

Stone Weirs Investigation by using Unmanned Aerial Vehicle Photogrammetry

Yu-Ming Chang (Institute of Marine Affairs and Resources Management, National Taiwan Ocean University)

Hung-Ming Kao (Institute of Marine Biology, National Sun Yat-sen University)

Wen-Yan Chiu (Institute of Marine Affairs and Resources Management, National Taiwan Ocean University)

Steven Chang (Morrison Academy Taipei)

ABSTRACT

Stone weirs are a traditional fishing method as well as an important underwater cultural asset of Taiwan. There are about 600 stone weirs in Penghu and more than 100 of them in the western coastal area of Taiwan that are still in use. This study utilized high resolution UAV photogrammetry and spatial analysis techniques to investigate the stone weirs of Qimei and Jibei islands in Penghu as well as the Houlong coast in Taiwan. By stitching aerial photos, the overall picture and Digital Elevation Model (DEM) of stone weirs could be understood. The technology developed by this study is able to provide a standard mode for the large-scale investigations in the Asia-Pacific region, and the database developed is able to become the basis of cross-disciplinary research.

Key words: stone weirs, UAV, tidal, photogrammetry, disciplinary

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INTRODUCTION

Stone tidal weir (石滬shihu) is an ancient fishing method. According to Chen (1996), the emergence of Shihu should be as early as the Neolithic period. Shihu is distributed all over the world, its materials include wood, bamboo, clay or stone. Although fishing techniques may be different, the basic principle is to use tides and to build embankments in the intertidal zone to trap fish, so it is a kind of "traditional wisdom" or "marine culture" that live with the sea. Taiwan has the most precious shihu group in Penghu, the total number of shihu is about 580 sites there. In terms of density, Penghu deserves the most important area of shihu in the world. Therefore, the shihu group of Penghu was evaluated and listed as a potential site of "World Heritage" by Taiwan's Ministry of Culture in 2009. On the island of Taiwan, Tamshui, Taoyuan and Miaoli also have a number of shihu group. In recent years, the traditional shihu are rarely used is in lack of regular repair. It is

estimated that there is only 20% of the remaining shihu is still in use, while most of shihu is facing the collapse or buried crisis. Therefore, how to further conduct investigate, research and preserve shihu is an urgent issue for Taiwan. The purpose of this paper is to develop a large-scale survey and information sharing methods on Shihu, and we look forward to extending it to other regions. We believe that this survey method may serve as a model to assist shihu group in the Asia-Pacific region to jointly apply for listing as a “World Heritage Site”.

LITERATURE REVIEW

Although the Taiwan government attaches great importance to the issue of shihu, there are still not many scholars or institutions engaged in the research on shihu. Chen (1989) firstly published his paper entitled “Fisheries activity system and its field management: Ecology of the Coral Reef Fishing Village of Penghu” with the finding of 13 shihus in Penghu. His research inspired enthusiasm of the following scholars to conduct a serial research on shihu in Penghu and/or in Taiwan. For instance, Hong (1999), Lin (2015), Lee (2015), Yang (2021) and Tamkang University (2015) applied different methods to establish their database of shihu. However, the traditional methods (on-site survey) are heavily depending on labor and are time and cost-consuming. It is until the last several years, aerial photos, GIS techniques and 3D modelling have been applied in the related survey project. And, all those research results are only for the purposes of relevant authorities, personal academic research and public education. There are not many opportunities to share with those information of shihu for interdisciplinary research, especially for the study on integrated coastal zone management. In this regard, this study aims to develop a cost-effective method for a large-scale shihu investigation.

METHODS

Based on the current situation of shihu, traffic conditions, the impact of the COVID-19 outbreak, self-financing research funds, tidal walrus consideration and investigation operation time and other reasons, this study selected three of Taiwan's more representative shihus as the case of on-site research: Qimei's double-heart shihu and Jibei shihu in Penghu archipelagoes and Wunai shihu in Miaoli of Taiwan Island.

