3D Laser Scanner as a Tool of Documentation for the Heritage Gardens

By: Heidi Ahmed Shalaby

Assistant Professor

Department of Architecture, Faculty of Engineering, Zagazig University, Egypt

Heidi.Shalaby@yahoo.com

Abstract:

The Heritage Gardens are a very important urban component in Egyptians' lives, from ancient times until now. In the modern era, a lot of very important and famous gardens have been established in Egypt, especially by Mohamed Ali Pasha and Khedive Ismail (1830–1895). Most of these gardens have been listed as Heritage Gardens by the National Organization for Urban Harmony (NOUH), but because of the shortage of data, the conservation process could not be completed.

The Heritage Gardens have deteriorated over time. They were built as privet gardens, palace gardens or public gardens.

One of the most unique gardens in Cairo is the Fish Garden and Grotto, which was established in 1867 as a privet garden for the royal family. It was turned into a public garden in 1902.

Because 3D laser scanning is considered an initial tool for documenting the huge and important Heritage Gardens in Egypt, this paper presents the technique of preparing a full, detailed documentation for sites and open spaces by the 3D laser scanner. It will prepare a high level of documentation, especially for the Heritage Grotto. The project takes eight weeks on-site and four weeks in-office to complete the documentation to finish the Fish Garden and Grotto (total area 10 feddan) from both the outside and the inside.

To reach the goal of the paper, the research goes through the historical background to present the importance of the garden as a Heritage Garden, as well as to show the importance of this garden in the local community. Then, the paper presents the documentation technique by using the 3D laser scanner and a sample of the outcomes to confirm the importance of using the 3D laser scanning as a revolutionary technology in the fields of cultural heritage and landscape site documentation.

Keywords:

Heritage Gardens- 3D laser scanner- Documentation- Zamalek fish garden.

1. Introduction:

The International Council on Monuments and Sites (ICOMOS) defined the Heritage Garden as 'an architectural and horticultural composition of interest to the public from the historical and artistic point of view' (O'Donnell, 2020). Located within the umbrella of cultural landscapes, historic gardens are as much a part of our heritage as our historic towns, architecture or literature (Hristov, Naumov and Petrova, 2018). The historic gardens have been thriving over the past few decades, particularly in Egypt.

According to historians, the art of garden design first appeared in Egypt during the Old Kingdom era and flourished throughout the years, especially during Islamic rule in Egypt, where it reached its peak during the rule of the Alawi dynasty (1841–1952) (Alkalawy, 2013). It was designed and implemented by French, Italian and Turkish engineers. It featured a variety of design styles, some of which were established like European gardens of the time, and it included unique architectural works, such as mountains, lakes, paved and gas-lit paths, and thousands of species of rare plants and trees that were imported from various countries and localised in Egypt before planting them in those gardens, thus becoming an environmental and cultural landmark (Elfardy, 2018).

Most of these gardens are now considered Heritage Gardens, so they need to be preserved. Since the first step of conservation is the documentation, laser scanning has become a popular technique for the acquisition of digital models in cultural heritage conservation and restoration nowadays.

2. The New Technique of Documentation:

With the continuous progress of computer and laser measurement technology, non-contact measurement based on laser scanning technology has been increasingly applied in the mapping and planning process. 3D laser scanning has been used as a new technology since the 1990s (Sameer, 2020).

De Reu defines the laser scanning as 'strategy for scanning the surface using laser light by examining a real-world or object's environment to collect 3D data' (De Reu, 2014). Also, it can record features of large, dense points and measure the surface of any object, especially when it is necessary to map the surface and entity of a complex structure that cannot be measured. In addition, it provides different outputs like 3D coordinates, reflectance and texture information, so as to rapidly reconstruct 3D models (Hu, Kong and Lv, 2021).

Compared with traditional single-point measurement, 3D laser scanning technology is considered a revolutionary technology, from single-point measurement to surface measurement. In the fields of cultural heritage, architecture and planning, more and more kinds of 3D laser scanners are used presently (Hu, Kong and Lv, 2021). The collected 3D point cloud data and 3D modelling results can be converted into standard format and output into file format that can be recognised and processed by other engineering software.

In recent years, with the wide application of 3D scanning technology in the field of cultural heritage, some scholars have made attempts to use 3D digital technology to map and record different kinds of gardens and rockeries, and also to demonstrate the feasibility of 3D laser scanning and close-range photogrammetry for landscape mapping (Dong, Zhang and Zhu, 2020). The next part of the paper presents the historical background of the Fish Garden and Grotto (a component of the garden) as well as its legal framework and management, which is to highlight its importance, both as a Heritage Garden and based on its impact in the local community.

3. The Case Study: The Fish Garden and Grotto

The Fish Garden and Grotto is one of the oldest and most ancient artificial grottos in the world. It was built on the model of the French grottos by the most famous French architects. In addition, after its conversion into an aquarium in 1902 AD, it also became one of the most important and oldest aquariums in the world. This grotto was part of the gardens of the famous Gezira Palace built by Khedive Ismail, which still remains until the present time after it was converted into the Marriott Hotel in the most famous Nile island, known as “Zamalek”.

3.1.The Historical Background:

The Fish Garden and Grotto is located on Zamalek island, very near to the downtown area of Cairo. Gezira/Zamalek island appeared in the Nile during The Mamlouk era, around 1340. It also represented a glorious phase of modern Egyptian history, especially the second half of the nineteenth century (Ismail and Al, 2020).

