Harmonious Coexistence of Cultural Heritage Protection and Tourism: The Mount Lushan Comprehensive Tourism Platform

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Harmonious Coexistence of Cultural Heritage Protection and Tourism: The Mount Lushan Comprehensive Tourism Platform

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Abstract

The coordinated development of heritage protection and tourism is the goal of both cultural heritage sites and sustainable heritage tourism. However, the development of sustainable heritage tourism can be restricted due to insufficient resources for heritage tourism marketing as well as insufficient cultural heritage protection measures. This study uses digital methods such as oblique photography, 3D laser scanning technology and panoramic technology to digitize the cultural landscape heritage site. Using these methods, we build a virtual tourism subsystem to improve tourists' experience of cultural heritage tourism resources and enhance the attraction of cultural heritage tourism. In addition, we build a tourist flow and environmental monitoring and management subsystem based on the Internet of Things technology. This subsystem can help managers adjust and regulate tourist flow according to the tourism carrying capacity threshold. We also conduct an ecological environment health assessment and management simulation according to the "Pressure-Status- Response" model, in doing so, we aim to enhance the protection of cultural heritage sites. Finally, we develop a comprehensive platform to integrate tourism marketing and heritage protection management functions. The results of this study provide a new approach for the coordination of and symbiosis between the protection of cultural heritage and tourism activity.

Keywords: Cultural heritage; Tourism; Platform; Digitization; Monitor; Lushan

Introduction

Since the 21st century, the rapid urbanization process and the growing tourism market have accelerated the development of heritage resources, which have in turn led to further tourism development and economic growth [1]. However, in its development process, it faces the contradiction between expanding tourist flow and avoiding the destruction of ecological

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environment and cultural heritage[2]. On the one hand, there is a conflict between heritage protection and tourism development. Overcrowding from an excess of tourists may destroy the value of the heritage sites [3]. It can also lead to biodiversity loss, generate additional solid waste, and cause water, air, and noise pollution, all of which destroy the environment of cultural heritage sites [4]. On the other hand, insufficient marketing of cultural heritage sites has reduced the attractiveness of heritage tourism. In recent years, three-dimensional virtual reality visualization has become of great significance to the marketing of cultural heritage sites [5]. However, due to the lack of infrastructure and human capital in these sites, virtual experiences cannot meet the needs of tourists[6], nor are they conducive to their development. Heritage tourism and sustainable development are closely related [7]. In order to sustainably develop the cultural heritage tourism industry, it is necessary to strengthen the marketing of cultural heritage sites. It is also necessary to improve the protection methods for cultural heritage sites.

Technology plays an important role in both heritage marketing and environmental protection. Three-dimensional virtual reality technology is the most innovative means of tourism marketing [8]. The application of virtual reality technology can make tourists experience immersive, enhance tourists' willingness to travel, and transform cultural heritage management into a digital tourism experience [9]. In terms of cultural heritage protection, 3D (three-dimensional) digital technology is usually used for digital preservation and reconstruction of historical buildings [10, 11]. Video surveillance technology and electronic ticketing systems can be used to monitor tourist travel behavior[12], while wireless sensors can be used to monitor sites and their surrounding environment [13, 14]. Therefore, the application of such technology can increase the level of protection for heritage sites while at the same time promoting tourism.

In terms of heritage digitization, there have been studies on digital reconstruction of cultural relics and less digital protection of large cultural landscapes. Scholars used laser scanning and digital photogrammetry technology in the process of digitizing large-scale historical sites[15], and large-scale cultural landscapes also need to combine different technologies. In terms of tourist flow management, scholars have begun to use the Internet of Things technology to collect tourists data and manage tourist flow[16], but there are still few studies on the regulation mechanism of tourism capacity, and it is necessary to further explore tourism capacity management with practical application value tool. In terms of ecological environment management, with the widespread application of Internet of Things technology in ecological environment monitoring, making full use of monitoring data and conducting environmental health assessment and management has become an important research direction[17]. Sustainable heritage tourism is a complex concept[18], involving many elements[19]. Existing studies have often considered unilateral aspects of heritage protection, tourism marketing and experience, tourist flow and environmental management, however, integrating relevant elements from a comprehensive perspective may be more beneficial to heritage Sustainable development of tourism.

If the cultural heritage tourism system is effectively designed and planned, cultural heritage protection and tourism can complement each other and develop together [20]. In this study, we have developed a comprehensive platform for the coordinated development of cultural heritage protection and tourism activity. The platform is aiming to achieve heritage management while meeting the diverse needs of tourists. This research is an exploration of the sustainable development model of cultural heritage tourism. It has certain reference value for the research and practice of the coordinated development of heritage protection and tourism.

Study site

Mount Lushan is located in Lushan County, Jiujiang City, China. It is a world-renowned cultural landscape heritage site and one of the spiritual centers of Chinese civilization. It has Buddhist and Taoist temples, as well Confucian landmarks, which combine with the beautiful natural landscape to create a unique cultural landscape of high aesthetic value. Its main area covers 30,200 hectares and its buffer area reaches 50,000 hectares. Ontological areas and buffer zones include ancient buildings, ruins, modern villas, stone carvings, alpine plants, waterfalls, and streams. These elements fully demonstrate the cultural and natural elements of the Lushan World Heritage Site. With its rich tourism resources, Mount Lushan became one of the top ten most famous mountains in China in 2003 and was rated as a national AAAAA Tourist attraction in 2007. This has stimulated the rapid development of tourism in Mount Lushan, attracting tens of millions of tourists every year.

However, through online and field research on Mount Lushan, we found that there are some obstacles to the sustainable development of cultural heritage tourism in this area. On the one hand, Mount Lushan mainly promotes and displays the cultural heritage landscape through tourism websites, such as the "China Lushan Network" (http://www.china-lushan.com/). Nevertheless, this approach presents a problem because the platform mainly introduces this scenic spot in a two-dimensional way (through pictures and text). Although there is a virtual tour section, tourists can only browse a few scenic spots in a panoramic view. People's immersion and interaction with the platform is not strong, and the virtual experience of tourists is not effective. This is not conducive to the area's successful tourism marketing. On the other hand, with the arrival of large numbers of tourists, a series of ecological and environmental problems have arisen [21, 22]. In this area, there is a lack of equipment to monitor the flow of passengers as well as environmental quality. Moreover, the monitoring data is not linked to the web portal. Tourists cannot view the tourist flow and the ecological environment from the website, which is not conducive to cultural heritage promotion and protection. The website also lacks e-commerce modules, which reduces the attractiveness of cultural heritage sites.

Methods and models

Based on the perspective of system thinking[23], the cultural heritage tourism system is divided into cultural heritage landscape elements, tourist flow elements and ecological environment elements. And the virtual tourism subsystem and monitoring management subsystem are constructed through digital methods, monitoring methods and management methods, respectively. In this research, the digitization of cultural landscape is the basis for the realization of the virtual tourism subsystem, and for achieving the purpose of cultural heritage tourism marketing and attracting tourists. The application of tourist flow and ecological environment monitoring and management methods is mainly to achieve the goal of cultural heritage protection. As an important part of cultural heritage tourism, the virtual tourism subsystem and monitoring management subsystem have laid a solid foundation for the coordinated development of cultural heritage protection and tourism. In the end, this research achieved the integration of related functions and goals by building a comprehensive platform. The technical flow chart is shown in Fig.1.