In view of the practicality of the Kreija, A., et al., (2018) investigation method, this study uses this method to apply the Agisoft photoscan software to 3D modeling in shihu, which can be said to be a new method on shihu study in Taiwan. In addition, it provides a more effective survey tool for shihu research, which will use high-resolution unmanned aerial vehicle (UAV) close-up photogrammetry technology to record shihu, and establish a set of shihu information system by high-resolution, close-range aerial photography and spatial information analysis technology. The expected results came up with this study include: (1) Aerial images of shihu by UAV; (2) Google Earth KMZ image; (3) Water depth map; and (4) 3D elevation model of shihu. Fig. 1 and Fig. 2 illustrate the operational procedures of this study.

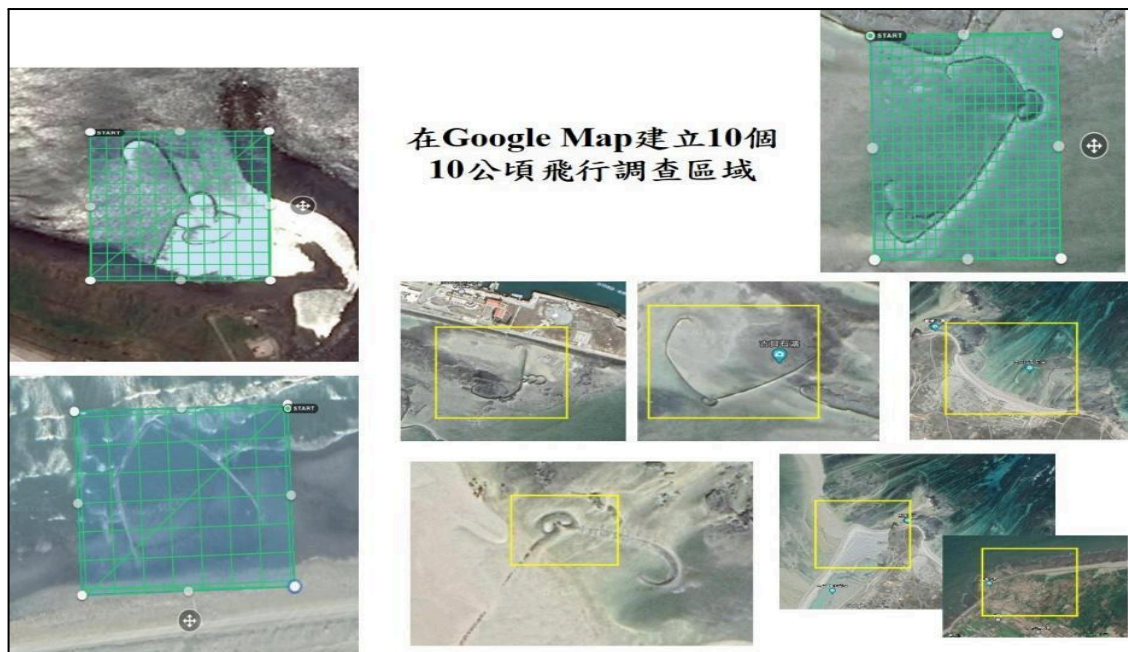


Figure 1: The planned areas on Google Earth for UAV photography.