For many years throughout the history of Cairo, Zamalek or El-Gezira was a green paradise you can spot from almost anywhere along either bank of the Nile. The south part of the Zamalek transformed to gardens and orchards to supply Cairo palaces with trees and decorative plants (Cairo’s Green Spaces: The Aquarium Grotto Garden, 2022). The island's landscapes were designed by Deschamps, who had once done the landscape designs for the City of Paris, along with his assistant, Gustave Delchevalerie (Elfardy, 2018).

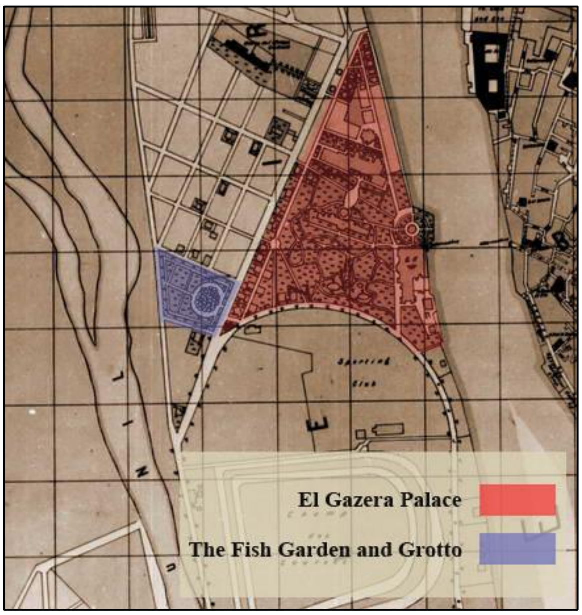
In 1868, the Gezira Palace, designed by Julius Franz Pasha near to the neo-Arab classicism style, was built with the intention of hosting the guests invited for the inauguration of the Suez Canal, such as Empress Eugénie, the wife of Napoleon III. After the inauguration process, the palace was used for ceremonial events and khedival meetings, occupied now by the Cairo Marriott Hotel (Elfardy, 2018).

Khedive Ismail was influenced by French civilisation, particularly after visiting the 1867 World Exhibition in Paris, so he established two grottos in the Gezira Palace Garden, a privet one designed and executed by Sipoz, the Turkish rock craftsman of Khedive Ismail. The other public grotto, today’s Fish Garden, dominated the western banks of the island (Elfardy, 2018). It was created in 1871 by Combaz and Dimilieu, two famous Parisian companies (Delchevalerie, 1871). It was made as an aquarium expanding over 22,000 square meters, including artificially made hills. The grotto was made from rocks fitted together with cement rather than wood. The same structural technique mixed with pointed iron fixtures was used to create stalactites imitating natural caves and grottos. The caves had a wide range of decorative colours and were decorated with alpine plants (Idem, 1899). It was once one of Cairo's highlights, as it was one of the few 19th century gardens open to the public. It was a garden of plants and home to the Khedive's exotic plants shipped from all over the world, and it also housed his collection of fish and reptiles from the Nile and Africa (Alkalawy, 2013).

In 1902, The Fish Garden was transformed to a public garden (as shown in Figure 1) under the leadership of the Giza Zoo Gardens. Captain Stanley Flower introduced the Fish Garden; as he added aquariums in the old grottos of the garden, it became home to a rare collection of African fish (Alkalawy, 2013).

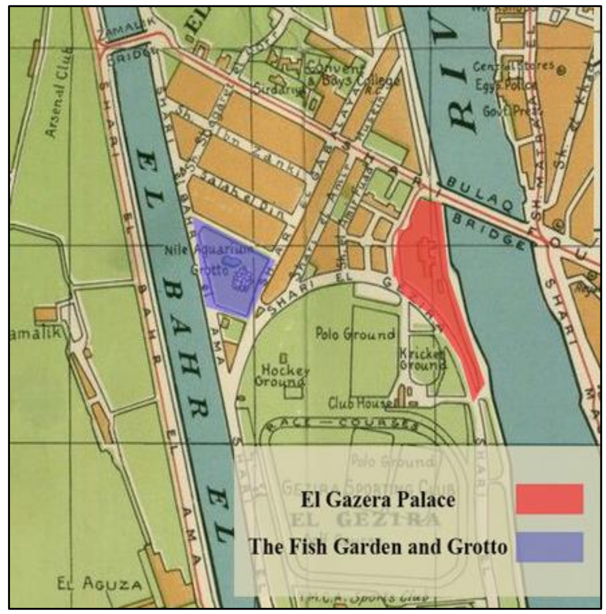
Later on, the master plan of El-Gezira had been changed, and the Fish Garden and Grotto were totally separated from El-Gezira palace, as shown in Figure 1. Then, the palace area got reduced, as shown in the map from 1933 as shown in Figure 2.

Figure 1: The Grotto and Gezira palace, 1910.



Source: http://www.egy.com/zamalek/(‘zamalek-

Figure 2: The Grotto and Gezira palace, 1933.



Source: Historic map of Cairo, by Alexander Nicohosoff ,1933 (Nicohosoff, 1933)

In 2009, The Fish Garden was rehabilitated and restored; damaged parts were rebuilt while retaining all original features. The rehabilitation project included plans to expand an existing lake within the garden. It divided into two parts: one for ducks and geese and the other for swans. The park is particularly characterised by the grottos and tunnels that house interesting fish aquariums. The aquarium settings are fairly original and the walk through the grottos is very pleasant. The garden is now illuminated with indirect lighting so that the scenery can also be enjoyed by night (*Cairo’s Green Spaces: The Aquarium Grotto Garden*, 2022).