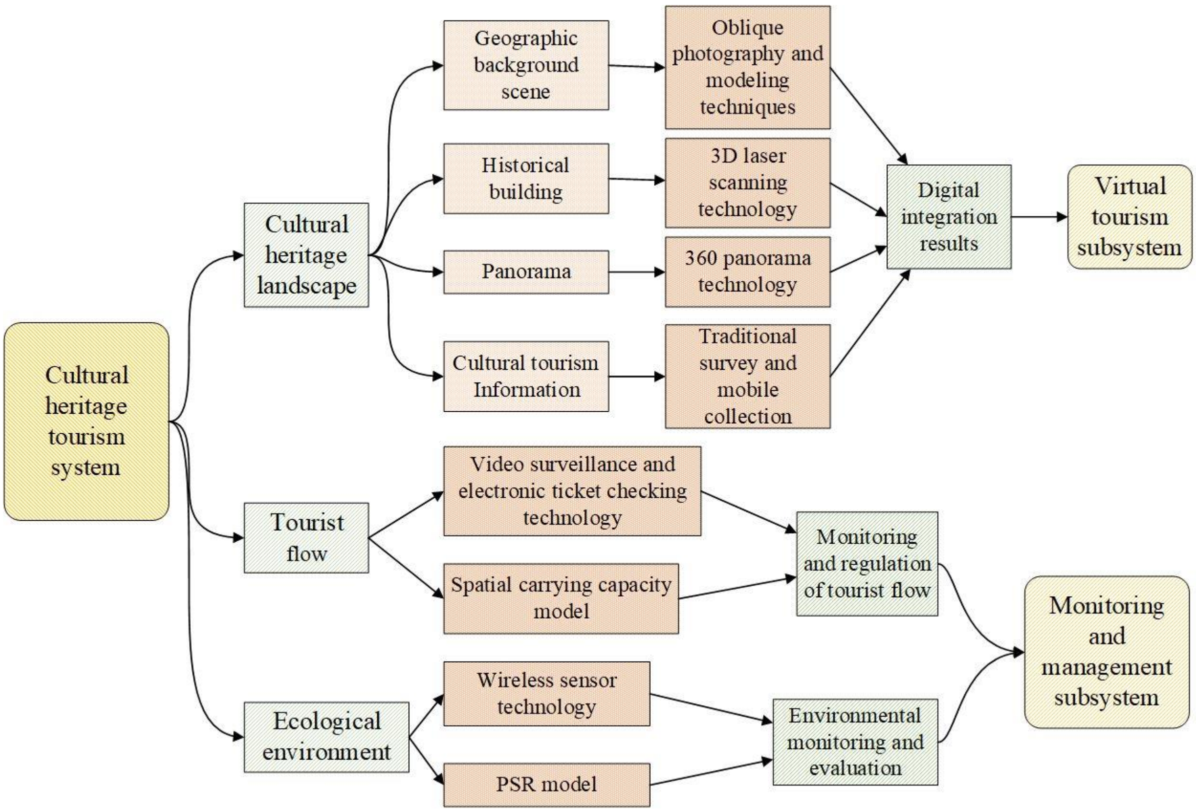

Fig. 1 The technical flow chart of this research

Digitization methods

This research has constructed a relatively complete digital framework, adopting different digital methods for geographical background scenes, cultural relics, panoramas, and other cultural tourism information, which considers the complex landscape composition, diverse tourism elements, and the wide geographical diversity of Mount Lushan. Through the comprehensive application of multiple digitization methods, the deficiencies associated with a single digitization method can be avoided, and the cultural landscape heritage sites of large scenes can be comprehensively and systematically digitized.

To digitize the geographic background scene, we adopted a technical process integrating a slanting 3D model establishment and 3-D (DSM, DEM, DLG) product production, as shown in Fig.2. This technical process ensured the accuracy of all products, as well as high efficiency and low production cost. First, the original image was obtained using oblique camera technology[24]; then, aerial photography was carried out using Unmanned Aerial Vehicles (UAVs) with oblique cameras. Next, we used a computer modeling system to perform automatic aerial triangulation calculations on the collected oblique photographic images, which enabled us to build a 3D model. We obtained data outputs for the Digital Surface Model (DSM) and the True Digital Orthophoto Map (TDOM) based on the 3D model. Digital Elevation Model (DEM) results were then obtained by editing the DSM results. We also collected Digital Line Graphic (DLG) based on the 3D model. Then, the features of the occluded objects were reproduced through field survey, in order to improve the accuracy of DLG rendering. We supplemented the geomorphic elements in DLG with semi-automatic generation of contour line and elevation points, according to the DEM results. In this study, we also used resampling to process DEM data, and we processed Digital Orthophoto Map (DOM) original data through image fusion, splicing, and resampling.

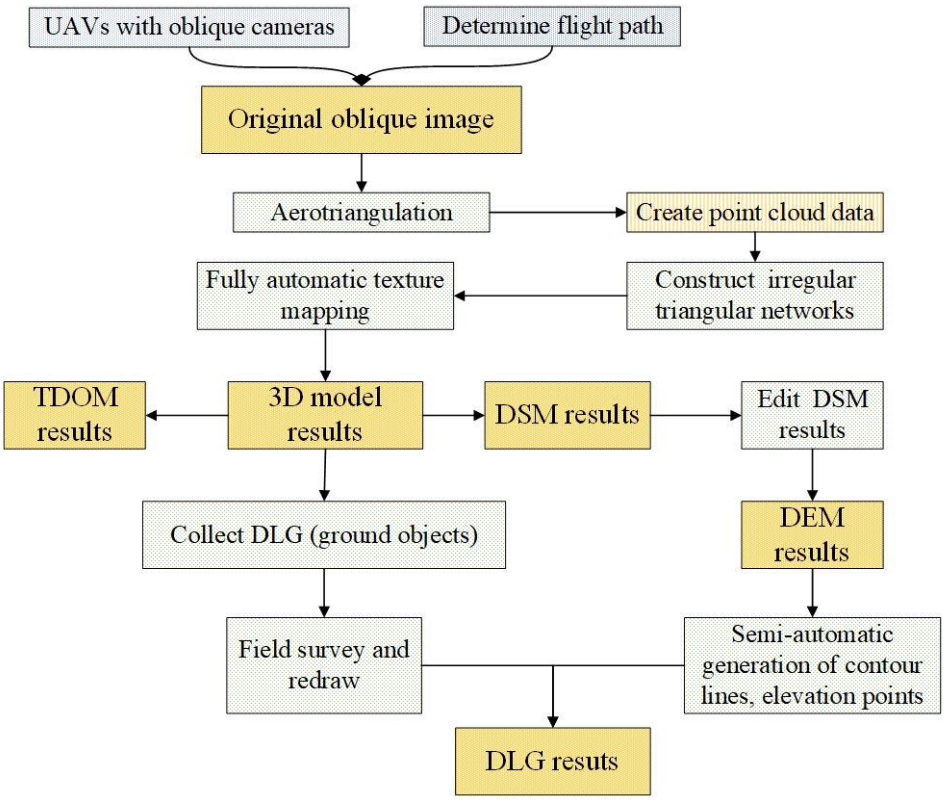

Fig. 2 Flow chart of the integrated generation of 3D models and 3-D products

The terrestrial laser scanner can quickly scan the measured object, it directly obtains high-precision scanning point cloud data without a reflection prism, which can efficiently carry out 3D modeling and virtual reproduction of historic buildings [11]. In this study, we used 3D laser scanning technology to obtain the point cloud data for historic buildings in Mount Lushan. We then used the 3Ds Max software to process the point cloud data in order to obtain the 3D model.

A 360-degree panoramic image can show a 360-degree horizontal viewing angle and a 180-

degree vertical viewing angle. 360 panoramic technology is a novel and complementary visualization method [25],which can integrate 360 panoramic images in a virtual environment. This method involves the use of a digital camera to take images and then uses software such as Photoshop for image stitching to form spherical and cube panoramas.

In this study, we used traditional survey and mobile collection methods to collect and digitize other cultural tourism resources. The traditional methods of investigation include digital photography, digital video shooting, digital audio recording, image and text scanning, and interview recording. The mobile acquisition method establishes a wireless data transmission network, uses a Personal Digital Assistant (PDA) acquisition terminal to communicate wirelessly with the background system in real time, and sends the collected data to the background system in real time [26].

Monitoring methods

In this study, we used Internet of Things technology to monitor and manage the flow of tourists and environmental conditions in scenic spots. Video surveillance technology and electronic ticket checking technology were used to monitor travel traffic, and Internet technology was used to visualize surveillance data. First, cameras were set up at the entrance and exit of the scenic spot and near its main attractions to monitor the flow of tourists. Electronic ticketing technology was used to measure the number of tourists entering the scenic area. Then, the established tourist flow monitoring and management system is used to process the video data of tourists, and to obtain statistics of the flow of tourists in real time. In addition, we used wireless sensor technology for environmental monitoring in scenic spots [27]. First, we arranged various sensors, such as sensors that measure as the levels of negative oxygen ion concentration, sulfur dioxide, temperature, and humidity. Then, link these environmental data with the established monitoring and management system to display the environmental conditions of cultural heritage sites in real time.

Models

In order to make full use of the monitoring data, we applied several relevant models to strengthen the management of the cultural landscape. Specifically, we strengthened the application level of the monitoring and management system by combining the spatial carrying capacity model with the tourist flow monitoring data and the pressure-state-response model with the scenic ecological environment monitoring.