由高解析度近距離無人機攝影測量和空間信息分析技術來建立一套包括：

- (1) 無人機空拍路線
- (2) 軟體運算
- (3) KMZ拼接地圖
- (4) 水深高程圖
- (5) Google Earth KMZ圖上傳

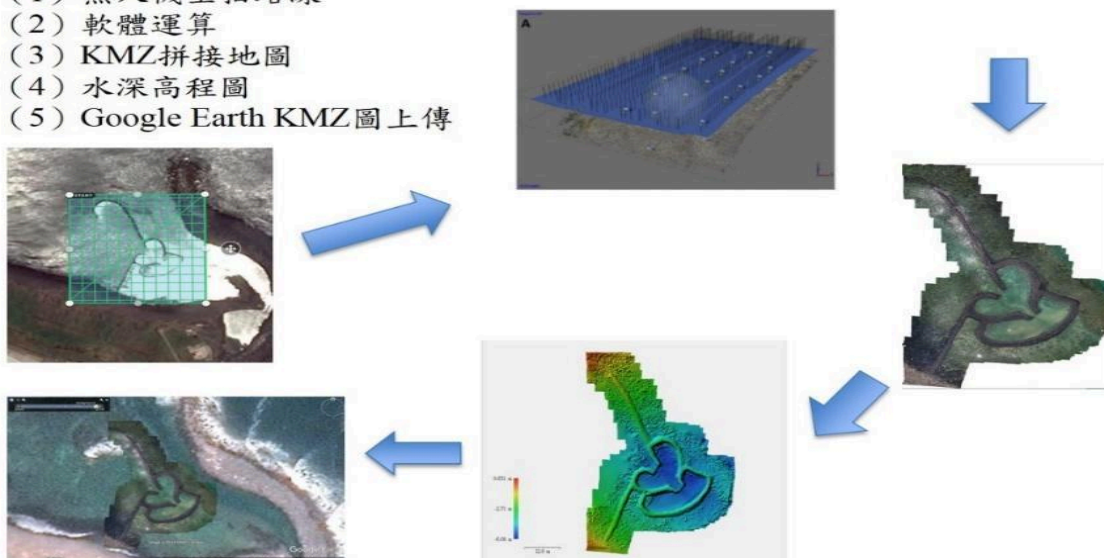


Figure 2: The procedures from aerial photos to high-resolution 3D modelling of shihhu.

RESULTS

In order to carry out the on-site survey of Qimei's double-hearted shihu, this study firstly used a computer for flying drone. After the acquisition of aerial images, the authors use Agisoft photoscan

software for 3D modeling of shihu. Before the practices, the items need to be set up including: (1) route of aerial photos; (2) photo quality requirements; (3) resolution; (4) flight altitude; (5) pre-drawn number of shots. The obtained aerial images were used 3D modeling of shihu.

Fig. 3 is the UAV cruise planning map for Qimei shihu and Fig. 4 is a photo synthesized from 139 aerial images. Because they are photos taken at low altitude, the resolution of Fig. 4 is much higher than that of current commercial satellite images. After the high-resolution photos are processed by 3D modeling software, all those photos can be stitched into a KMZ file with coordinates, which can be uploaded to Google Earth for public viewing, research and investigation. At the same time, the established 3D model can also provide the map of shihu's water depth with digital elevation model (DEM) (see Fig. 5). This resulted map is the biggest difference between this study and the aforementioned related studies in Taiwan. With improvement in the near future, we believe that this new method can serve as a model for large-scale investigation of shihu. Fig. 6 shows the results of the other two shihu.