Because of the unstable structural problems in the grotto, the aquarium didn’t have any lived fishes this days, in the other hand, the garden and the Heritage Grotto has a great image in the local community. It always hosts seasonal events like flea markets, flower festival in March, wedding photoshoots, etc. Figure 3 shows some of the social events in the fish garden and the grotto.

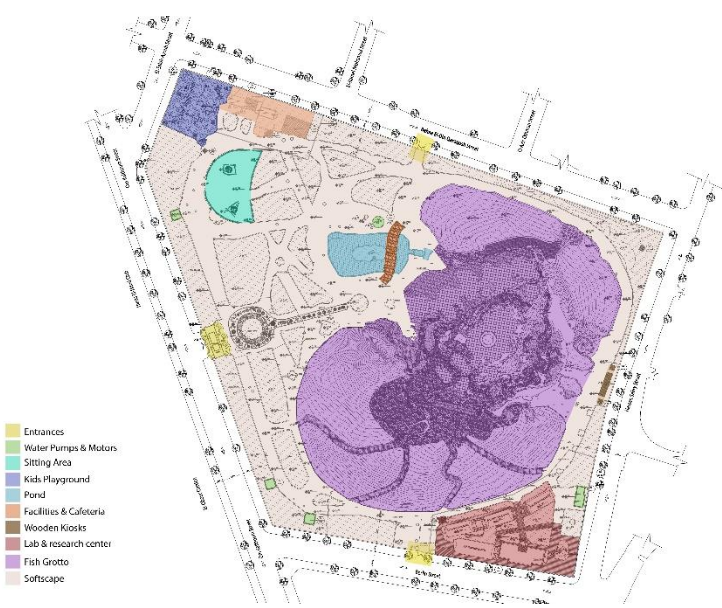
Figure 3: Some social events in the fish garden and the grotto

Source: https://www.facebook.com/CairoFleaMarket/, signed in : 1 Feb 2022

The Fish Garden Components:

The Fish Garden contains many elements, both in soft and hardscape. Figure 4 shows the main elements, such as the rare trees and plants from all over the world, some of which are still living there. It also has some facilities, like the bathrooms, cafeteria and kids' area, which were renovated in 2014 by Zamalek NGOs, in addition to the tank and mechanism buildings, which appeared like small rooms in the layout of the garden. There are also some wooden kiosks in the eastern part of the garden, which still have the original elements and design from the early 1900s. Next to the cafeteria, in the middle of the garden, there is a small lake divided by a wooden bridge. There are also four buildings in the south-eastern part that are used as a fish research centre and an applied laboratory. All of the garden's corridors were laid with coloured pebbles from Rhodes Island with geometric and botanical drawings (Figure 5).

Figure 4: The components of the fish garden in Zamalek



Source: The author.

Figure 5: The components of the fish garden in Zamalek

A: the colored pebbles in the corridors, B: the colored glass hoods, C: the upper grotto,

D: the heritage wooden kiosques.   Source: The author.

In the heart of the garden is the famous Fish Grotto, which is the oldest part of the garden now. It was designed as corridors or recesses inside a reef lying under the sea. When air passes through the corridors, it plays melodies very similar to the movement of waves (Alkalawy, 2013).

The Grotto is divided into two levels, and both of them contain 49 basins that contain diverse groups of fish from both the Nile and the Red Sea. In the upper level, the sun's rays reflect through the upper openings with the coloured glass (Figure 5-B). The building material of the grotto shown in Figure 5-C was Aswany's clay mixed with '*qorsomil*' and red sand, in addition to bricks made of a mixture of Aswany's clay and very hard supporting materials. These natural materials made the grotto appear as if it were a piece of rock that had been carved and emptied from the inside very brilliantly (Alkalawy, 2013).

3.2.The Legal Framework and Management:

Due to the high importance of the Fish Garden and Grotto in Egyptian history, in addition to the unique heritage value, the Garden and Grotto had been registered as a Heritage Garden since 2010, by the law 119/2008. In 2010, the Supreme Council of Antiquities registered the Garden in the Islamic and Coptic list, which moved the garden to the highest level of protection (NOUH, 2019).

The garden is managed by the general administration of the zoo gardens, under the Ministry of Agriculture and Land Reclamation, with the supervision of the Ministry of Antiquities and the

National Organization for Urban Harmony for any intervention. Finally, ignorance of the state may lead to obstruction of conservation/preservation projects.

The Egyptian National Archive for the Heritage Gardens has been established in 2019, and the Fish Garden and Grotto has been added to the national archive after El-Orman Garden in Giza, The Giza Zoo and El-Andalus Garden in Zamalek. And due to add any garden to the national archive, a full documentation must be done, either for the hard or soft scape of the garden, to evaluate the condition of each element in the garden toward making a full restoration or proper maintenance plan for each garden (NOUH, 2019).

In the case of the Fish Garden and Grotto, the documentation by the normal method cannot work, due to the long-time taken to finish the garden, and the lack of accuracy due to the special characteristic of the Grotto, as shown in Figure 6. Therefore, we have to use an advanced technique to make the documentation. The next part of the paper shows the documentation process for the Fish Garden and Grotto by using the 3D laser scanning technology.

