Practical 3D photogrammetry for the conservation and documentation of Cultural Heritage

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Abstract: The past few years has seen many developments in the world of 3D modeling of architectural and archaeological heritage. One of these developments is the expansion of 3D photogrammetry modeling programs into the practical and affordable world. Utilizing open-source software such as Meshlab, freeware such as 123D Catch, and licensed software such as Agisoft PhotoScan Pro, it is now cost-effective to utilize photogrammetry on any project. These programs offer the world of practical heritage conservation an innovative and powerful tool for documentation, visualization/virtualization, and planning. This paper reports on the results of developing a low-cost methodology to pursue photogrammetry in the conservation of cultural heritage and in archaeology in the State of Israel. Compared to high-cost alternatives such as laser scanning, which has been utilized in Israel before, the results have shown how effective photogrammetry is and can be for conservation and documentation of cultural heritage. Some of the applications include high-resolution rectified models of effectively 2D planes (mosaics, wall and ceiling paintings), conservation planning on small and large-scale cultural heritage sites, and the documentation of archaeological sites in 2D and 3D. By approaching photogrammetry from a low-cost level, it not only encourages its application in the field, it allows professionals at all levels to engage with the technology and to learn how to utilize the technology, whereas previously the application of the technology has been restricted to institutions and companies with enough capital and resources to spend learning and utilizing the technology and to hobbyists and other interested professionals, many of whom helped push the field towards lower costs.

Keywords: photogrammetry, conservation, heritage, documentation

Introduction: Digital Tools for Conservation of Heritage in Israel

The modern State of Israel is one of the world's leading places for heritage travel and archaeology, dating back to the origins of the Grand Tour (BARAM & ROWAN 2004). In the two centuries since archaeological work began in what was then the Ottoman Sanjak of Syria and the Sanjak of Jerusalem, over 30,000 sites have been uncovered and documented in the State of Israel. The sheer number of sites combined with the diverse and difficult climates and lack of monetary resources and time, cause many of these sites to not have proper documentation and conservation.

Digital tools for archaeology and heritage documentation are a recent phenomenon in the State of Israel. It has only been in the past decade that laser scanning has begun to be utilized as a tool for documentation and conservation of heritage sites such as the walls of Jerusalem and the site of Masada. Laser scanning is an effective and known tool in Israel; however, it is not a cost-effective tool and can only be utilized by sites with appropriate funding. Digital photogrammetry is also a known tool in Israel but until now, it has only been

used for digitizing small artifacts. For large-scale sites, only academic digs have begun utilizing digital photogrammetry in the State (KILLEBREW, *et al*. 2013). To answer this question, as a student intern with the Saving the Stones program of the International Conservation Center – Città di Roma in Old Acre, Israel, Waas approached a series of case studies utilizing freeware and open-source software to create photogrammetric models of sites in Israel (WAAS n.d.). The conclusion of that project found that digital photogrammetry could answer many of the issues facing the documentation and conservation of sites throughout Israel, but that there were limitations with the programs tested. This paper is the second stage of that project and focused our testing on professional paid software, further pushing the boundaries of what digital photogrammetry could offer in the field of conservation in Israel while remaining cost-effective and time-effective.

For this stage of the project, we determined three main objectives that we would examine:

1. How can 3D-modeling technology for conservation and documentation of cultural heritage be used successfully in Israel?
2. How can we establish a practical and low-cost methodology to implement this technology in Israel?
3. Can conservation planning be done directly on the 3D models?

We approached three case studies in three very different environments in the State of Israel: a wall at Tel Yokneam; a painted ceiling in Old Akko; and the latrine at Beit She'an.

Case Study 1: Tel Yokneam

Tel Yokneam is located to the east of the Carmel Ridge in the Jezreel valley near Haifa. The portion of the site we tested is a rapidly deteriorating portion of the remains of a wall of the Crusader Church that was located on the Tel. Because it is deteriorating rapidly and that it is a prominent part of the landscape of the Tel, it provided a great opportunity to test and see what digital photogrammetry could produce for developing a solid conservation and intervention plan. To capture the site, we used Autodesk 123D Catch and a Canon EOS 7D DSLR camera with wide-angle lens. The results can be seen in fig. 1.