The spatial carrying capacity model is adopted to represent the tourism capacity of Mount Lushan. The model also refers to the amount of tourist activities that can be accommodated by tourism resources within a certain period of time[28], on the premise of maintaining the quality of tourism resources. It can also reflect the capacity of scenic resource spaces, which can be measured from the aspects of planar capacity and linear capacity.

The planar calculation method is applicable to areas with relatively flat terrain and relatively uniform distribution of scenic spots and reception facilities. It is obtained as follows:

$$C_1 = \frac{A}{A_0} \times \frac{T}{t_0} \quad (1)$$

C_1 is the spatial carrying capacity (persons/d), A is the scenic area (m^2), A_0 is the reasonable area occupied per capita (m^2), and T is the average daily opening time (h). Although the scenic area is open 24 hours per day, tourists are mainly visiting during the daytime, so T is set to 8 hours in our study. t_0 is the average time required for visitors to visit the scenic area (h).

The linear capacity calculation method is suitable for tourists that visit the area along a tour path. The channel where the inlet and outlet are not in the same position is a complete channel, and the resource space capacity is obtained as follows:

$$C_2 = \frac{L}{L_0} \times \frac{T}{t_0} \quad (2)$$

If the path is incomplete and the entrance and exit are in the same position, tourists can only return by retracing their steps on the original path. The spatial carrying capacity formula is as follows:

$$C_3 = \frac{L}{L_0 + (L_0 \times t_0 / T)} \times \frac{T}{t_0 + t_1} \quad (3)$$

In Equations (2) and (3), C_2 and C_3 both refer to spatial carrying capacity (persons /d). L is the length of the path (m), L_0 is the length of reasonable possession per capita (m), and t_1 is the return time along the original route (h). The total number of tourists calculated using the area method and the line method, which constitutes the resource space capacity of the scenic area.

The PSR model was first proposed in 1979 for the study of environmental problems. It has become a commonly used model to evaluate environmental quality[29]. In the PSR model, "P" refers to the pressure index, which is used to describe the pressure applied to the ecological environment under the influence of human activities. "S" refers to the status index, which is used to describe the status of the ecological environment. "R" refers to the response indicator, which describes the positive management actions taken by human beings towards the ecological environment. The PSR model answers three basic sustainable development questions: what happened, why it happened, and what will happen in the future.

In our study, we used this comprehensive evaluation index to reflect the ecosystem quality of Mount Lushan. A weighted summation method was used to perform the calculation [30], namely:

$$Z = \sum (X_i \times Y_i) \quad (4)$$

Z represents the comprehensive evaluation index, X_i is the normalized value of a single index, and Y_i is the normalized weight of the evaluation index.

Case study verification

Heritage digitization and visualization

Multiple types of digitization

The technical process shown in Fig. 2 was used to digitize the geographical background scene of Mount Lushan. We produced a large-scale 3D model using DLG and TDOM data.

DOM and DEM data of the four seasons were also generated. These results are shown in Fig. 3a-3e. The 3D model of the large-scale scene produced has high accuracy and adequately shows the Mount Lushan area. For example, the Donglin Temple in Fig. 3a is 0.004 meters in pixel size. The generated DOM at 1:2000 resolution vividly shows the Lushan area during different seasons (Fig. 3b-3c shows the spring and autumn landscapes of Flower Road). The generated DEM data (about 350 square kilometers) for Mount Lushan can be used to simulate the topography of the area (see Fig. 3d). Combined with DEM and multi-temporal DOM data, it can simulate the natural landscape and topographic features of Mount Lushan in different seasons, and it can provide a basic geographic display platform for other data (e.g., tourist routes, etc.). The DLG data collected only had a small error margin, meeting the mapping accuracy requirement of 1:1000 scale (such as the White Deer Cave Academy shown in Fig. 3e).

Fig. 3a 3D model results of large scene (Donglin Temple)

Fig.3b DOM results diagram (Flower Road/ Spring)

Fig.3c DOM results diagram (Flower Road/ Autumn)

Fig. 3d DEM result diagram (Mount Lushan / 350km^2)

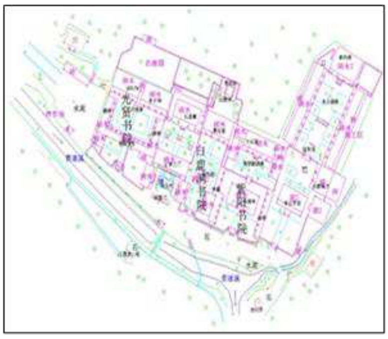

Fig.3e DLG result diagram (White Deer Cave Academy)

Fig.3f Colorful point cloud data (White Deer Cave Academy)

Fig.3g 3D model diagram of the building (White Deer Cave Academy)

Fig. 3h Panoramic map (Ruqin Lake/Spring)

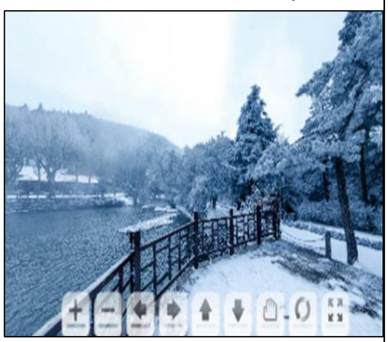

Fig. 3i Panoramic map (Ruqin Lake/Winter)

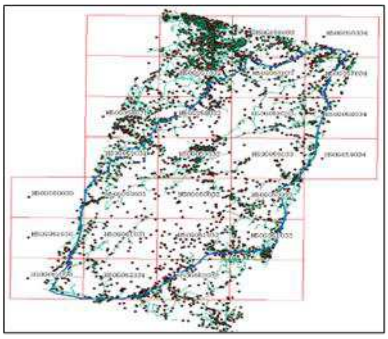

Fig.3j Scenic spot address data (Mount Lushan /about 350km^2)

Fig.3k Vegetation community data (On Xiufeng Mountain)

Fig.3l Geological and geomorphic data (Xiufeng Mountain)

Fig. 3 Digital results

Education, politics, architecture, natural scenery, religion, and other elements of typical cultural heritage landscapes were considered when conducting the digital modeling process. This process was based on 3D laser scanning, 3D modeling, 360 panoramas, and other technologies. The results are shown in Fig. 3f-3h. The 3D laser scanner was used to scan the architectural cultural landscapes, and fine point cloud data of the buildings were obtained. The point cloud data included important appearance features such as the size and shape of the buildings, as well as the texture of the scanned buildings (as shown in Fig. 3f). We then generated a 3d model with texture based on point cloud data (see Fig. 3g). The point cloud data were modeled and processed to establish some high-resolution three-dimensional models, providing accurate and detailed information for cultural heritage protection. Drone and ground acquisition equipment were used to obtain the air-based and ground-based panoramas of scenic spots in each season. Fig. 3h and Fig.3i show two panorama images of Ruqin Lake in spring and winter.

We collected and digitized materials from the Taoist and Buddhist cultures, including ancient poems and paintings, ancient books, ancient cultural relics, historical narratives, and written accounts by using traditional data collection methods. Other data on the heritage site (scenic spots, traffic, shopping, accommodations, entertainment, tourist facilities, geological data, vertical zonal soil profiles, plant communities, etc.) were collected and digitized using the mobile collection method. As shown in Fig. 3j, 7128 geographical names and addresses covering an area of about 350km^2 were collected. Fig. 3k shows the vegetation landscape of the Xiufeng Mountain that was photographed. Fig. 3l shows the geological and geomorphologic features of Xiufeng Mountain. The data formats included text, picture, audio, video, and panorama, which greatly enriched the digital content.

Visualization and virtual tourism implementation

The SuperMap software can manage large amounts of data. It has many GIS analysis functions and has a high-quality rendering effect. In this study, we utilized the SuperMap to develop a virtual tourism subsystem. We have integrated the existing digital results to achieve efficient 3D virtual visual display, as shown in Fig. 4. The virtual tourism subsystem of Mount

Lushan is a display platform integrating sound, text, images, three-dimensional models, and maps, as well as a variety of human-computer interaction technologies. This model is intuitive, dynamic, interactive, and rich in information content. The 3D virtual scene of Mount Lushan supports the rapid positioning of scenic spots, and realizes the combination of 360 panoramas, 3D models, and other visualizations of the Mount Lushan features. This way, tourists can view the relevant information of scenic spots in a holistic and three-dimensional way.