Figure 6: The special characteristic of the grotto from the inside and the outside.

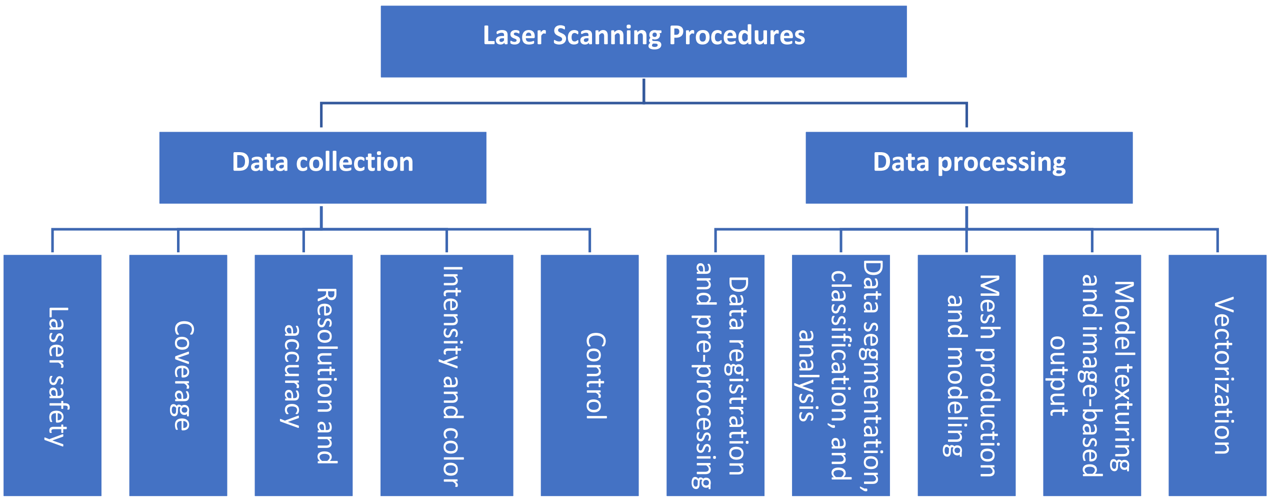
Source: The author.

4. The Documentation of the Fish Garden and the Grotto:

Due to the heritage value of the garden, and due to the unique structure of the grotto, the traditional methods cannot be used for the documentation process. The traditional method is to orthographically shoot the various parts of the components, and record then manually map them. In the case of the grotto, easy accessibility of this process cannot be guaranteed, as there are parts that are impossible to reach, measured omissions, mistakes and other issues to be taken into consideration. The application of 3D laser scanning technology can overcome these disadvantages of the traditional method.

3D laser scanning technology, which is used in the mapping of irregular and complex sites, can effectively improve the deficiency of traditional mapping methods (Boulaassal, Landes and Grussenmeyer, 2009). In this paper, the 3D laser scanner ‘Scanstation P40’, which was produced by Leica Company, was used in the mapping of the Fish Garden and Grotto. The scanner has many merits, such as high accuracy, it works in all kinds of environments, is multidimensional, has easy operation, and so on. Therefore, it has the strong superiority of being able to rapidly obtain 3D data and create a 3D model (Zhang et al., 2015). The application of 3D laser scanning technology in heritage sites mapping is mainly composed of data collection outdoors and data processing indoors (Zhang et al., 2015), as shown in Figure 7, an illustration of the flow chart of 3D laser scanning technology used in heritage sites mapping.

Figure 7: The flowchart of 3D laser scanning technology used in heritage sites mapping.

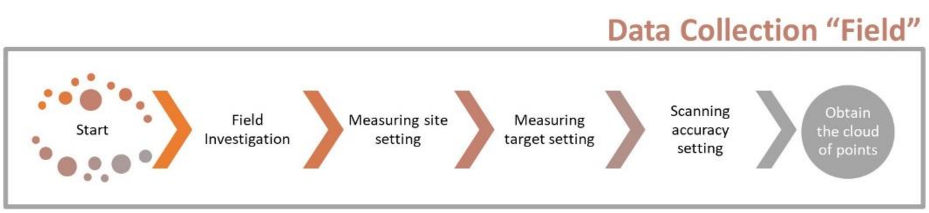


Source: The author, out of the literature review.

4.1.Data Collection "Field"

Field data collection is the process of inspecting the sites, determining the number of scans needed, the positions of the scans, possible blind spots in the site, the level of detail needed to be scanned to determine the accuracy of the scanning; thus, the field data determines the time needed for all the scans and properly set the proper timeline for the project (Zhang et al., 2015). This section explains in detail the process of data collection in the field from start to the cloud of points. Data collection involves a few steps, which include field investigation, setting of measuring sites, targets and scanning accuracy, and obtaining the cloud of data points (Zhang et al., 2015), as shown in Figure 8.

