of instantaneous symptoms.

However, when 3D documentation technologies are considered, they have also some disadvantages [20-22]. Some technologies such as ground laser scanning techniques are not used widely due to the high costs and required expertise [23-25]. Although photogrammetry can create point clouds with lower costs, it has large data files, which require allocating more time for data management [26-27]. Within this context, various studies, which present methods intended for creating virtual reality environments to close the disadvantages of the gap between 2D mapping, photogrammetry and laser scanning and to determine the material deteriorations, have been conducted in the literature. These studies may be classified under two headings: those produced from 3D models and those produced from 360-degree panoramic images. Virtual reality environments, which are produced from 3D models, are costly, since they require time and knowledge of 3D. However, the virtual reality environments, which are produced from panoramic images, have the advantage of creating rapidly. It is seen that the use of global panoramic images provides great convenience in 3D documentation procedure to the user in terms of time and cost [19]. A significant example by Mah et al. [23] is consisted of the hard data used in creating the virtual tour, which is produced for the temple structure built from stone material, global images collected via 360° camera and 2D high resolution images obtained via digital single-lens reflex camera. It is determined that this method is advantageous because of increasing the accessibility for heritage practitioners through a 360^0 camera, which does not require high levels of technical specialty when compared with the other digital and visualization technologies, and the relatively low pricing of the 360-degree camera; and facilitating the future practices. Within this context, it is seen that besides 2D documentations, 3D documentation is a new and effective way of preserving and using culture. It is necessary to combine different techniques to obtain a representation of the historical buildings [28].

In summary, today 3D documentation of cultural heritage through digital archiving became a global objective. In this respect, use of digital and visualization technologies to document the cultural heritages is increasing [29-30]. Many of these approaches require the introduction of new data collecting and processing systems [31-32]. Remote sensing technologies enable us to model the object without touching it [33-35]. Within this context, the aim of this study is to present a method, which integrates the photogrammetry and virtual reality technologies in order to obtain 3D model of a stone building with a reasonable cost and in a short time; and to research the stone material deteriorations over the 3D model obtained. The study is significant in terms of systematically presenting the methods how the material deterioration maps are obtained over the 3D model of a stone building in a virtual environment. Mardin Şeyh Çabuk Mosque, which shall be investigated as case analysis under the study, was firstly investigated on-site, and 360-degree panoramic images were taken related with the building. 3D virtual environment was created from the panoramic images on Mozilla Hubs programme, which is an open web-sourced platform. Stone material deteriorations were determined over the model in the virtual environment, and determinations regarding the stone building deterioration types were entered into the schedules prepared. As a result of the study, it was concluded that the virtual 3D environment regarding the building can be created from the global panoramic photographs with the suggested method on Mozilla Hubs platform, which is an open-sourced website, with a reasonable cost and in a very short time; and stone material deteriorations regarding the building can be determined easily on this virtual environment. The presented method enables to display a stone building as 3D with a reasonable cost and in a short period by eliminating the cost caused by the laser scanning to create a 3D model and the data burden regarding the 3D point cloud obtained through photogrammetric methods. Furthermore, the presented method eliminates the disadvantages of 2D documentation by enabling complete documentation of the diagnosis of the material problem on the building, since it displays the link between the damages on more than one side as 3D in virtual environment.

In line with the aim identified, initially information on the building is provided under the study, and in the second section the method, which was followed to be able to create the virtual environment of the building, is described. In the following stage, images from the virtual environment, which are the findings of the study and the determination schedules of material deterioration are provided, and suggestions are made for future studies.

1.1. Location and History of the Building

Şeyh Çabuk Mosque is in Mardin Province, Çubuk Neighbourhood and on the South of the 1st Avenue (Figure 1).