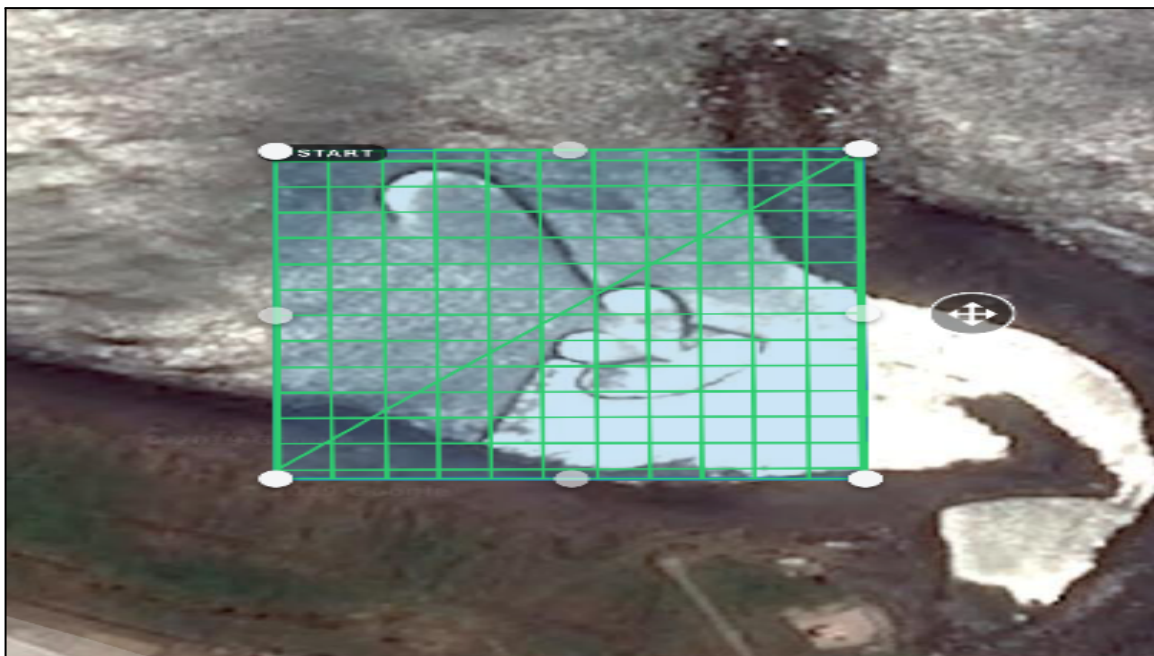


Figure 3: UAV cruise planning map for Qimei shihu.

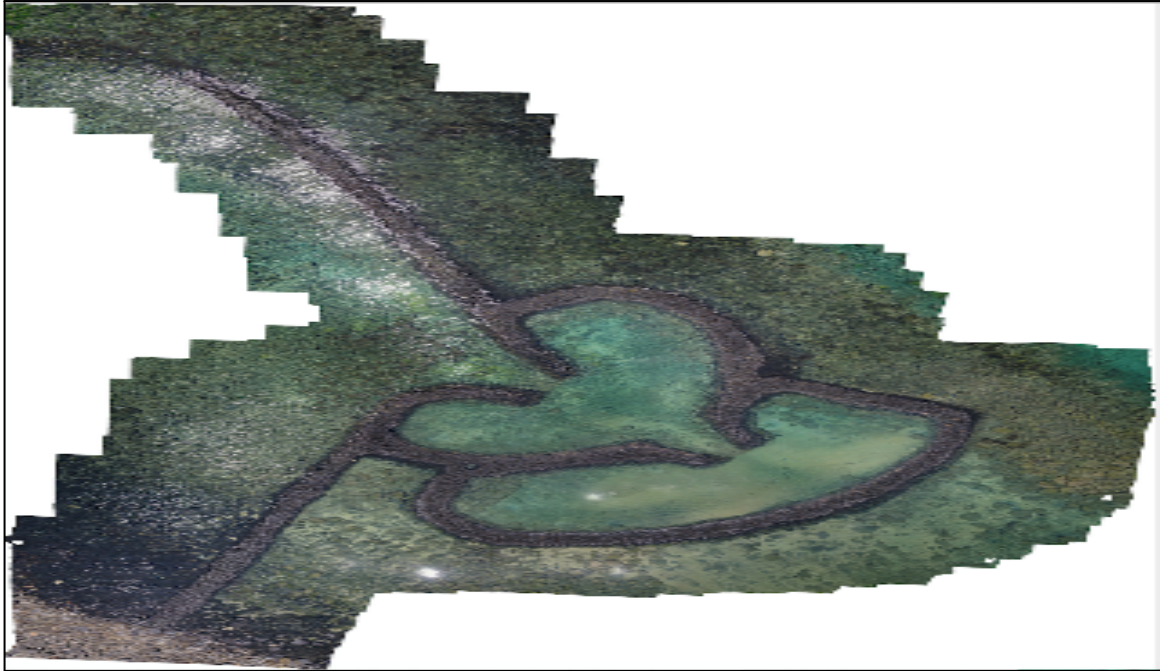


Figure 4: High-resolution KMZ stitched photos of Qimei shihu.