The platform integrates approximately 350 square kilometers of 1:2000 DEM data, multi-temporal DOM data, and large-scale scene 3D models. The natural landscape features of "magnificent, strange and beautiful" are prominently displayed and the landscape features during different seasons are well presented, as shown in Fig. 4a. It also shows the spatial location relationship and spatial location structure of each scenic area. Additionally, the platform integrates scenic site information, road networks, tourist facilities, cultural relics, and architectural models, in order to fully display the cultural features of Mount Lushan.

Different perspectives have different requirements regarding the form and accuracy of three-dimensional data. When viewing a building model from the air, it is necessary to show a large-scale scene, while a closer view requires higher accuracy of data. The virtual tourism subsystem we constructed shows the external structural features of the building from different perspectives. Taking the Donglin Temple as an example, we comprehensively used oblique photography, geometric modeling, 3D laser scanning, 360-degree panoramic technology, and other technical methods to construct the model. Visitors can view the architectural model from different perspectives, as shown in Fig. 4b-4c.

Fig. 4a 3D scene of the natural landscape (The north of Mount Lushan) **Fig. 4b** 3D scene of the Donglin Temple (Aerial view) **Fig. 4c** 3D scene of the Donglin Temple (A close view of the front door)

Fig. 4 3D virtual visualization diagram

The virtual tourism subsystem mainly includes spot information, virtual reality experiences, tourist routes, geology and landforms, vegetation, and soil type, among other functions. For example, Fig. 3k shows information on the vegetation type, Fig. 3i reflects geomorphologic information, and Fig. 4 shows the function of virtual reality experience. The diversified display effects not only enhance the virtual experience of tourists, but also enrich the educational functions of the platform, which can enhance tourists' awareness of cultural heritage protection.

Monitoring and management of tourist flow and environmental quality

Monitoring and regulation of tourist flow

Based on video surveillance technology and electronic ticket checking technology, we have built a tourist monitoring and management subsystem for cultural relics. The subsystem can count the number of people entering and leaving the scenic spot and the number of people remaining at the site in real time. It can also generate data, graphs, and reports at any selected time period.

The subsystem can provide various services for tourists. First, when buying a ticket, identity information such as the tourist' ID number and name will be associated with the electronic ticket to facilitate the rapid search and location of the lost tourist, which is conducive to tourist safety. Second, the subsystem can also display the number of tourists, personal information, location information, and real-time tourist flow data in the scenic spots in the form of charts. Tourists can then adjust their routes according to the tourist flows displayed.

Most important, the subsystem provides a platform for tourist flow regulation and management for scenic area managers. The tourist capacity of each route and each scenic spot can be limited, and the tourist capacity threshold can be correlated with the subsystem. When the number of tourists in each route and scenic spot exceeds the tourism capacity threshold, the subsystem will issue an early warning. Scenic spot managers can temporarily restrict ticket sales for overcrowded sites and guide tourists to other areas, which reduces the negative environmental impacts.

We conducted a survey to determine the tourism capacity threshold. There are many scattered scenic spots in the Mount Lushan area, and there are many choices of tour routes. Most of the scenic spots can be calculated by using Eq. (1). Tourists visit the Shimen Stream, the Longshou Cliff, the Hanpokou-Taiyi Village, Wulao Mountain, and the Sandie Spring scenic spots by walking on the same tour path. Therefore, Eqs. (2) and (3) can be used to calculate the tourism capacity of the tour path. The calculation results are shown in Tables 1 and 2.

For ordinary scenic spots, we assumed that a reasonable occupancy area per capita is 500 m^2/ person. The Sanbao Tree and Lushan Botanical Garden sites have large surrounding areas and natural landscapes, so the reasonable occupancy area per capita is assumed to be larger, around 3300 m^2/ person. The Guling scenic spot is a popular place for tourists. Although its tourist capacity is calculated at 50,000 (persons/d) according to the formula, it needs to exclude 21,400 residents from the town of Guling. So, the actual tourist capacity of the Guling scenic spot is 28,600 persons /d. We added up the tourist carrying capacities to estimate the total capacity of Mount Lushan to be 42,227 people.

Table1 Spatial carrying capacity calculated according to Eq. (1)

Scenic spots	Available area (km^2)	Area occupied per capita (m^2/person)	Time required to complete the journey (h)	Tourist capacity (persons /d)
Guling(牯岭)	25	500	-	28600

Flower Road (花径)	0.315	500	2	2520
Jingxiu Valley(锦绣谷)	0.089	500	2.5	534
Xianren Cave(仙人洞)	0.052	500	1.5	520
Datianchi(大天池)	0.438	500	2	3504
Sanbao Tree(三宝树)	0.813	3300	3	493
Lulin Lake(芦林湖)	0.12	500	2	960
Lushan Botanical Garden (庐山植物园)	1.472	3300	3	892
Total	/	/	/	38023

Table 2 Spatial carrying capacity calculated according to Eqs. (2) and (3)

Tour routes	Tourist path	Length of tour line (m)	Length of per capita (m/ person)	Time required for completion of tour (h)	Time required to return along the same route (h)	Tourist capacity (persons /d)
Shimen Stream - Longshou Cliff (石门涧-龙首崖)	Complete channel	13000	20	4	/	1300
Hanpokou-Taiyi Village (含鄱口-太乙村)	Incomplete	1600	3	1.5	1	1517
Wulao Mountain - Sandie Spring (五老峰-三叠泉)	Incomplete	6500	6	3	2	1387
Total	/	/	/	/	/	4204

Note: "persons /d" means the number of persons suitable for the scenic spot every day.

We constructed the tourist flow adjustment and control mechanism based on the spatial carrying capacity of each scenic spot, route, and panoramic area, as well as with the help of the tourist monitoring and management subsystem. Such a subsystem can refine tourist flow management and bring better tourism experience to tourists.

Monitoring and evaluation of ecological environment

The ecological environment monitoring and management subsystem mainly collects monitoring data, such as air quality and meteorological information. It dynamically monitors the ecological environment, provides corresponding services for tourists, and provides visual management tools for scenic spots.

First, we need to realize real-time monitoring and environmental information services. The atmospheric and meteorological data monitored in real time were collected through the GPRS (General Packet Radio Service) data transmission module, and then transmitted back to the local server via the GPRS network to establish an ecological monitoring database for the real-time data. The database analyzes information to obtain real-time data, monthly data, and longer timescale data. Visitors can view the monitored data on LED (Light Emitting Diode) screens installed at the tip of each sensor device. They can also view the environmental information data through the mobile system. In addition, managers can understand the environmental changes of Mount Lushan in a timely manner through air quality analysis. This enables them to provide meteorological information to tourists and remind them to avoid sightseeing during adverse weather conditions. In the case of emergencies such as fires, managers at scenic spots can quickly take measures to better protect the cultural heritage.

Next, what we want to achieve is a non-real-time environmental information monitoring-feedback-management mechanism (using annual data for lag management). We input long-term environmental monitoring data and other annual indicator data into the PSR model and use this model to strengthen the ecological environment management of Mount Lushan. We established 12 index factors based on the PSR model and constructed an ecological environment health evaluation index system, as shown in Table 3. Lushan County is under the jurisdiction of Lushan City, and most of the index data cames from Lushan City. However, it was difficult to obtain certain indicator data. Because Lushan County belongs to Jiujiang City, some indicator data were obtained from Jiujiang City. The original data of ecological environment from 2016 to 2018 are shown in Table 4.

Table 3 Environmental quality evaluation for Mount Lushan

Target layer	Second layer	Third layer	Source of data	Unit	Index trend	Index weight
Environmental quality index	Pressure indicators	Total number of visitors	Jiujiang Yearbook	10,000 persons	-	0.08
		Sulfur dioxide emissions	Statistical Yearbook of Jiujiang	ton	-	0.08
		Smoke emission	Statistical Yearbook of Jiujiang	ton	-	0.08
		Total permanent population	Statistical Yearbook of Jiujiang	person	-	0.08
	Status indicators	PM2.5	Monitored data	μg/m^3	-	0.08
		Sulfur dioxide concentration	Monitored data	μg/m^3	-	0.08
		Forest area	Work Report of Lushan Municipal Government	ha	+	0.08
		Negative oxygen ion content	Monitored data	per unit volume/cm^3	+	0.08
	Response indicators	Environmental management expenditure	Jiujiang Ecological Environment Bureau	ten thousand yuan	+	0.08
		Expenditure on pollution control	Jiujiang Ecological Environment Bureau	ten thousand yuan	+	0.08
		Area of newly planted forest	Lushan Forestry Bureau	ha	+	0.08
		Expenditure on forestry cultivation	Lushan Forestry Bureau	ten thousand yuan	+	0.08

Note: "+" represents a positive indicator and "-" represents a negative indicator; we assume that the weight of each index is equal and set at 0.08.

