ZHAISHAN TUNNEL 3D DIGITIZED AND DISPLAYED IN KINMEN

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Abstract

There were some battles for defending Taiwan straits safety that is Kinmen's past experience, for example, Guningtou battle, 93-cannon battle, 823-cannon battle. Therefore some unable be wiped out historical vestige and battle historical remains are remained. Else historic spots, ancestral hall and special folk custom are historical culture worthy, the Central tunnel shelter of Taiwu-mountain, Qingtian-hall, Qionglin's tunnel shelter, Mason broadcast station, Zhaishan and Jiugong tunnel shelter that are special battle culture in Kinmen. That important value is connoted with special geographical features and deep historical memory. This plan has spirit in accordance with digital book reservation is a responsibility of information society and global conservative development. To choose tunnel shelter that has wartime and historical value to be digital book reservation target. Develop correlative digital reservation areas with network and compile web contents with existence results, base information, science papers and research reports. Book reservation contents include precision space information of 3D digital cloud points of architecture and virtual guiding web. Get the purpose of the optimum digital reservation. The plan result can be increased and showed by other Kinmen's culture and has continuity reservation operating environment.

1. Introduction

In Taiwanese history, Kinmen's tunnel shelters are the most important and particular cultural property because it has been passed through some battles in the latest of 1960s. The tunnels were built for defense, store and transportation during the wartime between. In civil engineering field, these tunnel shelters were extremely difficult works due to being excavated by hands of soldiers, who used mattock, power drill and dynamite to dig through the hill. Over the span of past years, the situation between China and Taiwan become more ease, Kinmen's tunnel shelters had transferred from military affairs into a kind of martial culture and tourism. For historic conservation in civil engineering, these tunnels provided the knowledge in both history and technology. The '*Zhaishan* tunnel shelter' is the only one granite tunnel shelter to open to the public in Greater Kinmen Island. It has very plentiful martial culture value behind, and then becomes the

most famous location for tourism.

Nowadays, 3D laser scanning techniques are widely used in different fields, such as historic conservation （Rüther et al., 2009）, archaeology （Lerma et al., 2010）, civil engineering （González-Aguilera et al., 2008）,structure health monitoring （Teza et al., 2009）, urban planning, forestry （Vosselman et al., 2004） and so on. Based on laser technology, the 3D laser scanner systems allow researchers to acquire a huge number of data points distributed across the observed surface with high accuracy and rapid acquisition rate （Armesto-González et al., 2010）. Meanwhile, it integrates the digital camera to capture the images to finally produce the point cloud and colored 3D surface model.

The aim of this paper is to use 3D laser scanning technique, photography and 3D modeling for the documentation of the '*Zhaishan* tunnel shelter'. In the past, the studies on this subject are generally on books, reports, drafting, technical literature and scientific papers. For a tunnel shelter, its structure is a hidden, long distance and underground structure, so that the non-spatial is not contented for conservation. Therefore, the spatial data are presented more effective, reliable and distinct information.

2. The site

The site is located in the Kinmen County where the off-shore island of Taiwan, located in the southwest of Taiwan Straits, inside the Amoy gulf （Figure 1）. This county includes *Greater Kinmen Island*, *Lieyu* （also known as *Little Kinmen*）, *Dadan*, *Erdan* and *Wuqiu*, of a total of twelve islands and islets.

The '*Zhaishan* tunnel shelter' is the one of the Kinmen's battle sites, located in *Jincheng* township （Figure.1） where in the southwest corner of *Greater Kinmen Island* and the tunnel is a part of *Gugang* area of Kinmen National Park at present.

The *Zhaishan* tunnel shelter （24° 23′25.34′′S；118° 19′14.74′′E） was constructed began in 1961 and then completed at March 22, 1966, with a length of 101 meters, width of 6 meters and height of about 3.5 meters. Inside it, there are seven rooms that served as barracks. A unique feature of these tunnels is their A-shaped waterways （Figure 2）. These waterways are around 357 meters long, 11.5 meters wide and 8 meters high （http://www.kmnp.gov.tw/）, and were used to conceal 42 small naval vessels for disembarking and supplying. For geographical position, the *Zhaishan* tunnel has a very important relation with *Jiougong* tunnel, *Lieyu* for supporting each often in militarism function.

This tunnel shelter was spent 5 years to build after 823-Cannon Battle. The Army soldiers only used mattock, power drill and dynamite to dig through the hill. The main function was to provide a turning way of supplements operations by small naval vessels for the navy deploying. On the other hand, the tunnel is all covered by strong granite as waterways, so that the navy could enter into the mid-hill from the sea directly and then be safe inside the tunnel.