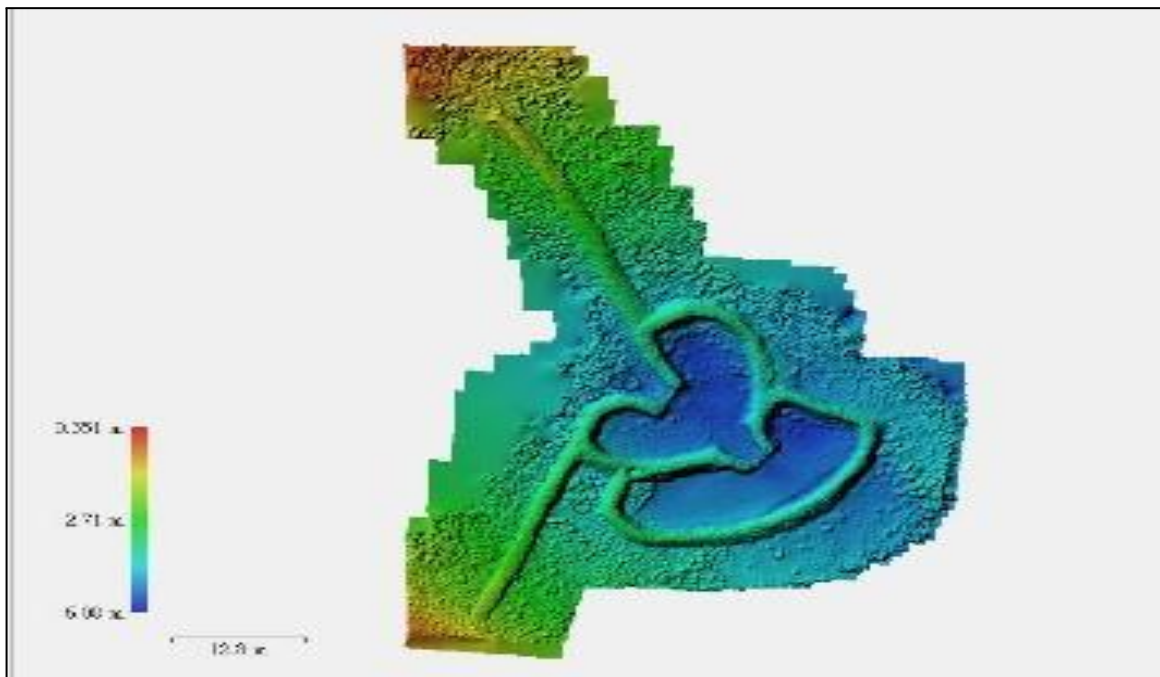


Figure 5: Map of 3D elevation model with water depth for Qimei shihu.

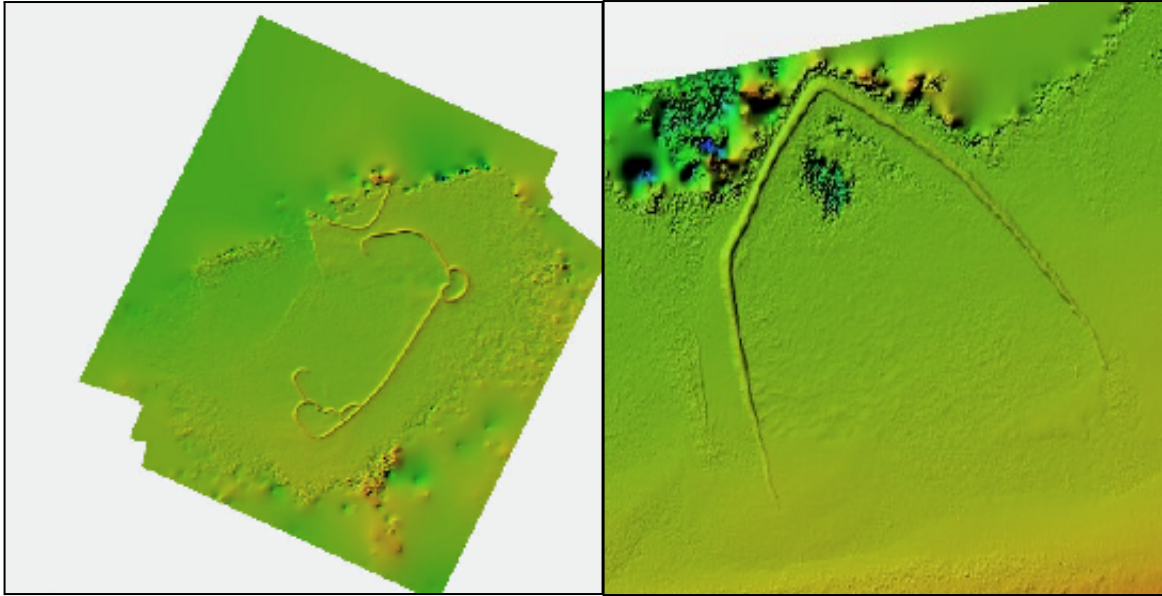


Figure 6: Map of 3D elevation model for Jubei (left) and Wunai (right) shihu.