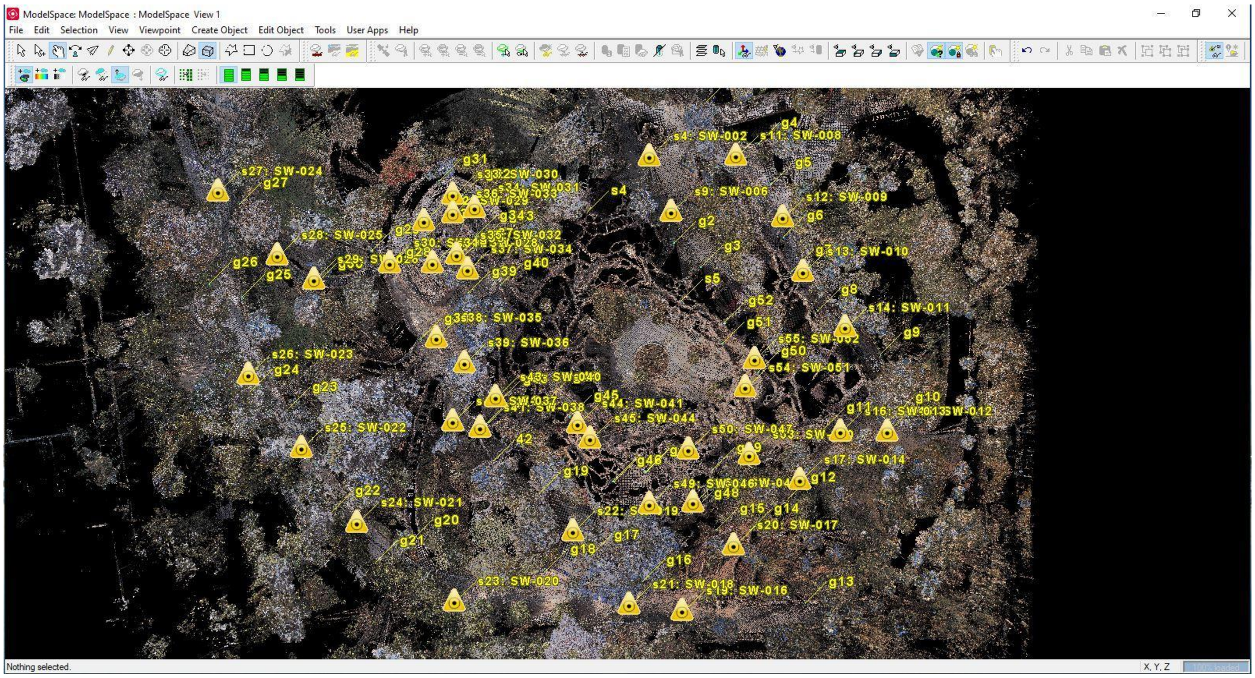
Figure 8: This flowchart shows the steps of data collection in the field.



Source: The author, out of the literature review.

In the Heritage Grotto, it had more complicated angles and dark areas, so multiple measuring sites and measurement targets were set through multi-station, multi-directional scanning. Figure 9 shows the 85 stops in the sites that have been set in this mapping of the garden with a total area of 9.5 feddan. In order to have multiple stations scanning different coordinates of points within the cloud together into the same coordinate system, and to obtain the complete surface information of the grotto, a well-arranged target placement was especially important.

Figure 9: Measuring sites and measuring targets placement throughout the grotto garden

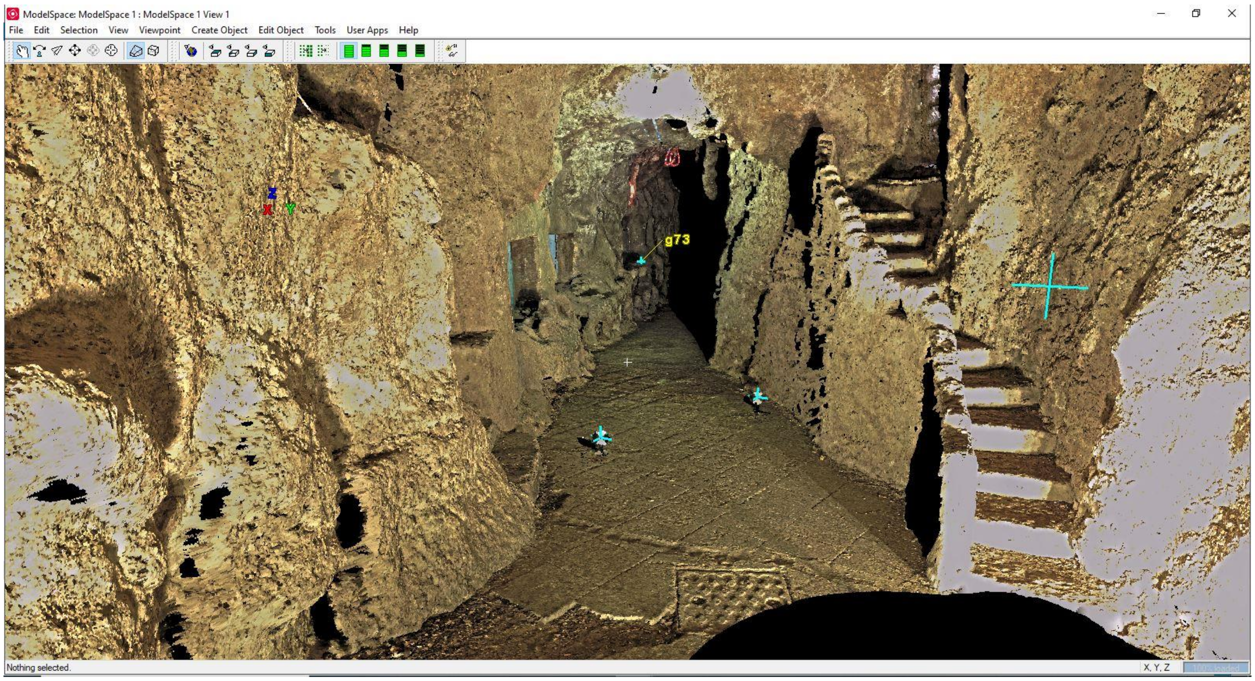


The basic methods or principles are as follows: First, every two stations should be separated by a few scattered targets in the field that are not in a straight line. Second, the position of the measurement target should follow the principle of ‘overlapping with the next station’, which means setting the target in a coordinated location where it can be scanned as much as possible by multiple scanners in order to reduce the number of targets and any resulting error of points in clouds during multiple site splicing processing. Third, when setting up, it is important not to forget about the goals you have established (Zhang *et al.*, 2015).