Due to more peaceful situation, there was a move toward removing the military in Kinmen Island. A review of these military facilities showed that the *Zhaishan* tunnel shelter is often suffered from accumulation of sand and then not enough manpower or budget to maintain. Hence, the tunnel was closed and abandoned in 1986. Later on, there have been increasing interests in protecting and preserving historical properties. The tunnel became a focal point for remembering those who fought for Kinmen. For this reason, on May 23, 1997, the responsibility for conservation of *Zhaishan* tunnel shelter was taken by the Kinmen National Park which compiles an annual budget to repair and maintain the tunnel, so that they can reopen for public. Under an agreement with the Ministry of Defense, the military is allowed access to the tunnel during the war time or for conducting exercise （http://www.kmnp.gov.tw/）.

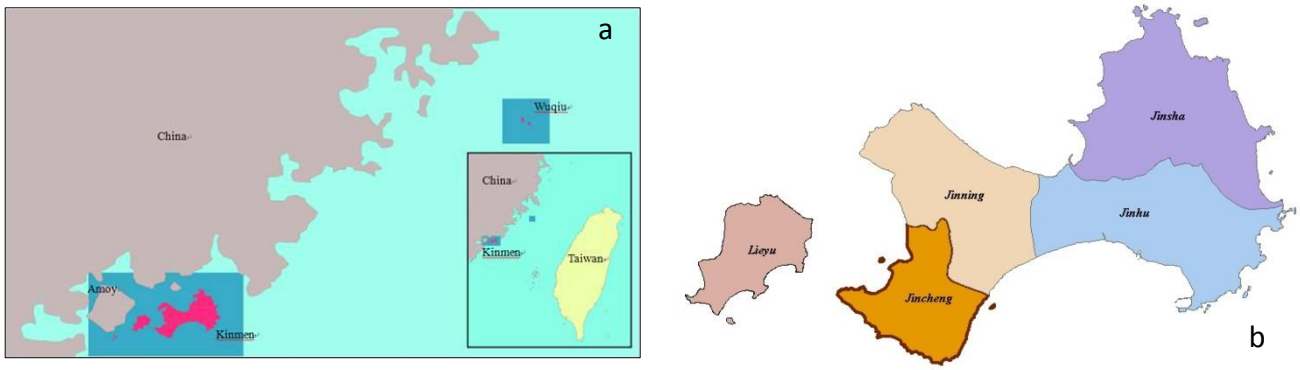

Figure 1. (a) Location of Kinmem county. （From Web Wikpedia） (b) Map showing location of *Jincheng* township, Greater Kinmen Island.