Eq. (4) was used to calculate the 2016-2018 index data, and a comprehensive index value was obtained for each year. Table 4 also shows the analysis results regarding the pressure, status, and response of the Mount Lushan ecological environment in recent years. In 2018, Mount Lushan had the highest environmental health index（0.64）, which is attributed to the fact that, in 2018, the ecological response and the status comprehensive index were highest. However, the response index in 2018 remained the same as that of 2016 due to reduced financial expenditure on pollution prevention and forest management. The evaluation of the ecological environment conducted through the PSR model has an early warning function. In order to maintain the steady improvement of the ecological environment of Mount Lushan, decision-makers in Jiujiang should insist on increasing investment in ecological environmental protection.

Table 4 Environmental health index and relevant data from 2016 to 2018

Secondary layer	Third layer	Original data			Comprehensive index		
		2016	2017	2018	2016	2017	2018
Pressure indicators	Total number of visitors	4235	5012	6180	0.16	0.24	0.16
	Sulfur dioxide emissions	153	0	0.01			
	Smoke emission	175	1.13	0.1795			
	Total permanent population	24.36	24.48	24.57			
Status indicators	PM2.5	40	40	38	0.001	0.08	0.32
	Sulfur dioxide concentration	12	10	9			
	Forest area	22400	22503	22677			
	Negative oxygen ion content	2497	2496	2550			
Response indicators	Environmental management expenditure	375	361	738	0.16	0.09	0.16
	Expenditure on pollution control	5431	1678	1123			
	Area of newly planted forest	2065	3000	3000			
	Expenditure on forestry cultivation	6007	1058	1145			
Environmental health index					0.32	0.42	0.64

Based on the PSR model and with the help of environmental monitoring and management subsystem, the staff in scenic spots can manage the ecological environment of Mount Lushan in non-real time. The dynamic changes of the environmental health index form the basis of Mount Lushan's environmental management. The dynamic feedback of related indicators encourages local governments and scenic area managers to take measures. Decision makers in the scenic area and in the local government should strive to maintain the stability and growth of the environmental health index.

Construction of comprehensive platform

The relationship between heritage and tourism is interdependent. It is necessary to establish a framework and strategy for sustainable development based on a systematic perspective[19], which is of great significance to resolve the contradictory relationship between cultural heritage and tourism. This research links the relationship between heritage protection and tourism by building a comprehensive platform.

We integrate the virtual tourism subsystem with the monitoring and management subsystem, and develop a comprehensive cultural heritage tourism platform integrated with other systems (e-commerce systems, tourism enterprise service systems), as shown in the Fig.5. Fig. 5 shows the design architecture of the integrated cultural heritage tourism platform. It is based on the concept of heritage protection and sustainable development of tourism, aiming at cultural heritage protection and tourism marketing. The function of tourism flow and environmental management is mainly to meet the needs of cultural heritage protection, and the function of virtual tourism mainly meets the needs of tourism marketing and attracting tourists. At the same time, the research has designed "other service functions" (such as e-commerce functions) to meet the diverse needs of tourists. The research considers tourism marketing and the purpose of attracting tourists when designing the management function (for example, tourists can query the tourist flow and environmental information of scenic spots). The virtual tourism function also realizes the need of cultural heritage protection to a certain extent through the process of heritage digitization. The platform integrates related functions and is mainly for tourists and scenic area managers. To better face users, we have developed a web version, mobile APP, etc. By using PCs, smart phones, LED screens and other equipment in the scenic area, so that tourists can access the site at their convenience, and the administrators can perform their duties more efficiently.

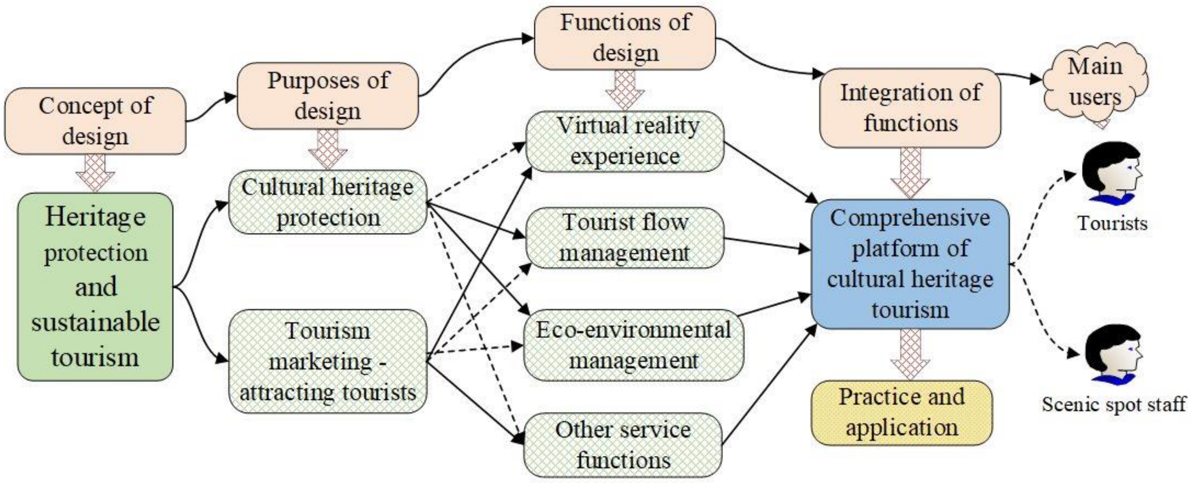

Fig. 5 Architecture of the cultural heritage tourism comprehensive platform

Fig.5 also reflects a new model of cultural heritage tourism advocated in this article. The new model is based on smart technology, comprehensively coordinating many key elements that affect sustainable development, taking cultural heritage protection and tourism development into consideration, and seeking a balance between service and management. This model innovatively realizes the coordinated development of cultural heritage protection and tourism.

Conclusion and Discussion

This article takes the Mount Lushan cultural heritage site as an example, builds a comprehensive tourism platform, and draws the following conclusions:

(1) Although scholars from many parts of the world regard digitalization as an important tool for heritage protection, the digital content of cultural heritage sites is fragmented, especially for large-scale cultural heritage sites that lack a comprehensive digital framework [31]. In this case study, we applied comprehensive and diverse digital methods to construct a digital framework for large-scale cultural heritage landscapes. The digital framework for cultural heritage landscapes includes large-scale geographic background scenes, medium-scale cultural heritage landscape points, and small-scale refined cultural building models. This research provides a reference case for the digital research of cultural heritage sites with complex landscape elements.

(2) Based on digital content, we have created a multi-functional virtual tourism subsystem and applied this platform toward the marketing of cultural heritage tourism. Its core feature is the traditional 3D virtual experience function, which allows users to have an immersive experience through 3D scene reproduction. The platform has a more prominent 3D virtual experience effect due to the diversity of scene data and the diversity of viewing angles. It has both stunning natural landscapes and fine cultural relics and architectural landscapes. It has both 360 scenes and 3D model scenes, as well as pictures and audio presentations. The scene content of the virtual tourism subsystem is relatively rich, which greatly enhances the virtual experience of tourists. The versatility of the virtual tourism subsystem makes the platform highly practical[32]. This research incorporates cultural heritage virtual exhibition functions, educational and other functions into the platform, and fully displays the natural landscape and cultural heritage knowledge of cultural landscape sites to tourists through popular science. This increases the functionality of the cultural heritage virtual tourism system.

(3) Based on the Internet of Things technology, this research has built a tourist and environmental monitoring and management subsystem for cultural heritage sites. The concept of providing services to tourists is innovatively integrated into heritage management. By opening tourist flow data and environmental quality data of scenic sites to tourists, it can meet visitors' needs for obtaining relevant information and help improve the quality of their experience. In the study of tourist flow management, the efficiency of tourist flow adjustment is improved by setting the threshold of tourism carrying capacity of each scenic spot. In terms of environmental quality management, the concept of combining real-time monitoring and non-real-time management can enhance the efficiency of environmental monitoring-feedback-management of cultural heritage sites.