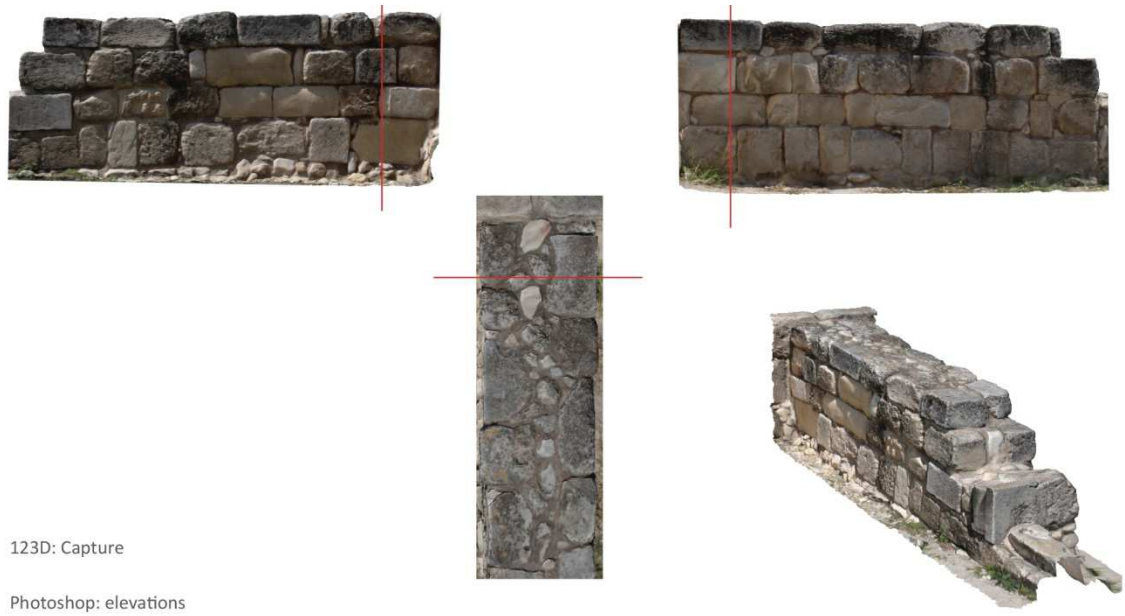

Fig. 1 – Model and elevations of the wall of the Church

The results were excellent. To process the model and to produce the orthorectified elevations a combination of Adobe Photoshop and Sketchup was used. For our needs in conservation in Israel, this presented a clear example of how powerful the technology could be for documentation while achieving our goals of low-cost and time-efficient application of digital photogrammetry for conservation. However, this site is small in scale and comparatively straightforward and simple. In addition, as we later discovered (WAAS, n.d.), 123D Catch performs admirably well on small-scale sites such as this wall, but the larger the site, the more distorted and difficult to process it became. For our second and third case studies, we utilized Agisoft Photoscan Pro (trial edition) to understand what professional paid software could offer us in the conservation world.

Case Study 2: Painted three-dimensional ceiling in Old Acre

Our second case study was located inside of the Old City of Acre, located on the Mediterranean Coast. The site presented a series of different challenges from the Tel Yokneam site. Unlike at Tel Yokneam, which provided optimal lighting conditions for capturing the model, the painted ceiling was located inside a room that had diminished natural lighting because the windows were all sealed off (see fig. 2).