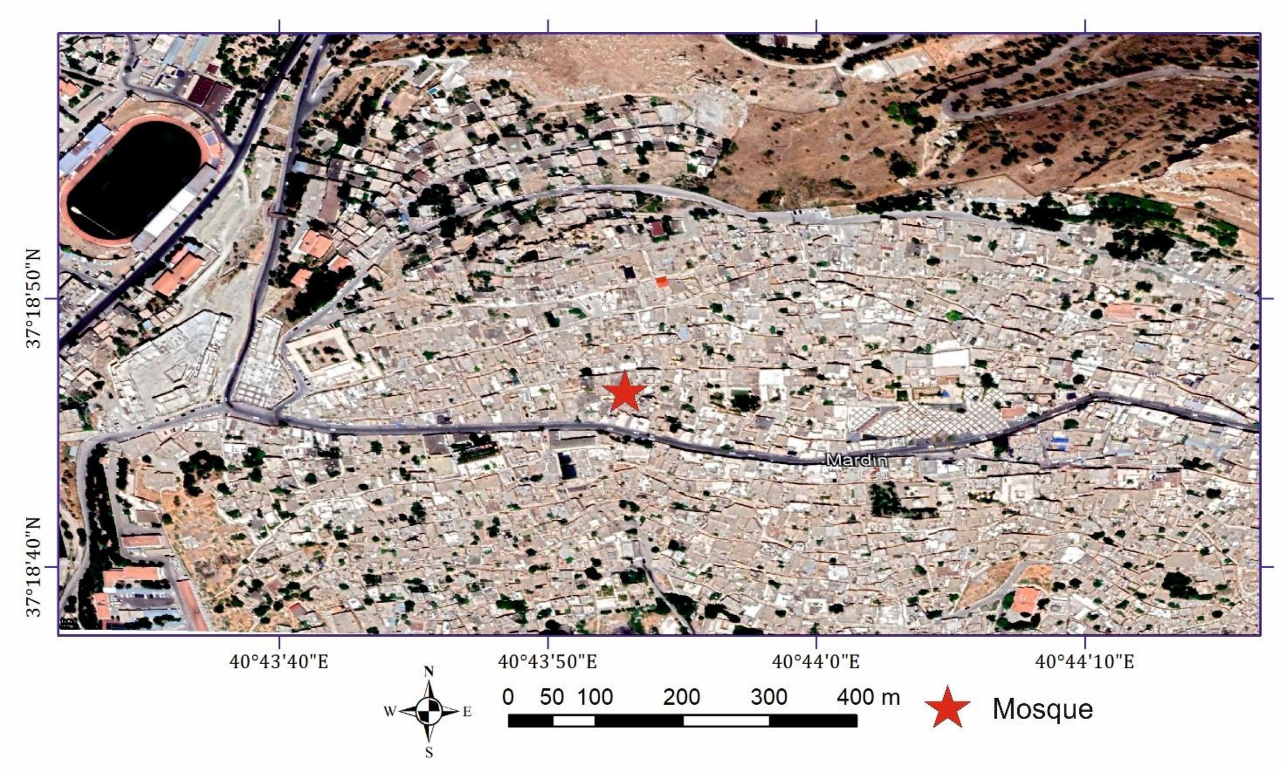


Figure 1. Location of Şeyh Çabuk Mosque within the city

The year of construction of Şeyh Çabuk Mosque is unknown and it has been repaired two times in the 19th century. The building has been mentioned as masjid in the 16th century Ottoman records and it is estimated that the part on the south of the entrance was tersanctus place. It is estimated that the building has been converted into masjid from zawiyah and to a mosque afterwards. The delubrum located within the mosque belongs to Abdullah Bin Enes El Cüheyni, who has been the messenger of Mohammed. It is written on the epigraph on its door that it has been repaired in 1843. Women's section, which has a separate entrance, was added afterwards on the North side of the mosque. West part of the building has been changed, as the building is under the risk of collapsing frequently due to the gap underneath. The women's section of the building, which was separated in 1967, is opened today, and added into the main sanctuary section [36] (Figure 2 and 3).