Scanning accuracy settings have a direct impact on the final results of the garden and grotto mapping. Therefore, medium resolution scanning (6mm/10m) was typically utilised for positioning measurement and integral measurement of single structures like buildings, but high-resolution scanning (3mm/10m) was used for specialised detail components that need scanning of intricate components like the grotto.

Degrees of exposure must be adjusted in accordance with the surroundings and atmospheric conditions (Zhang *et al.*, 2015). When the info point cloud occurs in a very dark area, the degree of exposure must be increased, and when the info point cloud occurs in a very bright area, the degree of exposure must be decreased. Because the lighting inside the grotto was minimal, the team had to install temporary lighting and adjust the 3D scanner to be able to scan in low illumination and shadows had to be eliminated in order to not have any blind areas in the scans. These obstacles were determined during the field investigation and assessment and were directed to the team to come up with solutions to provide optimum quality and fastest results. Figure 10 shows one of the scans inside the Grotto after we added the lighting units.

Figure 10: Scan illustrates the adjustment of the exposure and resolution levels to accommodate the dark interior of the grotto



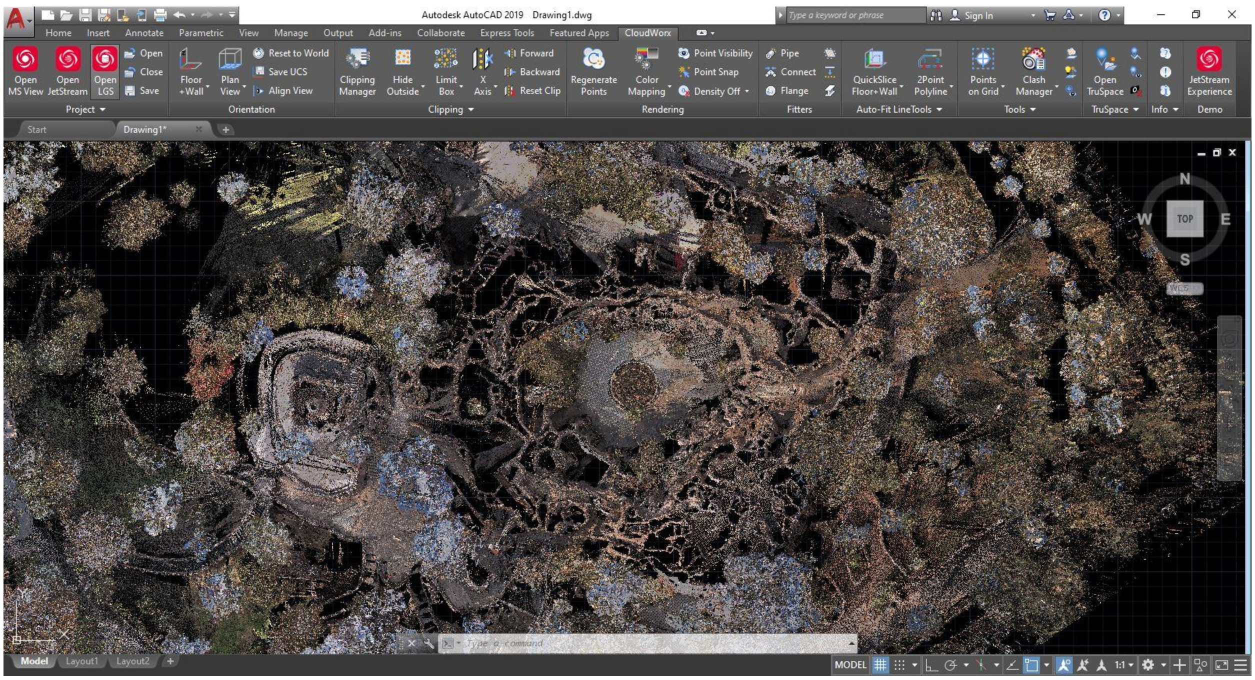
4.2.Data Processing “Office”

Data processing is what happens after the cloud of points obtained from the scanner finally ends up in the assembly of 2D or 3D drawings using appropriate programs. During this study, Cyclone was used to process the cloud points, and AutoCAD and Cloudworx were used to produce the drawings. Data processing mainly includes merging and noise elimination for the purpose of cloud data, the generating CAD graphics and 3D space image, and data storage and export to be used. Merging primarily used the tactic of ‘group positioning system’, to position a single area and therefore its detail components into the full site, and multiple stations’ point clouds were merged into the identical system in order to get the target entity’s complete spatial data.