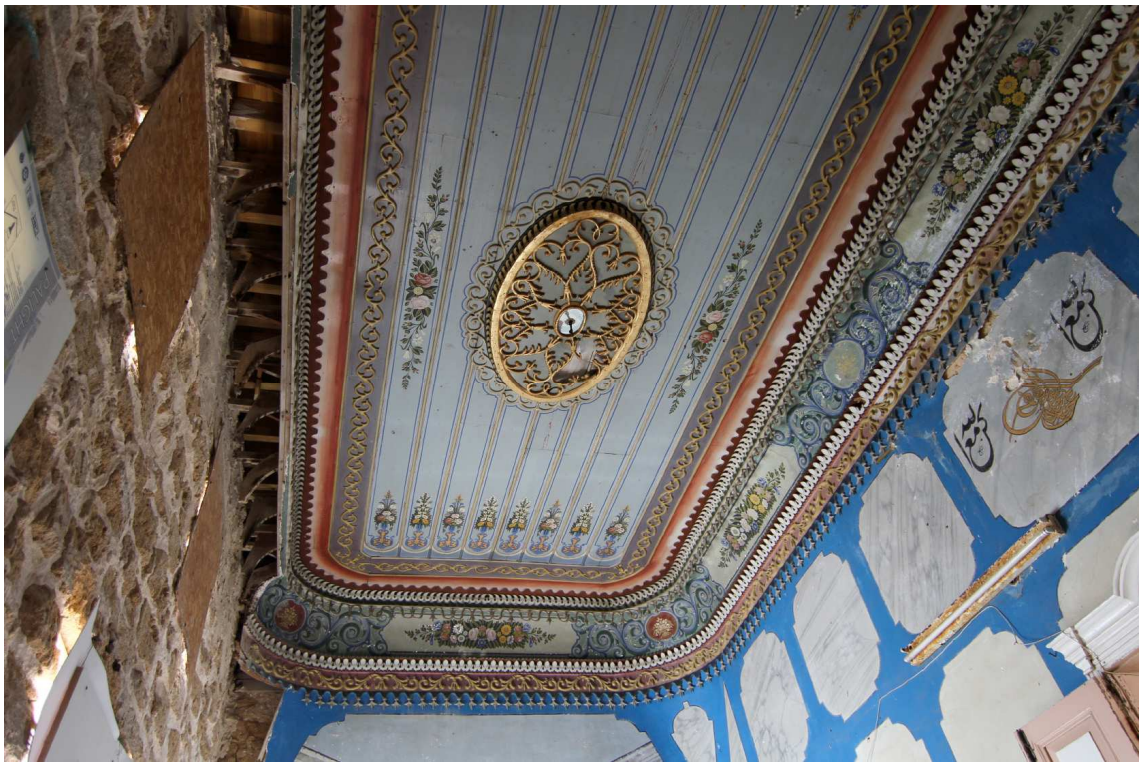

Fig. 2 – Photo of the ceiling showing the sealed windows inside of the room.

The home belonged to a prominent Beiruti family that moved to Ottoman Acre in the late 19th century and now belongs to a private owner awaiting conservation and redevelopment. In the Old City of Acre, before any development can be approved legally, the building has to undergo a documentation, which includes the historic documentation, urban survey, engineering report, and conservation proposal. For this building, the historic documentation was performed by the author (WAAS).

As a part of the historic values section of the documentation, digital photogrammetry was tested to showcase conservation issues of the ceiling. Section cuts and orthorectified photos were produced, giving us a good comparison between older approaches in conservation and new technologies. The previous documentation of the building utilized hand-drawn sections and for rectified photography, stitched together several photos of varying quality and accuracy. The differences in accuracy of the representation are stark. The orthorectifed view of the ceiling obtained from Agisoft PhotoScan Pro does not contain the distortions that the stitched rectified photo does (fig. 3). Furthermore, it fixes the issue of perspective, giving a more correct understanding of the current state of the ceiling. For conservation, this is an important and key feature because it provides an understanding of the shape of the object, which in conjunction with the section cuts gives an understanding of the construction of the ceiling.

Fig. 3 – Top: Orthorectified view of the ceiling produced utilizing digital photogrammetry in Agisoft PhotoScan Pro. Bottom: Orthorectified photo produced by stitching together three separate analog photos (1998).

Another key feature of digital photogrammetry is the creation of photo-realistic textures. These textures, if produced correctly, allows the conservator to understand in two-dimension and three-dimension key features and conservation issues in high detail. In the case of the painted ceiling, it would be possible to create stencils for conservation and restoration and identify colors to the level of pixels (fig. 4). Before, with analog photography, it was not possible to be able to see

Fig. 4 – Top: View of the flower detail on the ceiling. Down: Magnified view of the center of the feature showing the level of detail of the colors.

this kind of detail without utilizing a very powerful camera. Now, with the ability to see the colors on the pixel level, it is possible to accurately depict and represent the ceiling and make suggestions for the conservation and restoration of parts of the ceiling that no longer exist.