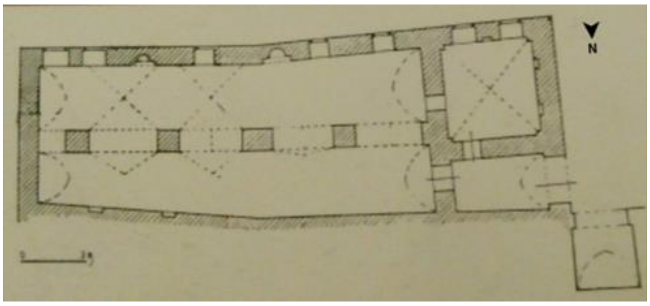
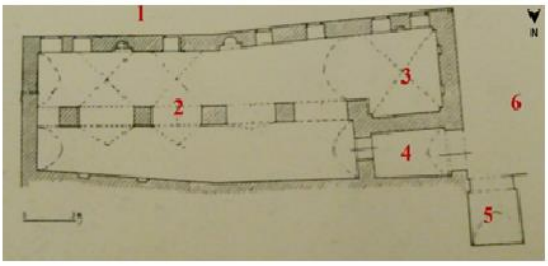


Figure 2. Plan according to the status in November 1967 [36]

1.2. Spatial Characteristics of the Building

In Şeyh Çabuk Mosque, a transverse rectangular plan scheme is seen and the main venue is consisted of two naves covered by two barrel vaults parallel to the mihrab wall. The entrance to the building is provided by the north-west iwan (space nr. 4) opening to the main courtyard (space nr. 6). The main sanctuary is consisted of the spaces nr. 2 and 3, and there is an iwan (space nr. 5), which is used as lumination place today on the North side of the building (Figure 3).



Space Nr	Original Function	Current Function
1	Back courtyard	Back courtyard
2	Men's Section	Main sanctuary
3	Women's Section	Main sanctuary
4	Iwan	Iwan
5	Iwan	Lumination place
6	Front Courtyard	Front Courtyard

Figure 3. Plan scheme of Şeyh Çabuk Mosque Ground Floor

2. Material and Method

Mardin Şeyh Çabuk Mosque, which shall be investigated as case analysis under the study, was investigated on-site, and 360 degree panoramic images were taken related with the building. 3D virtual environment was created from the panoramic images on Mozilla Hubs programme, which is an open web-sourced platform. Stone material deteriorations were determined over the model in the virtual environment, and determinations regarding the stone building deterioration types were entered into the schedules prepared.

2.1. Obtaining 360 degree panoramic images

Initially, 360 degree panoramic images of the buildings were taken with NCTech iris360º Model Panoramic Imaging by visiting the building, in order to create the 3D environments (Figure 4).

Figure 4. NCTech iris360º Model

The panoramic images obtained shall be used in 3D virtual environment on Mozilla Hubs, which is an open source platform in internet environment (Figure 5).

Figure 5. 360 degree panoramic image of Mardin Şeyh Çabuk Mosque taken by NCTech iris360º Model Panoramic Imaging Device

Mozilla Hubs platform is a free platform, which may be accessed by everyone at any place with internet connection, and may be used without downloading any software or programme onto the computer environment. The buildings are transformed into 3D environments, where the insides can be toured, utilising the feature of transforming the panoramic images into 3D environments, provided by Mozilla Hubs platform.

Furthermore, if it is desired to add other 3D models into the venue, again 3D point clouds may be obtained by importing the 360 degree panoramic photograph of the selected building into the photogrammetric modelling programme "Agisoft Photoscan", which supports 360^0 image infrastructure. The use of these models may be downloaded into the environment, which is created through uploading into skechfab open source, which is a feature of Mozilla hubs site. In addition, sketcfab is a source, which is open-sourced and in which the individuals all around the world may upload their 3D models, and every model created as such and uploaded into sketcfab is a data source for the students and other interdisciplinary professions involved in cultural heritage.

2.2. Stages of obtaining 3D virtual environment

First, login in Mozilla Hubs internet site (https://hubs.mozilla.com). Then, 'Join Room' tab is clicked on the screen opened (Figure 6).