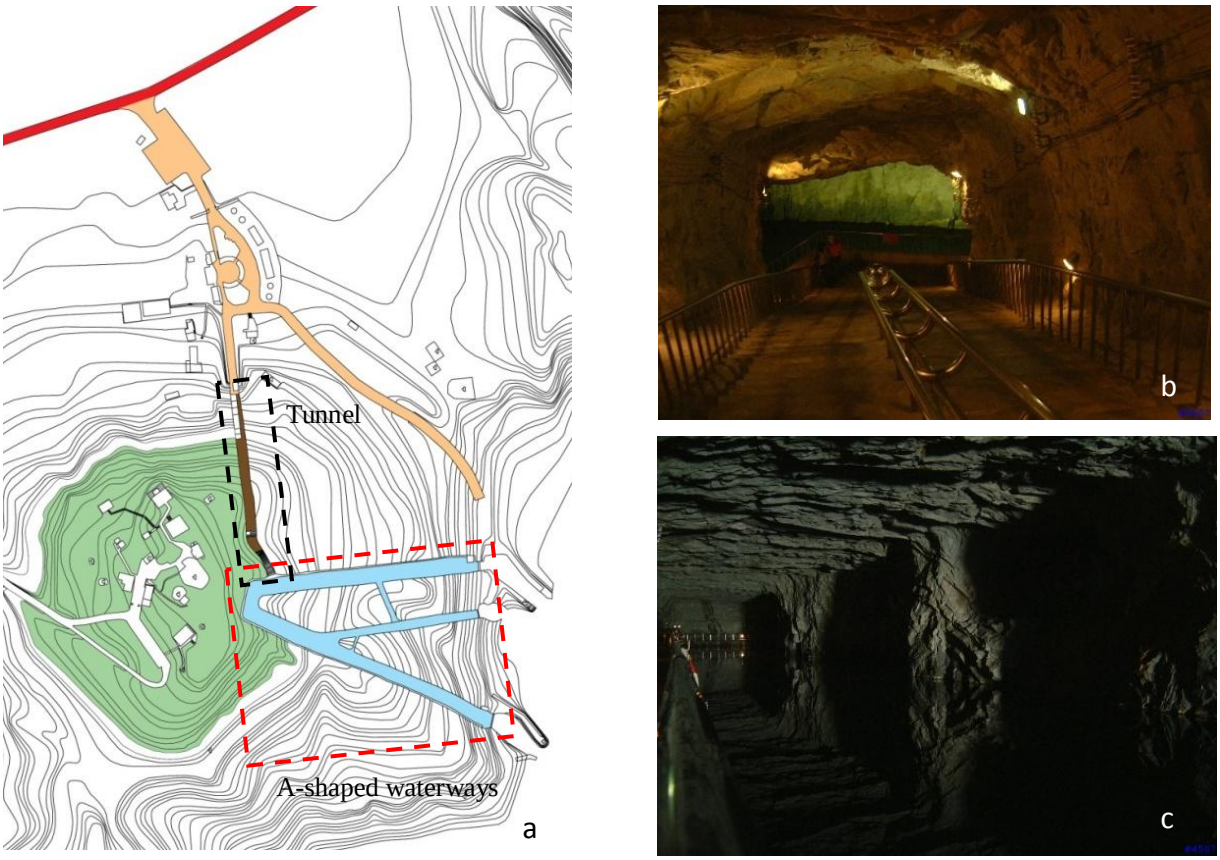

Figure 2. (a) 2D ground plan (b)、(c) Photograph showing inside of *Zhaishan* tunnel shelter and waterways.

3. Review of 3D laser scanner technology

The laser scanner is the fast laser range finder which includes rotated mirror inside. Compare to traditional survey system, it can measure coordinate of three dimensions without reflection mirror. The laser range finder can shoot the laser beam and receive the signal from surface of object at the same time. For every point, the coordinate can be known through the calculation of horizontal and vertical angle with the slant range which is from survey station to the object. The Cartesian coordinates X, Y, Z can be measured for any point on the surface of the object considered using this spherical coordinate system （Armesto-González et al., 2010）. Thus, scan results are the large quantity of points in a systematic pattern. They are also so-called point cloud. The 'point cloud' generated is a high of millions of points in space. Normally the point data （x, y, z）also includes a reflection intensity value. These data sets can be manipulated with various software applications in order to create realistic and practical surface models （Fekete et al., 2010）. Final results after processing of the raw data can be line drawings, CAD models, 3D surface models （with

artificial or photorealistic textures） or video animations （Boehler and Marbs, 2004）.

Laser scanning is generally used to record only surface information in order to generate 2D sections, profiles and plans, and 3D models. Laser scanner can operate from the ground or in the air by an airplane. It provided a point cloud in a local coordinate system with intensity values; additional information such as RGB values is usually provided by internal or external digital cameras. The camera technique is directly referenced with respect to the point cloud that is used to obtain colour from the scanner（Lerma et al., 2010）. Moreover, on other advantages of the 3D laser scanning system are follows:（1）Laser scanner only requires one sit-up point for operation and capture the high accuracy & rapid acquisition rate by non-contact surveying techniques;（2）it is automatic survey system and the techniques can be worked in the dark environment with low light;（3）the product of point cloud data can be colored, thus it is convenient to transform the real world to hypothesize by colour 3D spatial information.

More recently, the 3D laser scan technique is widely using in the documentation of historic conservation. The present several works and analyses can be found in e.g. H. Rüther et al. (2010); J. Armesto-González et al. (2010); N.A. Haddad (2011) and others. According to the contents of articles, the main purpose of these researches is to use scientific methods to build up the reliable recordation with spatial information, establish digital reservation database and assist professional judgment. Consequently, as the same causes and goal, in the project of *Zhaishan* tunnel 3D digitized, this paper also expects to use a high accuracy automated 3D laser scan system combined with photography, 3D image, 3D modeling and hypothesized solid boundary (a full 720° views) to document the site and its immediate environment.