For the conservation and documentation of this building, three-dimensional digital photogrammetry provided an important tool for understanding the ceiling and how to propose conservation for it and document its important features. One of the side benefits for this site is that since it is a private building with limited access, the models can be published and seen on sites such as sketchfab.me (See mwaas.sketchfab.me to see this model). Because conservation issues in Israel are in many cases tied to tourism development, this allows many people to experience the site without physically being there.

Case Study 3: Latrine at Beit She'an

Beit She'an, located just south of the Sea of Galilee in northern Israel, near the Jordanian border, is one of Israel's most famous sites. The large tel, famous for the Egyptian governors house found at the top and the Roman and Byzantine city found below the tel is constantly undergoing conservation and monitoring as both local and international tourists come to visit the site year round. The latrine in the Roman city at Beit She'an is located near the amphitheater complex, in the eastern bathhouse. It is a site that has been documented

and conserved before so it gave us an opportunity to update the documentation and use the opportunity to monitor how the previous conservation works have survived.

The first stage of the process was to generate a plan views and section cuts (fig. 5).

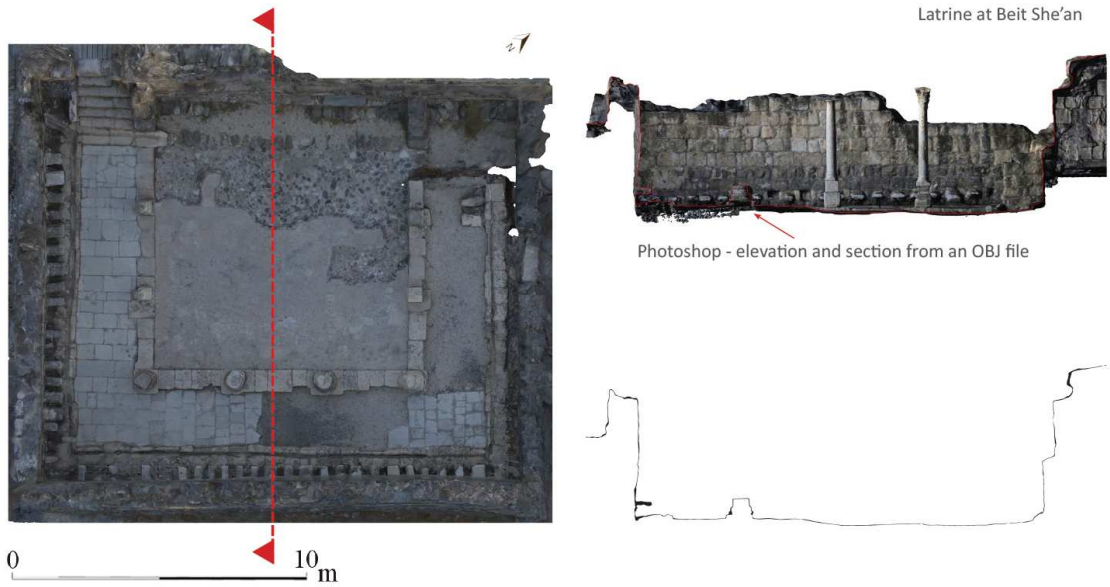

Fig. 5 – Plan view generated in Photoscan and section cut and elevation produced in Photoshop.

In comparison to previous work, we discovered the plan view and section cut to be more accurate and representative of the site. The second stage of the process focused on the mosaic floor in the center of the latrine. Using Photoshop, six horizontal sections (fig. 6), descending in height, were generated showing the lacunae and deformations in the floor.