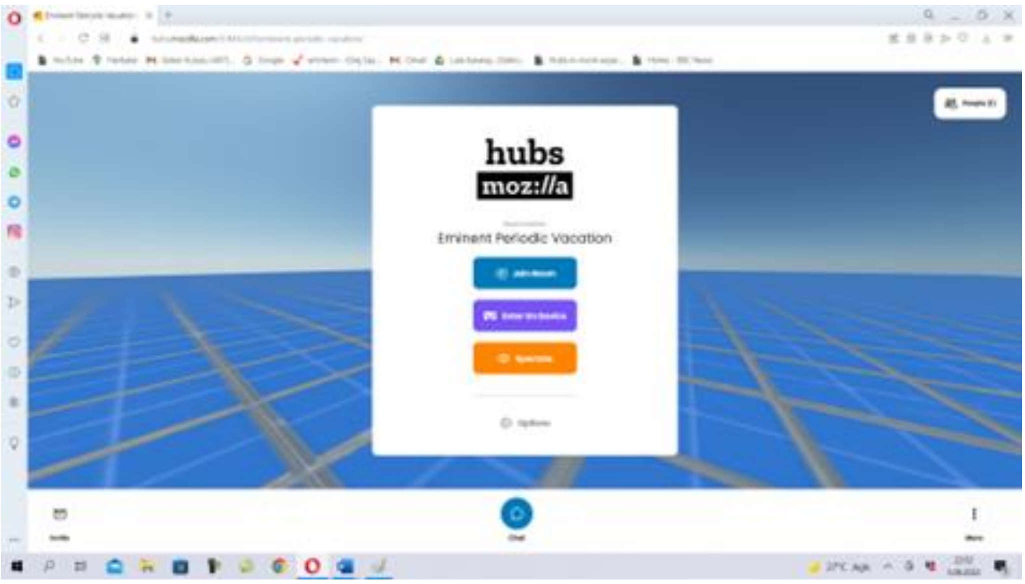


Figure 6. Mozilla Hubs login screen

Afterwards, the “place” tab is clicked on the screen opened and “scene” is clicked on the window opened. Then, the environment is entered in by clicking ‘new project’ tab on the new window opened (Figure 7).