4. Scanning of the *Zhaishan* tunnel

4.1 Equipment - FARO Photon 120

The *FARO Photon 120* generates highly detailed 3D replicas of complex environments. The resulting image is a collection of millions of 3D measurements, providing an accurate digital representation of as-built or as-is conditions. This scanner is based on phase shift measurements and then transmits continuous 785 nm laser light. This device measures distance in a range of 0.60-153 meters indoor or outdoor with low ambient light and 0.60-120 meters in outdoor cloudy environments on 90% reflective surface. The field of view covers 320° vertically and 360° horizontally. The circular beam diameter at the exit is 3.3 mm, and the beam divergence is 0.16 mrad. The scanner capture data speed is at the blistering rate of 976,000 points per second with a reach of 153 meters and the accuracy is smaller than was equal to ±2 mm systematical distance error at 25 meters (http://www.faro.com; Armesto-González et al., 2010).

4.2 Zhaishan Tunnel's specific situation and solutions

Zhaishan tunnel is the most popular stop point for sightseeing in Kinmen. There are numerous of tour group and travelers visit this tunnel every day. The official opening hours is from 8:30AM to 5PM daily, open all year round and closed on Lunar New Year Eve or day based on government's announcement and other special occasion, everyone can through into the tunnel freely. For this reason, the first scan operation was usually stopping by tourist. By the assists from the Kinmen National Park to organize the time interval for scanning, the work team could arrange all the scan works when the tunnel was emptied. In addition, the *Zhaishan* tunnel is an underground structure with highly moisture and low light. For the tunnel with A-shape waterway with total length 476 meters (tunnel: 101 meters; waterway: 376 meters), deep, long distance and non- straight, the precision of scanning was ordering in 260,000 points per second quality, thus one survey station is accomplish in 7 minutes. Thus, whole scanning operation required 30 survey stations and 16 hours to complete this operation.

4.3 Operational processes

For digital documentation database of the *Zhaishan* tunnel by laser scanning system, the main operations are including an advance plan of the scan area, laser scanning in practice and the point cloud matching. The approach used to obtain a high-definition laser scanning with digital photography can be summarized as following steps:

1. Establish an advance plan of the area scanned: This is the first step that cannot abridge before scanning operator. For ensuring a successful data, the survey stations chosen are except to experience, and simultaneously, to use 3D spheres for point cloud matching. The sphere requires up three setup points for basic one scanning and been the reference of 3D modeling.
2. Collect the spatial information collection: put up to 3 spheres and laser scanner orientation and then precede the scanning operation. The spheres are carried out in order to have all the scans in a single and common coordinate system. For the purpose, the spheres act as tie points to occupy the maximum volume (Figure 3).
3. Capture the image from digital camera. After the single scan, the digital camera *Nikon D200* was replaced at the position where the original of laser scanner located and then through the scanner to control the digital camera operation.
4. Remove the survey station and the spheres to obtain another direction spatial data by reiterating the step from 1 to 3 until the object range closed.
5. Operate internally 3D point cloud matching and 3D modeling. For 3D model texture, in this case, the work team applied the *FARO SCENE* software to have the final results as shown in 4.4.

Figure 3. (a) Data acquisition in *Zhaishan* tunnel. (b) Replace the digital camera for image obtaining.

4.4 Results

After the scanning was completed, download the raw point cloud data and then cope the information with *FARO SCENE* software, by the following steps:

1. Percolating miscellanea: The scan results were effected by the causes of environment or/and dirty rotated mirror, so the miscellanea leads intensity data lower, and then through *SCENE* software intensity limits set up so as to eliminate disorder point cloud to enhance the correctness of scan data.
2. Matching point cloud of survey stations: The separate survey station has the respective coordinate system, so that in this step, a base coordinate of particular survey station was selected to combine the spheres to transform all point clouds data into identical coordinate system.
3. Matching inaccuracy confirm: The point clouds which match precision quality depends on the tie point (the spheres) correspondently. In other words, when the sphere matching error lower, the scan precision will be higher. Based on this point, the tie point matched is limited to ±1 centimeter.
4. Processing digital image from point clouds: For *FARO Photon 120*, the raw point cloud data do not including RGB value. In this project, the team used the high-definition digital camera *Nikon D200*

which is applied with the concept of concentric, coaxial and *SCENE* software to fit image with point clout data. Thus, the spatial information of tunnel has then possessed the coordinate data and RGB value in the meantime. Otherwise, the 3D visualization will not close to the real world.

