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Design and Research of Campus Culture Application Based on Sensor Data and Metaverse Technology

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With the development of science and technology, virtual reality (VR) and interactive technology are playing an increasingly important role in the promotion of campus culture. In this study, we created an app to introduce campus culture using VR and metaverse technology by 3D modeling based on the data obtained by an unattended aerial vehicle and various sensors loaded on it. The contents of the app were selected through user demand analysis using the fuzzy Kano model, the entropy weighting method, and the technique for ordered preference by similarity to ideal solution method (TOPSIS). According to the indicators defined in the analysis, necessary data and information, including geospatial data, tilt photography, real scene data, point cloud data, and 3D virtual scenes, were collected with various sensor technologies such as Da Jiang innovations (DJI) first person view (FPV) sensors, DJI X5S single lens, and global navigation satellite system real-time kinematic (GNSS-RTK) on the DJI Inspire 2 model unmanned aerial vehicle (UAV). The data and information were used to create a 3D point cloud model for a VR environment and develop the campus culture app based on the model. The app has interactive functions that provide information on campus culture in the metaverse. The app can be used to publicize campus culture and provide appropriate information, and also allows interaction with and between users and with various social media platforms. A relevant user interface and metaverse were created to enable users to browse, communicate, and exchange information interactively. In the future, more innovative features such as game scenarios and auxiliary psychological elements can be added through 5G and the Internet of Things technologies.

1. Introduction

With the sudden coronavirus pandemic that began in 2020, closed-loop management measures were adopted on most campuses in China. The pandemic hindered students from

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returning to campus for normal activities. In this situation, a need arose to maintain the university culture, which has attracted much research interest. One of the proposed means is to utilize the metaverse. The term metaverse appeared for the first time in the science fiction novel *Snow Crash* by Neil Stephenson, published in 1992. This novel describes humans living as digital avatars in a virtual 3D space, the metaverse, where everything in the real world is replicated digitally. The metaverse is shown as the existence of the virtual world in the real world, both of which interact with each other.

An app can be developed to reproduce campus culture digitally and transfer the campus culture into the metaverse. This metaverse-based campus culture app is developed on the basis of real-time dynamic electronic data maps, which are created with data obtained with sensors on an unmanned aerial vehicle (UAV) and by 3D cloud modeling. Using mobile phones as the platform for users, the metaverse technology overcomes space restrictions and creates a virtual campus environment for virtual roaming, human-computer interaction, and campus culture promotion. Besides providing university members with information and campus culture, it may be used to advertise universities to raise recognition. The metaverse campus culture app enables users to experience campus culture with a single- or multi-sensory approach. It also provides realistic activities on the campus via an interactive and immersive environment. Therefore, the development of a campus culture app in the metaverse is of practical significance for establishing a digital campus platform.(1)

To develop the app, "campus culture" and how to publicize it need to be understood to enable decision about how to develop the app and what it should contain, which is also related to which information needs to be included and delivered and how such information is collected.(2) Campus culture can be understood from various perspectives, including a country's culture, innovative cultural activities, and cultural expressions.(3) Currently, the three main research directions exist to understand and communicate campus culture: studies of multicultural background, exploring the use of the internet platform including web pages and various mobile apps, and the use of metaverse technology. Although many colleges and universities have been advertising themselves on websites and apps owing to the development of the economy and technology, introducing campus culture may be limited to showing pictures, which does not satisfy visitors, raise awareness, or sufficiently promote campus spirit. Therefore, several universities have developed smart campus apps in which digitized and interactive information is delivered with limited functions of virtual reality (VR) and augmented reality (AR).(4,5) Considering this background, the metaverse appears as a new and effective means with advantages in promoting campus culture and information based on its immersive nature, multi-sensibilities, and interactivity.

It is most important to include information in the metaverse app that users want to obtain in terms of campus culture. Therefore, developing the app requires understanding users' demands and collecting relevant data. In this study, we carried out user demand analysis with the fuzzy Kano model, the entropy weighting method, and the technique for ordered preference by similarity to ideal solution method (TOPSIS) based on expert interviews and a survey questionnaire to assess user's needs. Indicators to show the related information on the app were defined to create a framework for the app. On the basis of the indicators, sensor data were collected for the app to develop the appropriate user interface and functions. The study of this app provides the basis for further development of other metaverse apps. In addition, several suggestions for the further development and utilization of this app are given.

2. Methodology

2.1 User demand analysis

For user demand analysis, we collected and summarized users' needs with interviews and a survey questionnaire. The questionnaire was created to define indicators for the development of the app. An objective weighting method was used to calculate the information entropy and obtain a weighted matrix of the indicators. The matrix was analyzed with the TOPSIS method to choose indicators for designing the app and to decide the data and information that must be obtained.