(4) Finally, this research combines virtual tourism functions with tourist flow and environmental management functions, which are supplemented by other service functions. Our model employs system thinking to build a comprehensive tourism platform for cultural heritage attractions. We believe that the platform can be used to promote cultural heritage sites, to improve tourism marketing and to protect cultural heritage at the same time. It avoids the conflict between traditional cultural heritage attractions and cultural heritage protection[33],

and encourages the managers of cultural heritage sites to see cultural heritage protection and tourism as being mutually reinforcing. This comprehensive platform highlights the value concept of sustainable development research, that is, the coordination between cultural heritage tourism and heritage protection. This research uses intelligent technology to achieve innovation in the tourism industry and cultural heritage protection, by integrating cultural heritage services and management. This is a new form of cultural heritage tourism for which we advocate in this article.

This paper also has some limitations. First, the terrain and ecological quality of each scenic spot and route are quite different, and the number of tourists varies dynamically at different times. Future research should make full use of the tourist monitoring data, strengthen quantitative research, and set the tourism capacity more in line with the reality of the scenic site and the space-time characteristics of the tourist flow. Second, in the process of determining the PSR model, the data for some non-monitoring indicators were difficult to obtain, resulting in a small number of indicators selected for the study. Therefore, cooperation with local governments and data sharing need to be strengthened in the future, so that it they can contribute to the environmental protection of cultural heritage sites more efficiently. Finally, although this article advocates for an inclusive sustainable model for cultural heritage tourism, the tourism industry is highly complex. While there are many factors that affect tourism marketing and cultural heritage protection[34] ,this article only considered a limited set of factors. Therefore, more elements can be added to the comprehensive platform and the richness of the platform functions can be enhanced through further research. Examples include reducing the negative impact of traffic on the heritage site [35] and allowing local residents to participate in heritage management [36].

Abbreviations

3D: three-dimensional; 3-D: DLG,DOM,DEM; DLG: UAVs: Unmanned Aerial Vehicles； DSM: Digital Surface Model; TDOM: True Digital Orthophoto Map; DEM: Digital Elevation Model; DLG: Digital Line Graphic; DOM: Digital Orthophoto Map; PDA: Personal Digital Assistant；PSR：Pressure-Status- Response; GPRS: General Packet Radio Service; LED: Light Emitting Diode; PC: Personal Computer.

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Authors' contributions

ZC: Wrote this article; CF, QZ, FC: Reviewed the whole paper and put forward suggestions and suggestions for improvement. All authors read and approve the final manuscript.

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Availability of data and materials

The dataset supporting the conclusions of this article is included within the article .

Competing interests

The authors declare that they have no competing interests.

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References

[1] H. Zhao, L. Doyon, A Century of Archaeological Heritage Protection and Exhibition in China, Historic Environment-Policy & Practice, (2020).

[2] P. Lansing, P. De Vries, Sustainable tourism: Ethical alternative or marketing ploy?, Journal of Business Ethics, 72 (2007) 77-85.

[3] Y.Y. Kyoung, Evaluation on the Possibility for Sustainable Tourism of Cultural Heritage - Based on the Visitors' Perception of Sin-heung-sa, Journal of Environmental Impact Assessment, 19 (2010) 633-645.

[4] N.U. Saqib, A. Yaqub, G. Amin, I. Khan, Faridullah, H. Ajab, I. Zeb, D. Ahmad, The impact of tourism on local communities and their environment in Gilgit Baltistan, Pakistan: a local community perspective, Environ. Socio-Econ. Stud., 7 (2019) 24-37.

[5] A. Marasco, P. Buonincontri, M. van Niekerk, M. Orlowski, F. Okumus, Exploring the role of next-generation virtual technologies in destination marketing, J. Destin. Mark. Manag., 9 (2018) 138-148.

[6] A.G. Ambrosio Arias, J.J. Moreno Escobar, R. Tejeida Padilla, O. Morales Matamoros, Historical-Cultural Sustainability Model for Archaeological Sites in Mexico Using Virtual Technologies, Sustainability, 12 (2020).

[7] B. Garrod, A. Fyall, Heritage tourism: A question of definition, Ann. Touris. Res., 28 (2001) 1049-1052.

[8] L.P. Lin, S.C. Huang, Y.C. Ho, Could virtual reality effectively market slow travel in a heritage destination?, Tourism Management, 78 (2020) 11.

[9] A. Bec, B. Moyle, K. Timms, V. Schaffer, L. Skavronskaya, C. Little, Management of immersive heritage tourism experiences: A conceptual model, Tourism Management, 72 (2019) 117-120.

[10] Y.H. Jo, S. Hong, S.Y. Jo, Y.M. Kwon, Noncontact restoration of missing parts of stone Buddha statue based on three-dimensional virtual modeling and assembly simulation, Heritage Science, 8 (2020).

[11] G. Pavlidis, A. Koutsoudis, F. Arnaoutoglou, V. Tsioukas, C. Chamzas, Methods for 3D digitization of Cultural Heritage, J. Cult. Herit., 8 (2007) 93-98.

[12] J.H. Guo, T. Guo, K.M. Lin, D.D. Lin, Y.F. Leung, Q.H. Chen, Managing congestion at visitor hotspots using park-level use level data: Case study of a Chinese World Heritage Site, PLoS One, 14 (2019) 13.

[13] A. Perles, E. Perez-Marin, R. Mercado, J. Damian Segrelles, I. Blanquer, M. Zarzo, F.J. Garcia-Diego, An energy-efficient internet of things (IoT) architecture for preventive conservation of cultural heritage, Future Generation Computer Systems-the International Journal of Escience, 81 (2018) 566-581.

[14] Y. Wang, X. Dai, J.J. Jung, C. Choi, Performance analysis of smart cultural heritage protection oriented wireless networks, Future Generation Computer Systems-the International Journal of Escience, 81 (2018) 593-600.

[15] L. Hua, C. Chen, H. Fang, X. Wang, 3D documentation on Chinese Hakka Tulou and Internet-based virtual experience for cultural tourism: A case study of Yongding County, Fujian, J. Cult. Herit., 29 (2018) 173-179.

[16] M. Zubiaga, J.L. Izkara, A. Gandini, I. Alonso, U. Saralegui, Towards Smarter Management of Overtourism in Historic Centres Through Visitor-Flow Monitoring, Sustainability, 11 (2019) 23.

[17] E. Thomas, J. Brown, Using Feedback to Improve Accountability in Global Environmental Health and Engineering, Environmental science & technology, (2020).

[18] P. Buonincontri, A. Marasco, H. Ramkissoon, Visitors' Experience, Place Attachment and Sustainable Behaviour at Cultural Heritage Sites: A Conceptual Framework, Sustainability, 9 (2017).

[19] T. Loulanski, V. Loulanski, The sustainable integration of cultural heritage and tourism: a meta-study, J. Sustain. Tour., 19 (2011) 837-862.

[20] L.W.C. Lai, Sustainable development of heritage conservation and tourism: A Hong Kong case study on colonial heritage, Sustain. Dev., 28 (2020) 1181-1188.

[21] D.M. Xie, Q.H. Huang, S. Xu, Y.M. Zhou, G.H. Zhou, J.S. Jia, Z.Y. Zhu, Assessment of surface water quality in Lushan: a world heritage sites in China, Environ. Sci. Pollut. Res., 27 (2020) 18934-18948.

[22] W. Hui, T. Ceming, X. Wen, W. Xuan, A. Dahan, F. Qiang, Vascular plants in the tourist area of Lushan National Nature Reserve, China: status, threats and conservation, Eco Mont, 12 (2020) 60-63.

[23] F.M.Y. Roxas, J.P.R. Rivera, E.L.M. Gutierrez, Framework for creating sustainable tourism using systems thinking, Current Issues in Tourism, 23 (2020) 280-296.

[24] J.J. Wang, S. Zhu, X.G. Luo, G. Chen, Z.Y. Xu, X.W. Liu, Y.C. Li, Refined micro-scale geological disaster susceptibility evaluation based on UAV tilt photography data and weighted certainty factor method in Qingchuan County, Ecotox. Environ. Safe., 189 (2020) 8.

[25] A.P. Walmsley, T.P. Kersten, The Imperial Cathedral in Konigslutter (Germany) as an Immersive Experience in Virtual Reality with Integrated 360 degrees Panoramic Photography, Applied Sciences-Basel, 10 (2020).

[26] C.-H. Pack, S.M. Young, J.-S. Park, K. Jang-Hyung, 강진석, An Implementation of Mobile Platform using Location Data Index Technique, Journal of the Korea Institute Of Information and Communication Engineering, 10 (2006) 1960-1972.