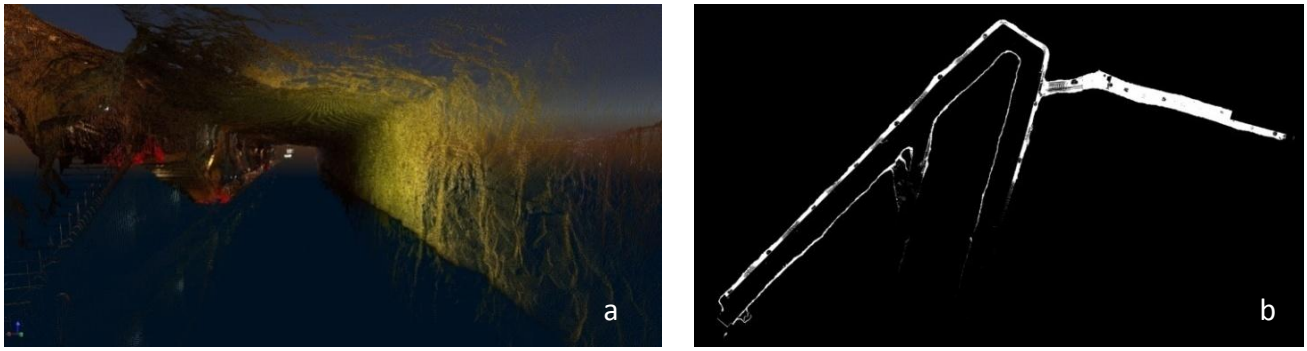

Figure 4. 3D presentation of the interior of the *Zhaishan* tunnel. (a) 3D surface model (b) ground plan.

5. Discussion

5.1 Conservation

According to Lerma et al. (2010) as well, from now on, the way conservation specialists (archaeologists, culture heritage conservators, etc.) document and analyses will rely on the presentation of 3D data. Obviously, from the results of the *Zhaishan* tunnel, this particular structure has adequately shown great advantages of having such as high-resolution and photo-realistic 3D information. Furthermore, the products of scan data are able to study and extract 2D and 3D details easily from various points of view and at different scales.

On the one hand, the *Zhaishan* tunnel has attracted the Kinmen National Park during recent years, so that, the tunnel will be examined and then restored in the near future. Consequently, the 3D detailed survey of this tunnel is an important reference for further examination. In this project, the 3D models allow to dissect the shape and dimension of the tunnel with much more accuracy and resolution.

5.2 Tourism

At 7th November 1992, the Martial Law was ended in Kinmen and the subsequently, at 7th February 1993, the Kinmen County has been opened to public for sightseeing by Central Government. At 18th October, Taiwan's sixth national park '*Kinmen National Park*' was established. This is the first National Park in Taiwan set up to maintain, protect important historic sites, especially battlefields and natural resources （http://www.kmnp.gov.tw/）. For visitors, Kinmen is full of plentiful culture with mystical color.

3D information of the *Zhaishan* tunnel has offered a variety of interactive features and made it possible to different applications, such as, the website guide for 3D virtual reality, a full 720° views display (Figure 5) and then the connection with Google earth 3D Warehouse etc. Furthermore, it is possible to link up the high-resolution of point cloud with reverse engineering further to produces small scale of model for souvenir that can be the part of sightseeing segment.

5.3 Digital documentation database

For documentation storage, the spatial data can be memorized and kept in a digital form at maximum resolution except for losing texture information. According to Lerma et al. (2010), it is important to save on different media not only the final deliveries and products but also the original raw data without compression. A good digital documentation database should allow manipulation and editing of data at any time and store in stable server system. For using requirement, the successful scan data provides valuable information that can be useful for the vast majority of application without back to the site frequently.

Figure 5. A full 720° views display by ArcSoft Panorama Maker 5 software.

6. Conclusion

Until now, 3D laser scanning system is the one of the best auxiliary equipment of technological advances in geomatics techniques for historic conservation without making direct contact with objects. This paper describes a methodology for applying the 3D laser scan technology to the documentation of digital database. The results of this work show that 3D data can be exported to the high quality image for graphic of 3D models and 2D plans. 3D point cloud also provides Cartesian to coordinate in real time. Further, another important purpose of the digital database with spatial information is that they can be displayed a precise and realistic 3D formation of the site. Therefore, the final artifact can be reconstruction to meet requirements from 3D scan data.

Indeed, the *Zhaishan* tunnel is a suitable example for archives Kinmen military culture. These results can assist conservation and restoration in the more practical quantity. In addition, aside from encouraging international tourism, the focal point of this work becomes a guiding tool for Taiwanese as well for others outside who are unavailable to visit the sites through its website.

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