2.1.1 Definition of target user

The users of the app are mainly members of universities, including administration, faculty, and students. Each group has different needs for the app. Administration mainly finds a way to increase public awareness, promote and disseminate the campus culture, raise the school's popularity and reputation, and promote the campus environment. Faculty members are more interested in scientific research and teaching and may lack an understanding of school history, culture, and landscape. They lack a sense of belonging and hope to develop a systematic understanding of rich campus culture, thereby enhancing their sense of belonging. Freshmen are not familiar with the campus environment and need to find different buildings for their courses. They lack campus life experience and adequate learning methods, so they expect to learn, explore, and experience the campus culture. Compared with new students, senior students expect to have more after-class self-study, activities, spaces for convenient learning, and an environment for leisure. They tend to look for efficient campus life and convenient services by obtaining information not only on the campus culture but also on postgraduate opportunities.

We used an online questionnaire and offline in-depth interviews with target users at the Hubei University of Technology (HUT), which was selected as the research site. A total of 227 questionnaires were distributed, 226 of which were valid. The respondents were 48% males; 95% of the respondents were university students, among whom 57% were freshmen, 13% were sophomores, 25% were juniors, 4% were seniors, and 1% were graduate students. Foreign students accounted for 4% of the respondents. A majority (71%) of the respondents did not know about campus culture, which reflected the lack of promotion of the campus culture. Regarding campus apps, 41% of respondents used them once or twice a month, while 38% never used them, which indicates the low rate of use and interest in existing campus apps and the lack of novelty in the apps.

2.2 Data analysis

The survey result was analyzed with the fuzzy KANO model (FKM), entropy weighting method, and TOPSIS.

2.2.1 FKM

The FKM represents the nonlinear relationship between user satisfaction and elements of product quality.(6) The user's demand index was selected as the design element of the app. The design element is classified to obtain functional guidance to improve user satisfaction and guide the innovative design. The FKM classifies product quality elements into five categories(7) as follows and as illustrated in Fig. 1.

1) Basic design requirements (M): the landscape of interactive elements must be incorporated into the design. A basic design needs to consider the satisfaction of users.
2) Desired design requirements (O): a linear relationship exists between user satisfaction and interaction. Thus, a new product needs to be interactive to enhance user satisfaction.
3) Exciting design (A): a game mechanism may be introduced to meet users' demands.
4) Irrelevant design requirements (I): the presence or absence of interaction with users affects their satisfaction.
5) Reverse design requirements (R): mechanisms and methods that must be avoided in the design process need to be considered.(8)

The traditional Kano model is based on established subordinate relationships, while respondents usually show uncertain attitudes when confronted with the ambiguity of design elements.(9) Using the FKM, design indicators can be reflected in a design of a new product. In the model, for a design element, a score of >0.5 means a necessity to adapt it, 0.4−0.5 means satisfaction with it, and 0.1−0.4 means acceptance of it. According to the results of the FKM, the satisfaction coefficient of a design element is calculated as

$$\text{Customer satisfaction: } CS_i = \frac{f_A + f_O}{f_A + f_O + f_M + f_I}, \tag{1}$$

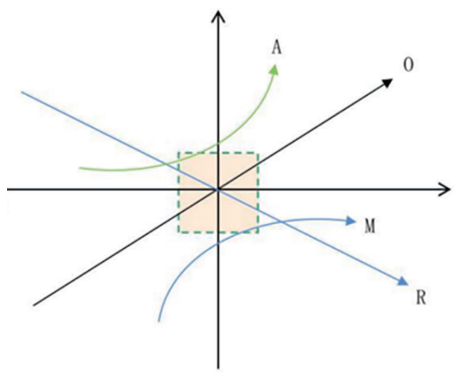


Fig. 1. (Color online) Kano model.

$$\text{Design satisfaction: } DS_i = \frac{f_O + f_M}{f_A + f_O + f_M + f_I}, \tag{2}$$

where A is for exciting design, O is for desired design requirements, M is for basic design requirements, I is for irrelevant design requirements, and i = 1, 2, ..., n.

2.2.2 Entropy weighting method

The entropy weight method (EWM) is an objective weighting method.(10) Unlike the expert scoring method, such as the analytic hierarchy process (AHP), which has strong subjectivity.(11) EWM objectively obtains the result of weighting by calculating the weight using the information entropy of the data. The calculation process is as follows.