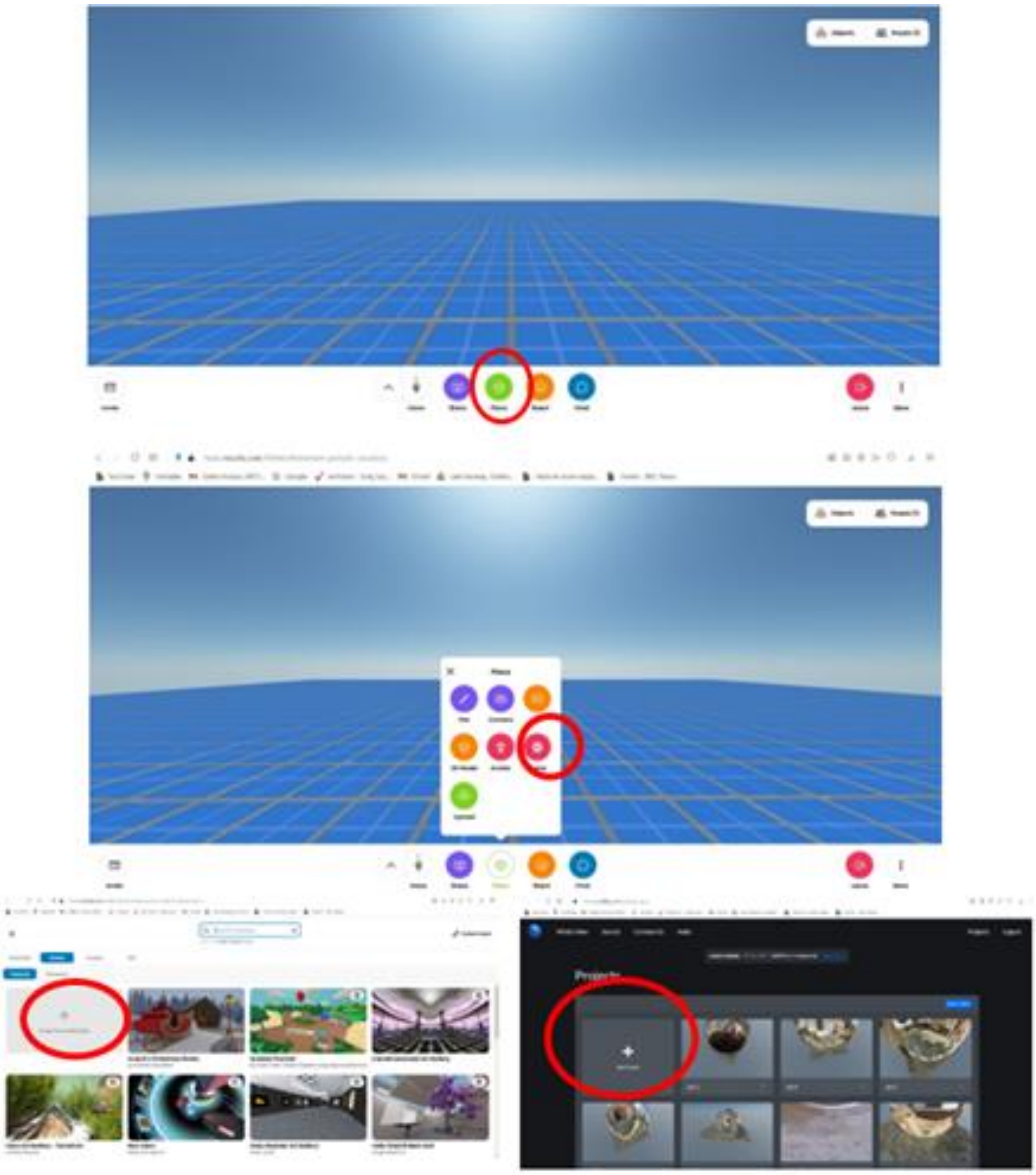


Figure 7. Creating scene on Mozilla Hubs platform

360 degree panoramic picture taken by Panoramic Imaging Device relating to structure, for which 3D image required to be taken, is uploaded by clicking on “image” section on the page appears. The uploaded picture shall come to the scene as flat. “360 degree tangular” button, which is on the tab next side, is clicked in order to transform this picture into 3D environment. When we enter into the environment, in order to walk around in a comfortable position, the “spawn point” tab again on the next side, that is the scale of the picture of the mosque imported into it with the scale of human eye, is adjusted and saved with the “image size” dimension again on the next tab. And, environment may be entered as 3D by clicking the “publish the hubs” tab placed on the rightmost upper side. In the section below, the screenshots of the steps that have to be followed in order to obtain 3D environment from a 360 degree panoramic picture in Mozilla Hubs environment are presented stage by stage (Figure 8).