[27] M. Maceli, Internet of things in the archives: novel tools for environmental monitoring of archival collections, Rec. Manag. J., 30 (2020) 201-220.

[28] R. Li, L. Rong, Ecotourism carrying capacity of Hangzhou Xixi National Wetland Park in China, Ying yong sheng tai xue bao = The journal of applied ecology, 18 (2007) 2301-2307.

[29] Q.J. Li, S.Z. Chen, R. Zhao, Study on Evaluation of Timber Security in China Based on the PSR Conceptual Model, Forests, 11 (2020) 12.

[30] J. Zhang, Y. Zhang, Assessing the low-carbon tourism in the tourism-based urban destinations, Journal of Cleaner Production, 276 (2020).

[31] S.F. El-Hakim, J.A. Beraldin, M. Picard, G. Godin, Detailed 3D reconstruction of large scale heritage sites with integrated techniques, Ieee Computer Graphics and Applications, 24 (2004) 21-29.

[32] Y.-S. Kim, T. Kesavadas, S.M. Paley, The Virtual Site Museum: A multi-purpose, authoritative, and functional virtual heritage resource, Presence-Teleoperators and Virtual Environments, 15 (2006) 245-261.

[33] S.J. Calver, S.J. Page, Enlightened hedonism: Exploring the relationship of service value, visitor knowledge and interest, to visitor enjoyment at heritage attractions, Tourism Management, 39 (2013) 23-36.

[34] G. Zhang, X. Chen, R. Law, M. Zhang, Sustainability of Heritage Tourism: A Structural Perspective from Cultural Identity and Consumption Intention, Sustainability, 12 (2020).

[35] A. Scuttari, F. Orsi, R. Bassani, Assessing the tourism-traffic paradox in mountain destinations. A stated preference survey on the Dolomites' passes (Italy), J. Sustain. Tour., 27 (2019) 241-257.

[36] J. Li, S. Krishnamurthy, A.P. Roders, P. van Wesemael, Informing or consulting? Exploring community participation within urban heritage management in China, Habitat International, 105 (2020).