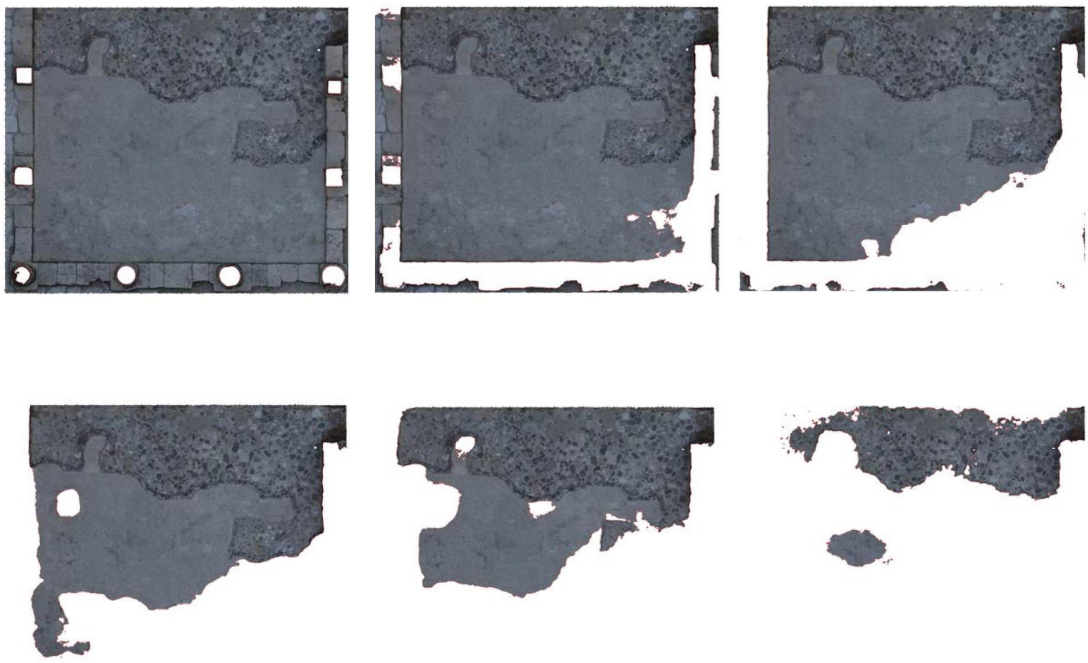

Fig. 6 – Horizontal section cuts of the mosaic floor.

Using PhotoScan, a digital elevation model of the mosaic floor was also produced and utilized in conjunction with the section cuts by overlaying the DEM with the section cuts in Adobe InDesign (fig. 7).