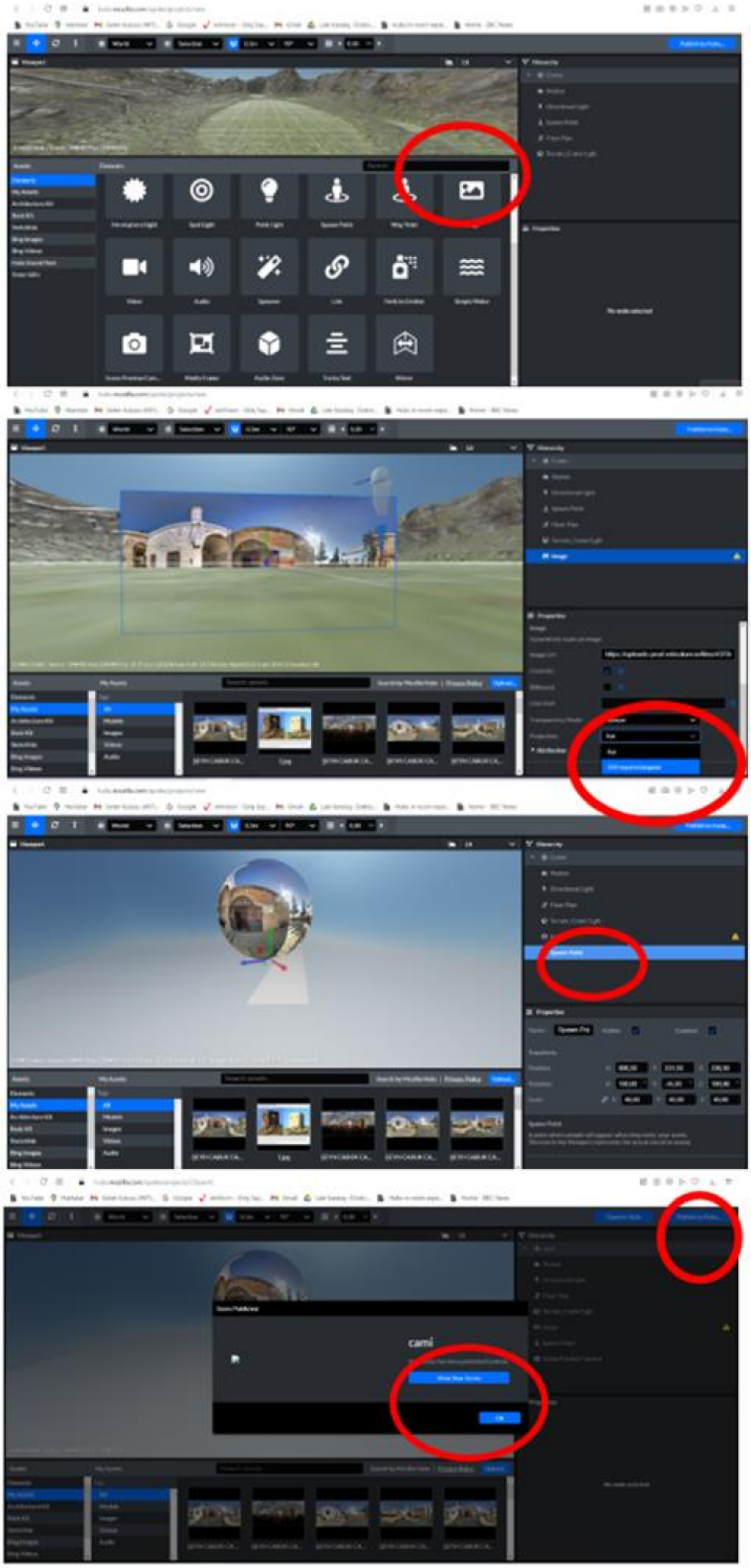


Figure 8. Transformation of 360 degree panoramic images into 3D virtual environment on Mozilla Hubs platform

3. Results

3D virtual environment was obtained regarding the building from the 360 degree panoramic photographs under the study and deterioration maps were defined over this virtual environment.

3.1. Obtaining 3D virtual environment of the building

Virtual environment of Melik Mahmut Mosque was obtained from 360 degree panoramic photographs in Mozilla Hubs programme. The building can be perceived clearly, toured in the virtual environment and the information on its materials and material deteriorations can be displayed in detail by zooming in and out thanks to the avatars. The images of the building in the virtual environment are presented in the figures below (Figure 9).