Figures

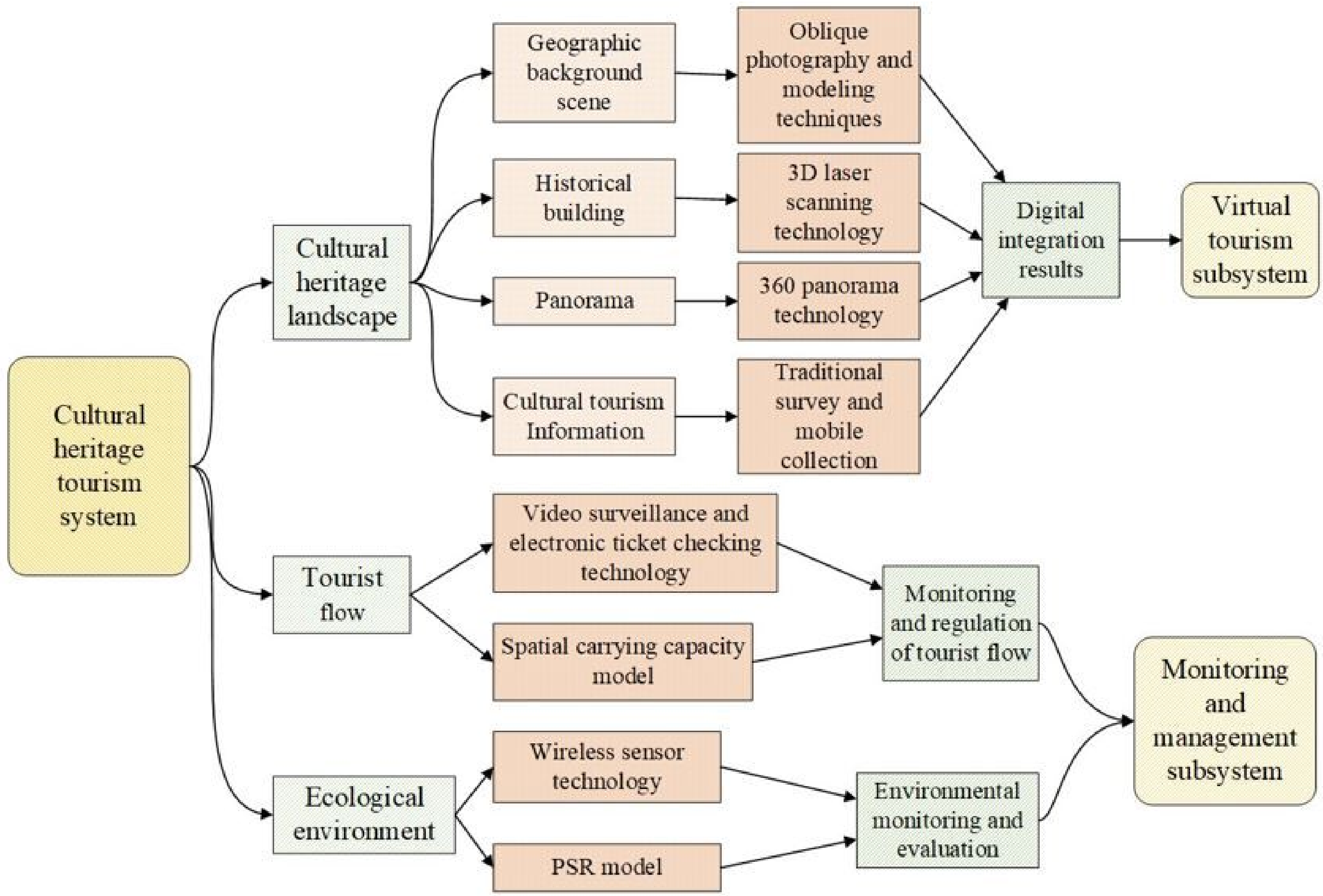

Figure 1

The technical flow chart of this research

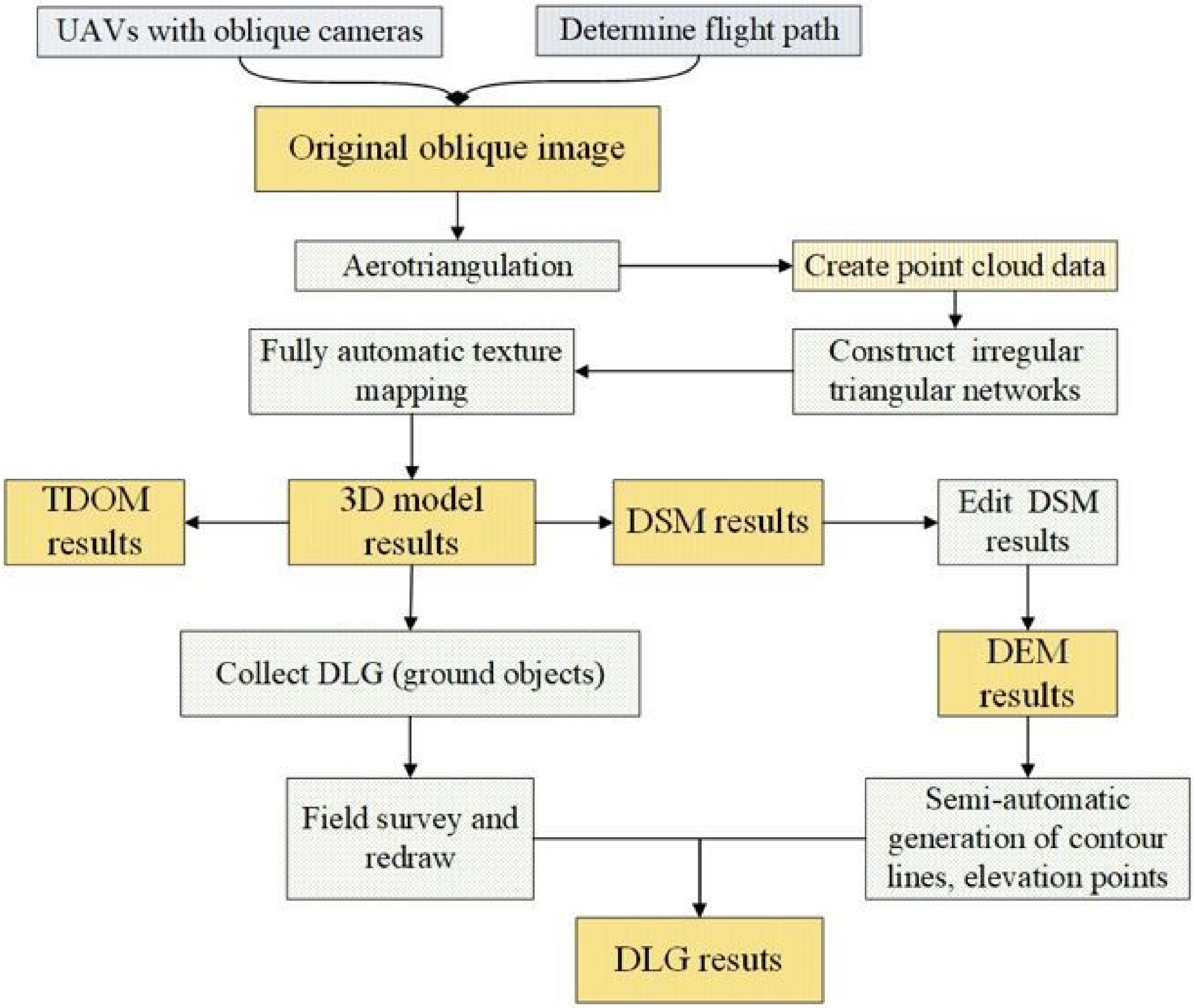

Figure 2

Flow chart of the integrated generation of 3D models and 3-D products

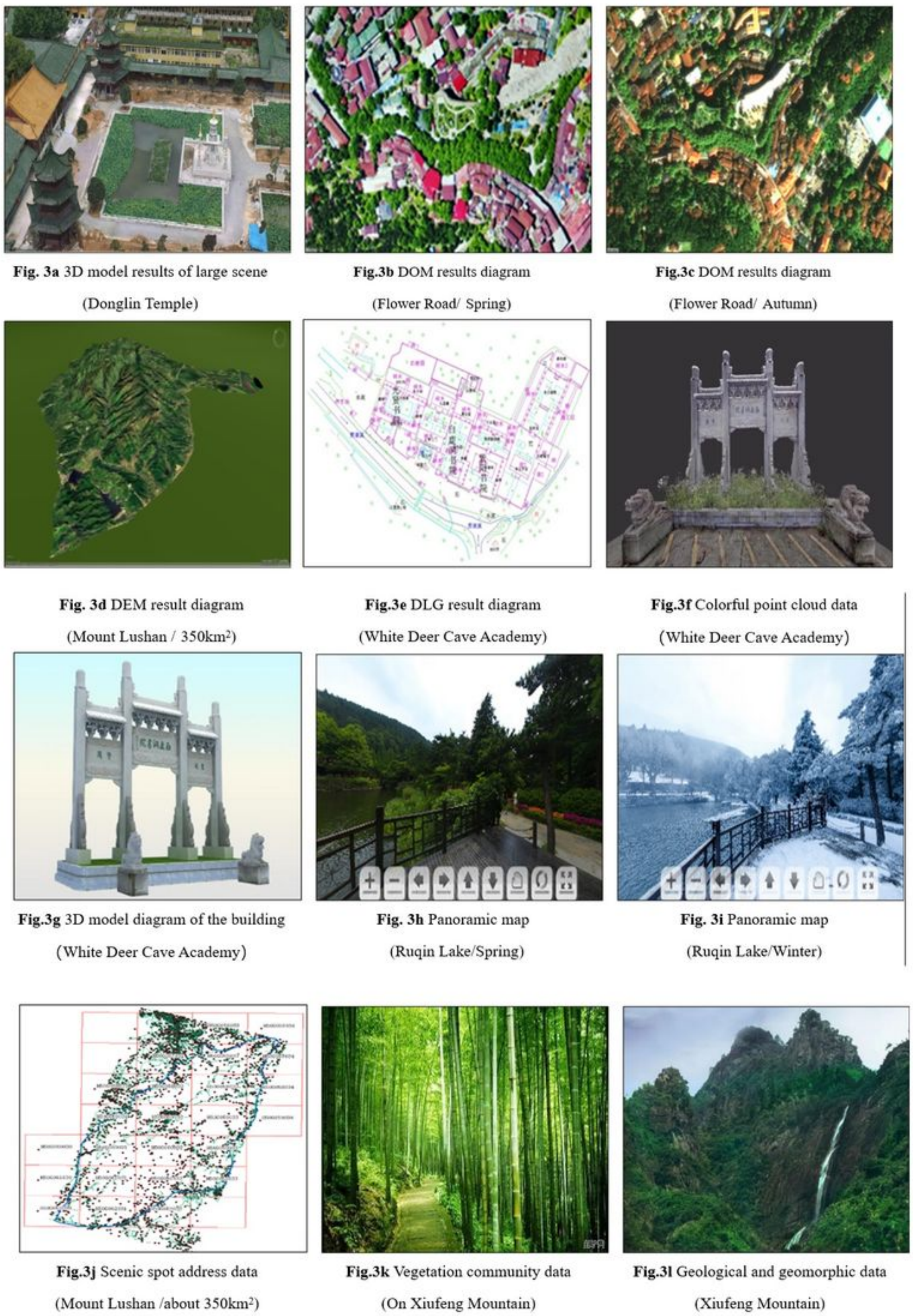

Figure 3

Digital results

Fig. 4a 3D scene of the natural landscape (The north of Mount Lushan)

Fig. 4b 3D scene of the Donglin Temple (Aerial view)

Fig. 4c 3D scene of the Donglin Temple (A close view of the front door)

Figure 4

3D virtual visualization diagram

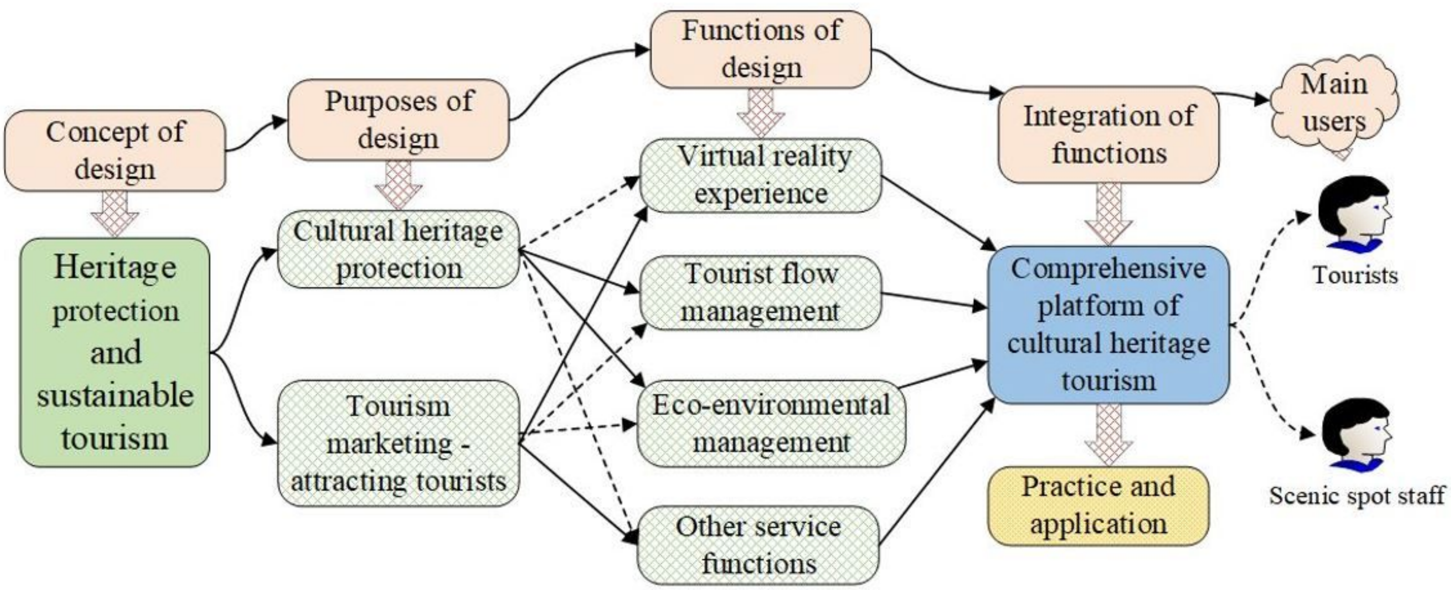

Figure 5

Architecture of the cultural heritage tourism comprehensive platform