Noise elimination is conducted to get rid of the invalid data points or irrelevant objects that may distort the drawing process, such as cars and trees in our case, to reduce the overhead of computer processing and enhance the power of computer processing. The noise on this mapping of the grotto was relatively obvious, so optic judgment and segmentation of the cloud of points was used to specify the objects needed to be removed, then they were deleted by a human computer method to eliminate the noise.

Because of the impact of the scanning mode to get the cloud of points, the cloud model that has been acquired has no accurate coordinate axis. Therefore, it is necessary to process the coordinates using Cyclone software first, then to insert the model into AutoCAD utilising the Cloudworx plugin to cut the plane in horizontal and vertical sections and profiles. Finally, the plane drawing, vertical drawing and profile drawing are described according to the cloud of points in AutoCAD. Figure 11 illustrates the drawing of the layout plan and section from the cloud of points.

Figure 11: Grotto Garden layout as imported from the cloud of points using Cloudworx plugin in AutoCAD program



Because of the noise and additions to the Grotto, the mosaic scanned picture was not ready to draw on it yet, so we have to make a horizontal section in different levels to remove the trees and get a clear picture. Figure 12 shows the section of the plan from the cloud of points. We can clearly see the black holes in the picture, which appeared because these parts were hidden by the trees when we made the scans, so we have to complete those areas by the scans that had been taken from the inside of the grotto. Because every point had the x, y and z coordinates, we could collect the picture from the outside with the scanned pictures from the inside, which cannot be done without the advanced 3D scanning system. To produce the 2D drawings in plane or vertical drawing and profile, we draw them from the cloud of points in AutoCAD. Figure 12 shows the final layout, with highly accurate, detailed documentation, and Figure 13 shows the dilates documentation for the flooring patterns in the Garden.

Figure 12**:** Grotto Garden layout 'Plane section cut' as imported from the cloud of points using Cloudworx plugin in AutoCAD program

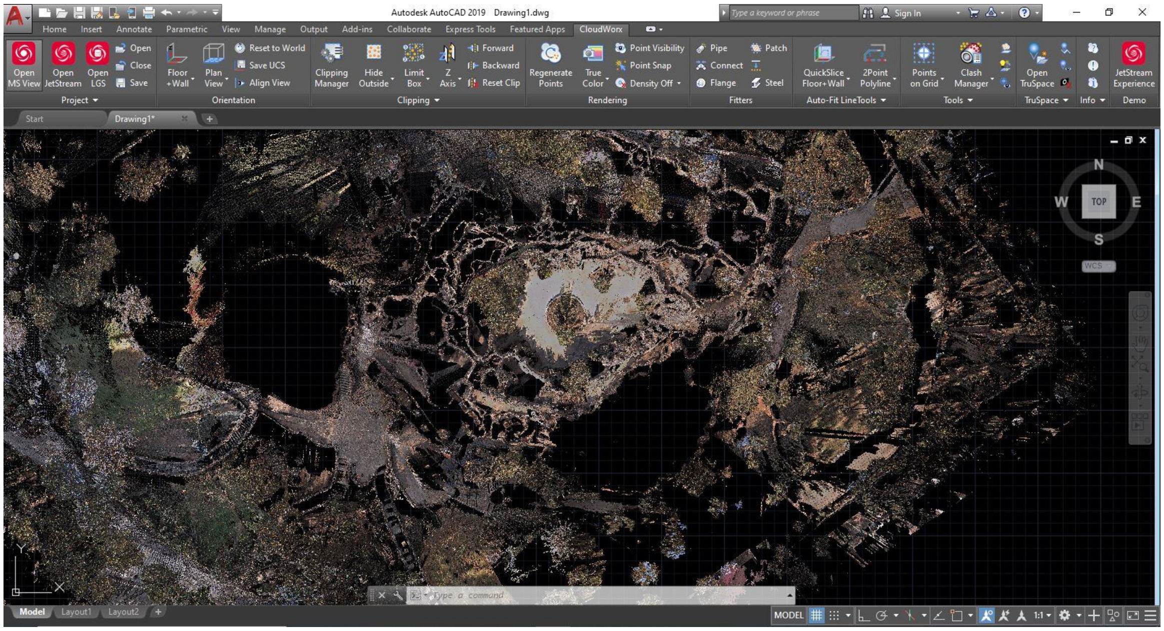


Figure 13: The final layout, with the high accuracy, detailed documentation.