For the purpose of detail measurement (e.g., width, length) of shihu, Fig. 7 serves as an example to illustrate the maps with high-resolution and accuracy by our method. These maps will be helpful to the monitoring and maintenance of shihu. The upload GIS information on Google Earth can also be shared with all experts and/or institutions who are concerned.

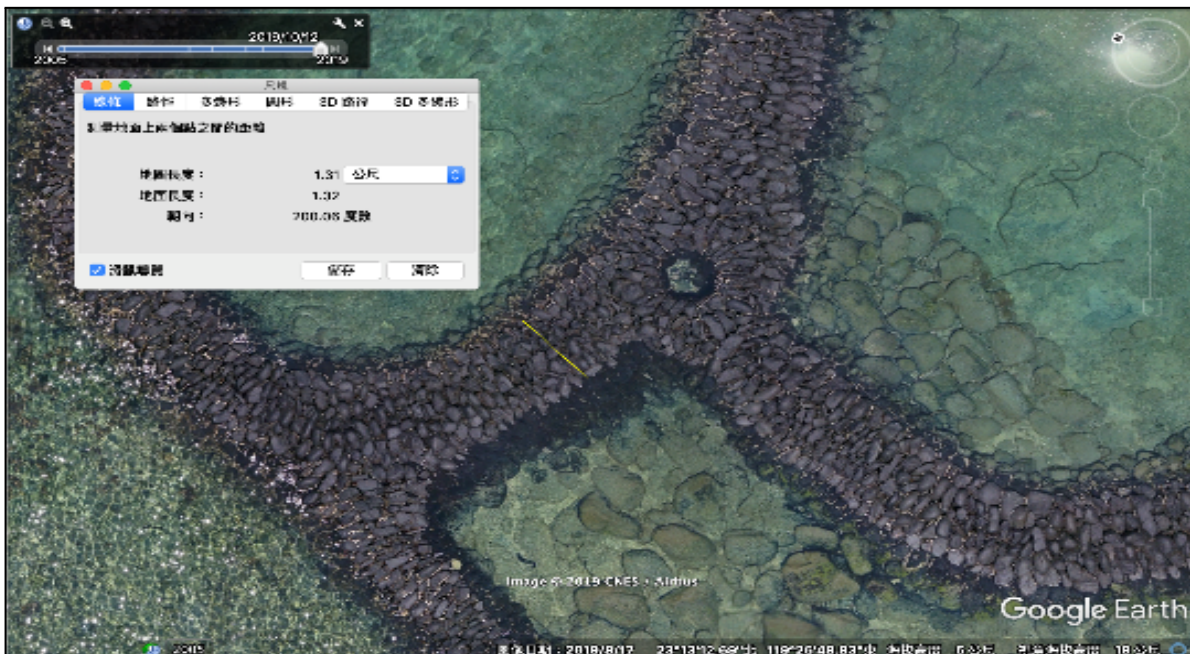


Figure 7: A high-resolution map resulted for detail measurement of shihu.

Google Earth satellite images are limited to commercial satellites purchased from them, so the captured images have a low resolution and cannot be clearly identified after zooming in, and are only suitable for large-scale image requirements. The low-altitude images captured by UAV can still clearly identify the details after being magnified, which is suitable for close-up surveys, monitoring or detailed research. In addition, this high-resolution aerial image can also obtain with minimal research expenditure. Figure 8 is a comparison between Google Earth satellite imagery and aerial photography KMZ file photos. It also shows the practicality of the aerial photography shihu survey method adopted in this study.



Fig. 8: A comparison between Google Earth satellite imagery (left) and aerial photography KMZ photo (right) resulted from this study.