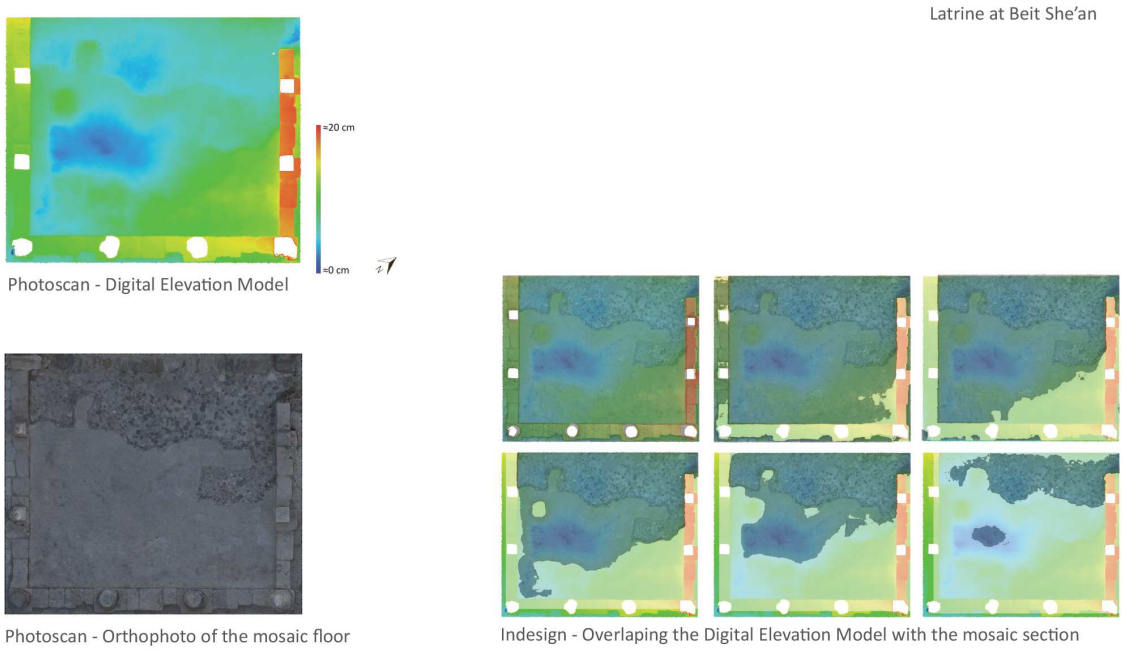

Fig. 7 – Horizontal section cuts of the mosaic floor with the DEM overlaid. The scale of the DEM is the brightest reds correspond to about 20 centimeters height and the darkest blues correspond to about 0 centimeters height.

The DEM provides an amazing tool for conservation because it can be seen quite clearly where drainage issues will occur and can provide the architect or conservation planner a base from which to design an intervention for the site. In this case, the DEM reinforces the lacunae and deformities found with the section cuts of the site and from surveying it initially. The DEM can also be utilized as a monitoring tool for the site to see if the deformations in the mosaic continue to grow. The third stage was to create a 2D orthorectified conservation plan and report (fig. 8). This, along with the

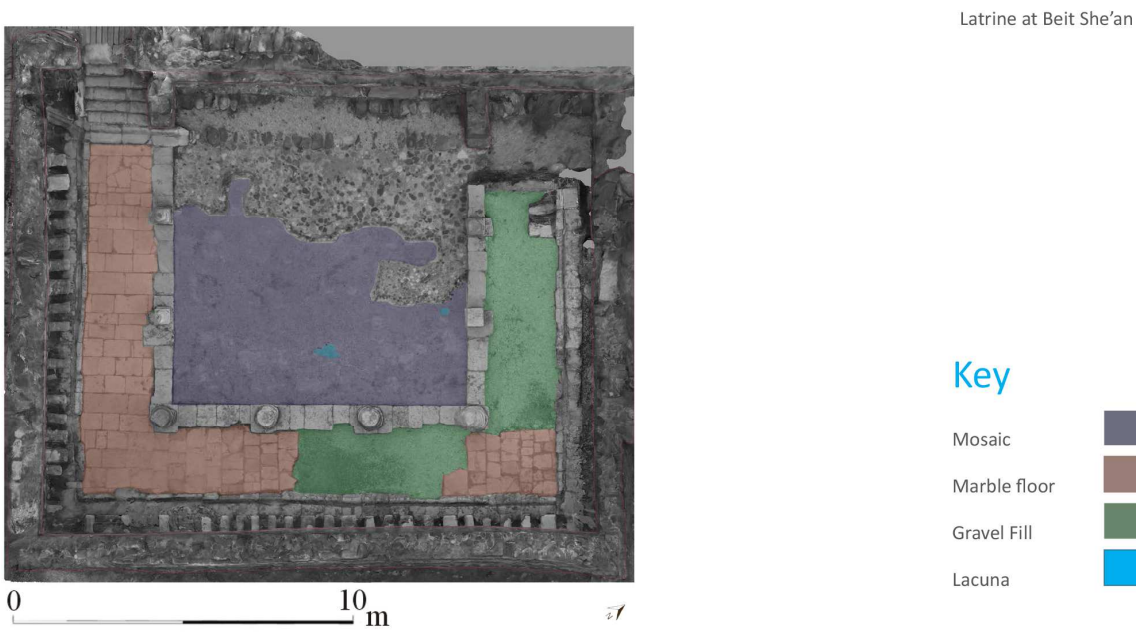

Fig. 8 – Conservation plan and report of the latrine at Beit She'an.

section cuts and elevations forms the basis of any conservation plan and documentation in the State of Israel.

The Future of Conservation Planning in Israel?

With all of our case studies, we have utilized the three-dimensional medium of digital photogrammetry for producing two-dimensional outputs for conservation planning and documentation. In our last case study, we attempted to do the conservation planning and documentation directly on to the three-dimensional model using Photoshop. The results can be seen in fig. 9.