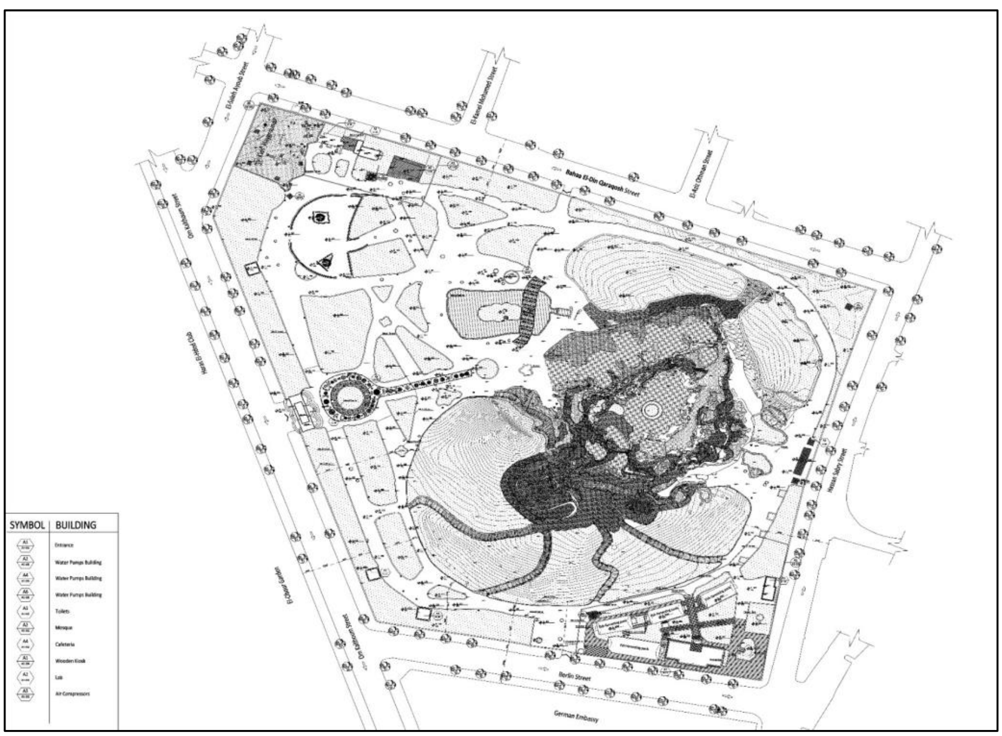
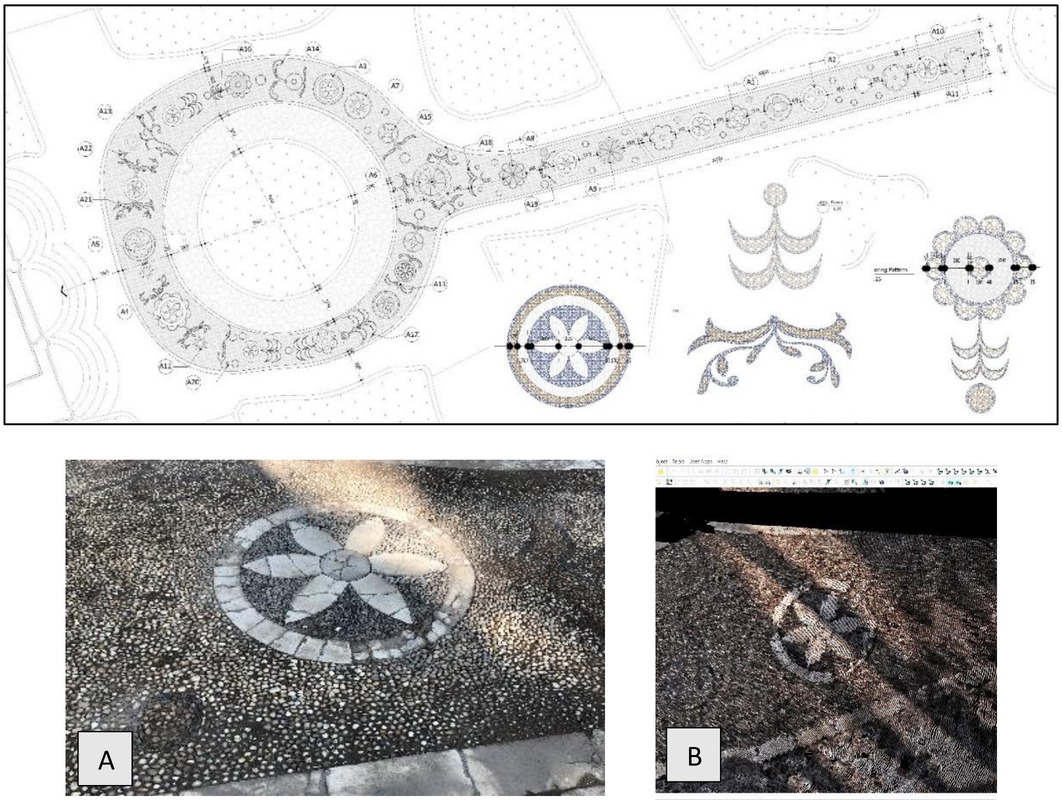


Figure 14: High resolution scanning of historic flooring details at the entrance of the garden, drafted from the imported cloud of points using Cloudworx plugin in AutoCAD program



A: the photographical Documentation **B: The cloud of point Scan**

5. The Conclusion:

The Heritage Gardens are a valuable heritage landscape that must be preserved and documented properly to identify the best technique to use in the documentation of other gardens, manual mapping, use of total station device and, at last, the 3D scanner. The accuracy of the mapping drawing has improved significantly compared with the mapping using the manual method and the total station. Comparing the time and resources needed for such a large scale project, the manual way took a much longer time with many participants to cover the whole area accurately. It still was hard to draft the grotto accurately, as it has a challenging topography with many layers and slopes. Then, the total station was used, which was easier and faster than the previous method, and the team was able to draft the topography of the garden, but the organic shape of the grotto remains hard to draft due to its special structure.

The 3D scanner mapping (Figure 13), which presented the challenge of requiring experience in using the devices and the programs, needed to get the data both in the field and in the office. However, with the right training for the team, this technique presented a timely process. It was easier for the person using the device, the outcome was more accurate and all the details needed for the drawings were in the scans with no need to revisit the site to re-measure the area. The scans were even used to determine the type of flooring in each area and the place and diameter of the trees and palms in the garden, in addition to the ability to produce the 3D model with the accurate details if needed.

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