DISCUSSION

1. The urgency of preserving shihu -- Affected by climate change, coastal development, human destruction and commercial overfishing, many of the remaining shihu groups are gradually falling, abandoned, submerged, incapacitated, and even disappeared. Since many shihu are difficult to reach, there is a necessity to use science and technology to speed up the investigation and research of shihu before their rapid disappearance.
2. The necessity to establish shihu databank – Although Taiwan currently has a digital collection of "Forms and Cultures of Penghu's Shihu", including its categories as "terminology", "architectural forms", "industry", "humanities", "bird's eye view of shihu", "legends of faith" and "shihu instrument", but these materials are mostly descriptive and historical literature information. On space information, the use of aerial photo, satellite imagery and 3D modeling has only begun to apply by academic community and civil society in recent years. Therefore, this study believe it is necessary to further use more advanced and efficient survey methods, and

add survey data such as water depth map, coordinate map, shihu structural image, etc., to establish a systematic digital database for Taiwan.

3. The efficiency of UAV photogrammetry technology -- Using the data obtained by UAV, we can quickly measure, calculate and mark the shihu information that you want to record, so as to avoid the time-consuming and laborious operation in the field. In the past, the on-site survey would have taken hours or days of measurement. By using the images recorded by UAV may be completed in minutes. Thus, the method has the advantages of high mobility and accessibility to reach shihu.
4. The reduction of direct disturbance or damage to shihu -- Most of shihu has not been used for a long time. In the case in disrepair, the structures of many shihu have shown fragile. Therefore, the less disturbance the better preservation. If the field investigation can reduce the impact on the climbing, stepping or shaking of shihu, that will extend the stability and existence of these heritage. The use of UAV surveys is conducted in a non-contact, non-invasive manner, greatly reducing the impact on shihu, and the information of entire shihu area can be obtained without interfering with the site.
5. The accuracy of KMZ map – Due to the travel ban of COVID-19 to Penghu archipelagoes, we can only take Wenai shihu in Miaoli to exam the accuracy of KMZ maps obtained from this study. Fig. 9 shows the KZM maps of Wunai shihu and Table 1 illustrates the comparison of length measurement between KMZ maps and on-site manual survey. For example, the length of A to B is 63.17 meters and it is measured as 62.33 meters on KMZ map. The difference is only 0.84 meters (1.32%). The length between B and C is 87.46 meters and which is measured as 87.74 meters on KMZ map. The difference is 0.28 meters (0.32%). The above results show that our survey method, with the error of less than 1.5%, can be said to be very accurate. And, this should be an important result of this study and implies the practical value of this method.

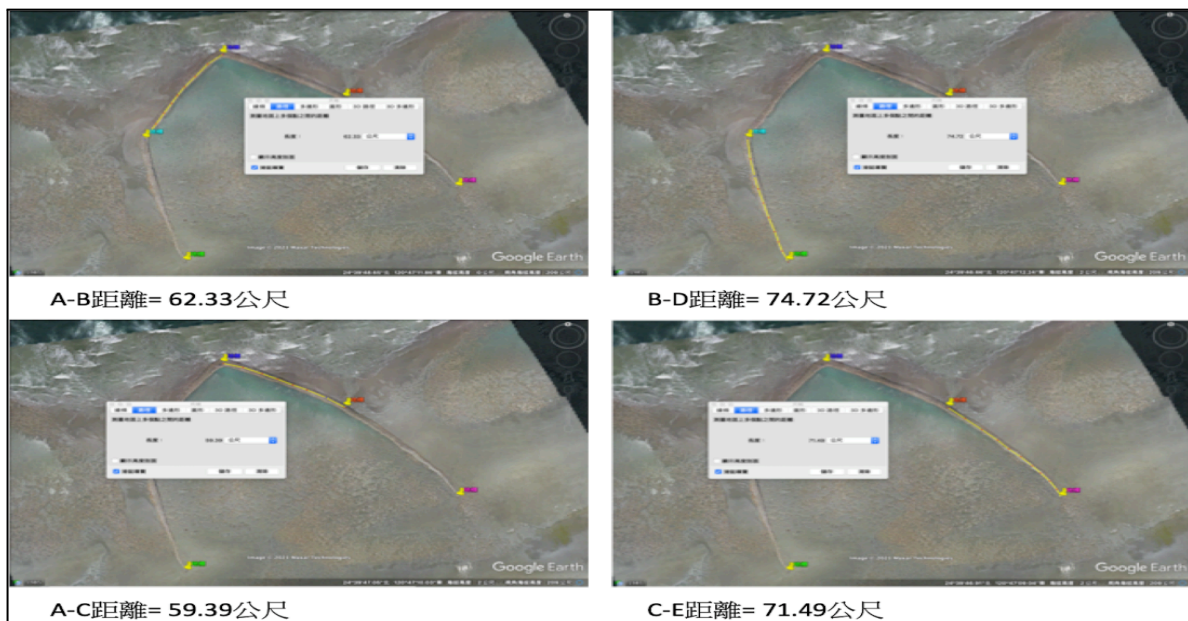


Figure 9: Length measurement for Wunai shihu. (Unit: meter)