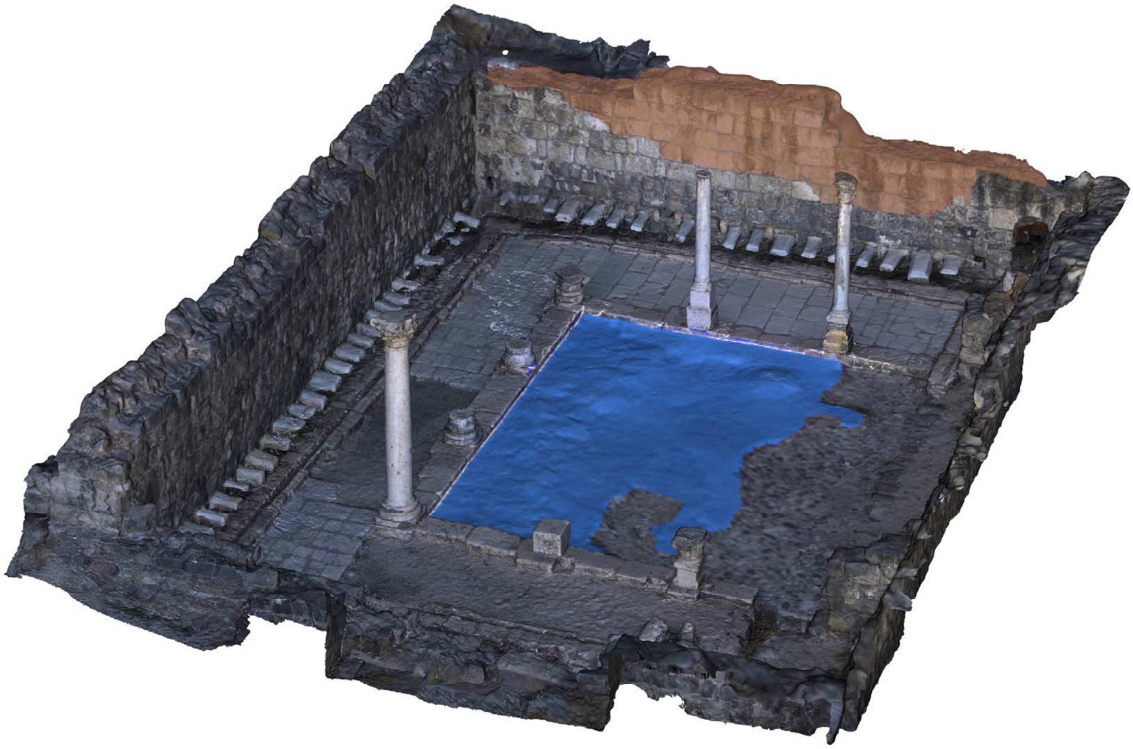

Fig. 9 – Test of planning in three-dimension. The blue represents the mosaic floor and the red represents the reconstructed wall.

In the future, planning on the three-dimensional model can be utilized to provide the conservator a visual reference of different areas to either be worked or to keep in mind. Furthermore, it is possible to integrate new objects into the model for planning purposes to show what suggested conservation interventions should be done at a site (WAAS n.d.).

Conclusion

In Israel digital photogrammetry answers a pressing need for more efficient and lower-cost tools for documentation and conservation. Because digital photogrammetry can significantly cut the time spent developing the documentation and conservation plans, it is a tool that can be implemented at sites throughout Israel. Unlike laser scanning, digital photogrammetry can be implemented at a site more efficiently and at a much lower cost. This is especially important for the majority of sites in Israel, which do not have the funding or the teams necessary to be able to afford laser scanning and the man-hours spent working with the material.

This paper is only the beginning of what could be possible for digital photogrammetry in Israel. The second and third case studies answer how the technology can be utilized and implemented in conservation and documentation of cultural heritage in Israel as well as whether it is possible to do the conservation planning directly on the model. It remains to be seen if we can establish a practical and low-cost methodology for implementation but the early returns are encouraging. In the future, we plan to move from these pilot project case studies to actual implementation in the field.

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