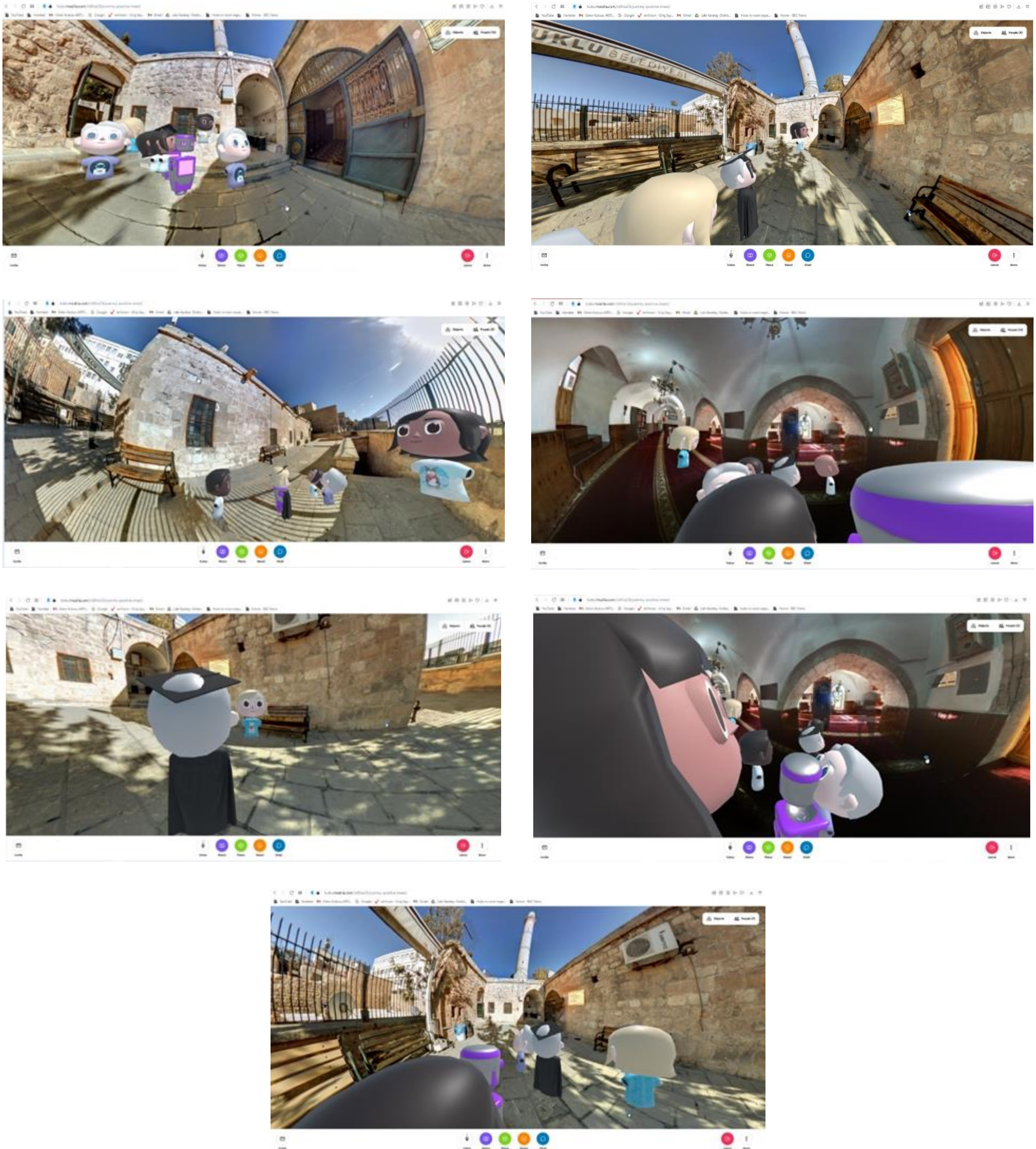


Figure 9. Images of 3D Model of Mardin Şeyh Çabuk Mosque on Mozilla Hubs Environment

3.2. Deterioration maps obtained from the virtual environment of the building

Material deteriorations viewed on the building in the virtual environment were defined on the schedules. According to the findings obtained, the faulty repairs caused by the use of cement are seen on the pillars in Şeyh Çabuk Mosque. Surface loss, gap-hole formation, discharge of jointing, rust stains, and colour changes as a result of damages on the stone material caused by the impact of moisture and due to the sunlight, were determined on the walls, which are the continuous bearings. Faulty material repairs are present partly with the use of cement instead of using the original of the material, as a result of the deterioration of the original state of the material. Plant and moss formation was found in the courtyard (Table 1) that has flat flooring. Wearing is seen on the stairs. Crack-fracture, formal deformation, wearing and colour change are present on the frames and wings of the wooden windows. Faulty repairs are present on the buildings, as non-original additions have been made to the building. Wearing was observed on the sills. Material deterioration was not found on the arches. Mouldings and gargoyles, which are the auxiliary stone elements are present in the building. Surface contamination is seen on the mouldings and gargoyles.

Table 1. Problems encountered on the construction materials of Şeyh Çabuk Mosque, which have been produced by masonry materials