Length Measurement	A-B	A-C	B-D	C-E	D-E	B-C
On-site manual survey	63.17	60.29	73.92	70.33	119.33	87.46
KMZ map	62.33	59.39	74.72	71.49	119.10	87.74

Table 1. A comparison of length measurement between KMZ map and on-site manual survey.

CONCLUSIONS

According to Article 3 of Taiwan's Underwater Cultural Heritage Preservation Act, "underwater cultural heritage" means all traces of human existence having a historical, cultural, archaeological, artistic or scientific character which have been partially or totally under water, periodically or continuously such as: (1) sites, structures, buildings, artifacts and human remains, together with their archaeological and natural context; (2) vessels, aircraft, other vehicles or any part thereof, their cargo or other contents, together with their archaeological and natural context; and (3) objects of prehistoric character. Shihu is periodically submerged by the sea, and contains rich traditional wisdom and human and social significance, it definitely meets the definition of "underwater cultural heritage" of the above law. As Taiwan has the world's richest shihu groups, the establishment of a perfect and accurate information system deserves the priority on the national cultural agenda. In addition, it is essential to link countries or regions in the Asia-Pacific region that own shihu to jointly apply for world heritage.

In the past, shihu's methods of research and investigation, relying on human, resource or poor-resolution satellite images, make the research and investigation work face considerable limitations. In view of this, this study introduces the latest UAV recording technology and integrating GIS data into the shihu survey method, so as to provide the basis for future research on shihu and coastal management issues. This method also provides a good research basis for the long-term monitoring and management of underwater cultural assets in the future.

For follow-up and future studies, the authors would like to make the following recommendations:

1. Under the limitation of funds, manpower, time and epidemic, only three field investigations can be carried out in this study. Although preliminary standard operating procedures have been established, it is still appropriate to keep pace with the times, continue to conduct research and improve the contribution of research methods. In addition, relevant government agencies (such as Ministry of Culture, Ocean Council, Ministry of Science and Technology, the Ministry of the Interior and local governments) are encouraged to provide appropriate funding to support long-term research on shihu issues.
2. The output of this study is the basic information of the space and structure of shihu. The issues related to shihu and coastal zone management are very wide, and it is recommended

that the government or academic insitutions should study cross-cutting and integrated research based on the basic database of shihu. For example, research disciplines of marine science (marine physics, marine life, marine chemistry, marine geology), climate change (sea level rise), social systems (shihu history, coastal community development), fisheries administration (fishing, fisheries species, fishery resource rehabilitation, regional fisheries law management) and biodiversity (marine ecosystems, marine protected areas) may all have new ideas in the "integrated coastal management".

3. In order to popularize the research, education and management of shihu, this study will establish a database to serve as a platform for sharing shihu information. A perfect database can promote the exchange of shihu culture and the sharing of knowledge. For the long-term monitoring and maintenance of shihu, it is also beneficial to the research of integrated coastal management.
4. Taiwan has precious and well-preserved shihu group, and the shihu group in Penghu has also been selected as the potential site of world heritage in Taiwan. Some internationally renowned scholars such as Professor Bill Jeffery of the University of Guam and Professor Akifumi Iwabuchi of Tokyo Ocean University are very supportive of Taiwan's efforts to promote shihu's application for world heritage. Taiwan should continue to improve relevant research techniques on shihu and to promote the methods to countries or areas in the Asia-Pacific region with shihu through international cooperation and initiatives. It is hope that all counties concerned can jointly establish the Asia-Pacific or Global shihu database, thereby recognizing the value of shihu, and strive to jointly become a "World Heritage ".

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