NATURAL STONE CONSTRUCTION ELEMENTS			PROBLEMS ENCOUNTERED ON CONSTRUCTION ELEMENTS MADE OF MASONRY MATERIAL IN MARDIN ŞEYH ÇABUK MOSQUE																		Faulty Repairs		
			Loss of surface	Fragmentation	Formation	Pitting	Cracks	Spalling	Foliation	Discharge	Surface	Shell	Efflorescence	Crystallization	Formation of plant	Formation of moss	Corrosion (Rust	Tear	Loss of form	Colour change	Use of cemen	Fall of plaster	Other
VERTICAL BEARINGS	SINGLE BEARINGS	Leg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
		Column																					
	CONTINUOUS BEARINGS	Wall	x	-	x	-	-	-	-	x	-	-	-	-	-	-	x	-	-	x	x	-	-
HORIZONTAL BEARINGS	FLOORINGS	Flat	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-
	Curvilinear	Vault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Dome																					
STAIRS			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
WALL OPENINGS	Window	Lintel/jamb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Door	Lintel/jamb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
	Arch		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUXILIARY ELEMENTS	Network																						
	Moulding		-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
	Gargoyle		-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
	Chimney																						
	Element for passage to the cover																						

4. Discussion

The aim of this study is to present a method, which integrates the photogrammetry and virtual reality technologies in order to obtain 3D model of a stone building with a reasonable cost and in a short time; and to research the stone material deteriorations over the 3D model obtained. The method presented within the scope of the study enables to display a stone building as 3D with a reasonable cost and in a relatively short period, such as 2 minutes, by eliminating the cost caused by the laser scanning to create a 3D model [22-25] and the data burden regarding the 3D point cloud obtained through photogrammetric methods [26], which are the disadvantages emphasized in the literature. Material deteriorations can be investigated in detail by zooming in and out with the avatars on the building, with the advantage of touring the building in the virtual environment. Thus, it enables the complete documentation of the diagnosis of the material problem on the building, since it displays the link between the damages on more than one sides of the building in the virtual environment. This conclusion demonstrates that the method presented in this study may eliminate the disadvantage [19] that 2D documentation enables only the regional focusing, which is emphasized in various studies in the literature.

In the study, the virtual environment could be obtained from the global panoramic images rapidly. This result supports the finding obtained by Napolitano et. al [19] that the virtual reality environments are obtained from the panoramic images rapidly and the use of global panoramic images provide great convenience in 3D documentation procedure to the user in terms of time and cost. Furthermore, the study results verify the finding obtained by Mah et. al [23] in their study results that this method is advantageous because of increasing the accessibility for heritage practitioners through a 360^0 camera, which does not require high levels of technical specialty when compared with the other digital and visualization technologies, and the relatively low pricing of the 360 degree camera; and facilitating the future practices.

5. Conclusion

With the study conducted, a method is presented, which integrates the photogrammetry and virtual reality technologies in order to obtain 3D model of a stone building with a reasonable cost and in a short time; and the detectability of the stone material deteriorations over the 3D model obtained is researched. Within this scope, as a result of the study it is concluded that the virtual 3D environment regarding the building can be created from the global panoramic photographs with the suggested method on Mozilla Hubs platform, which is an open-sourced website, with a reasonable cost and in a very short time; and stone material deteriorations regarding the building can be determined easily on this virtual environment.

As a result of the study, it is seen that it is possible to add other 3D models into the venue in, Mozilla Hubs environment. Another finding is that these models can be uploaded easily into the media that is created by uploading into the skechfab open source, which is a feature available in Mozilla Hubs website, after the 360 degree panoramic photograph of the selected building is imported into the "Agisoft Photoscan" programme, which is a photogrammetric modelling programme supporting the 360° image infrastructure, and the 3D point clouds of the buildings are obtained. Besides, it is seen that it is possible to upload the 3D historical building models we made and their materials free of charge on Mozilla Spoke page by clicking the 'custom url or file' button located on the rightmost upper part on sketcfab tab. It is seen that with this method it is possible to create an open data library, where the materials of the buildings and the material deteriorations may be investigated closely and determined, as Sketchfab is a source, which is open-sourced and in which the individuals all around the world may upload their 3D models, and every model created as such and uploaded into sketcfab is a data source for the students and other interdisciplinary professions involved in cultural heritage. As a result of increasingly growth of these open data clusters, it shall be possible to create a material library.

It is suggested to create the virtual environments of the historical buildings in different countries with the systematic followed in our study, in order to obtain a library regarding the stone material deteriorations in future studies. Thus, an open data library shall be created and every individual in another place of the world shall have the chance to view, tour and investigate all historical buildings, which are documented in this environment, free of charge.

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Conflicts of interest

The authors declare no conflicts of interest.

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