1) Creating a decision matrix. Assuming m elements and n experts' decision scores, the evaluation decision matrix is as follows.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}_{m\times n} \tag{3}$$

2) Calculating a normalized matrix with the ratio of column vectors and the sum of all elements.

$$x_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, j = 1, 2, \cdots, n, \tag{4}$$

$$Q = \left(q_{ij}\right)_{m\times n}, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n, \tag{5}$$

where $q_{ij} = x_{ij} \Big/ \sum_{i=1}^{m} x_{ij}^2$.

3) Calculating the information entropy. The information entropy of index J is obtained using Eq. (6) based on the normalized matrix.

$$H_j = -K\sum_{i=1}^{n} p_{ij} \cdot \ln\left(p_{ij}\right), j = 1, 2, \cdots, n, \tag{6}$$

where K is the adjustment factor, K = 1/lnn.

2.2.3 Demand indicators based on TOPSIS

TOPSIS is a decision-making method widely used in industries for multiple attribute problems.(12) First, a weighted decision matrix $\boldsymbol{B}$ is constructed according to the index weight,

$\boldsymbol{B} = (b_{ij})_{mxn}$, where b_{ij} is calculated as

$$b_{ij} = \omega_j \cdot q_{ij}. \tag{7}$$

Then, a positive ideal solution U^+ and a negative ideal solution U^- are calculated according to the weighted decision matrix $\boldsymbol{B}$.

$$U^+ = \left\{ \max_{1 \le i \le m} \left\{ b_{ij} \right\} \middle| j = 1, 2, \cdots, n \right\} = \left\{ U_1^+, U_2^+, \cdots U_n^+ \right\} \tag{8}$$

$$U^- = \left\{ \min_{1 \le i \le m} \left\{ b_{ij} \right\} \middle| j = 1, 2, \cdots, n \right\} = \left\{ U_1^-, U_2^-, \cdots U_n^- \right\} \tag{9}$$

The weighted Euclidean distance is determined between design indicators and ideal solutions based on U^+ and U^-.

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(b_{ij} - U_j^+ \right)^2}, i = 1, 2, \cdots, m \tag{10}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(b_{ij} - U_j^- \right)^2}, i = 1, 2, \cdots, m \tag{11}$$

Finally, the relative proximity value of each indicator is calculated and ranked.

$$\upsilon_i = \frac{D_i^-}{D_i^- + D_i^+}, 0 \le \upsilon_i \le 1, i = 1, 2, \cdots, m \tag{12}$$

The larger the value of υ_i, the more important the evaluation index. According to the ranking of indicators, decision-making can be carried out for product design.

3. Results and Discussion

3.1 Survey results

The survey results showed that the target group generally trusted the existing campus app and quickly accepted and learned new products. At the same time, users suggested practical requirements, such as introducing the campus environment and culture and convenient facilities for campus life. According to the survey, the primary demands of the target group concerning a campus app are summarized as follows: interesting user interface, information on the campus culture, various activities, epidemic prevention and control, convenient way to search for buildings, and campus culture-related notifications. Such information needed to be added to the app using the basic elements of the app design with the following user demands:

1) It is necessary to design and develop a convenient and efficient app to show and promote campus culture. The app needs to attract users to join the app, increase their interest in campus culture, help users understand campus culture, make campus life more relaxed and happier, and promote and disseminate campus culture.
2) Target users include faculty members, enrolled students, and prospective students and their parents.
3) Compared with apps for entertainment, showing campus culture is not particularly attractive. During the epidemic, students spent more time indoors, resulting in a loss of interest in traditional offline publicity. Web pages of universities significantly lack an immersive experience, which leads to the publicity of formal campus culture.
4) The app needs to act as a platform for cultural learning and entertainment based on VR technology. At the same time, it must be a platform for universities to provide campus exhibitions and online guidance to enrich and promote campus culture.
5) The app needs to be available on portable devices as a mobile app.

3.2 Design for campus culture app

In this study, we took HUT as a research object for developing a campus culture app. HUT's motto is "Campus spirit", which is a collection of ideals, beliefs, ideas, and plans for development and long-term operation. Thus, we regarded "Campus spirit" as the concentrated embodiment of campus culture. The most representative cultural landscape on the university campus includes the river and the industrial culture corridor. The Xunsi River runs alongside the campus. Along the river, there are three views, one pavilion, and one platform, which represent the university's spirit of cultivation. "Three views" refer to "cultivation", "meeting teachers", and "release"; "one pavilion" refers to the only pavilion on the campus, and "Jingxiu Pavilion" and the "one platform" refer to the hydrophilic platform, which refers to a platform above the water surface on the east side of the river. The river is the university's most iconic cultural landscape and is an important place for faculty and students to visit, rest, and communicate. The industrial culture corridor is located on the third north-south main campus road and the east-west main axis of the university as the main road to the library. The corridor is described as "one belt and five views." "One belt" refers to the north-south corridor, and "five views" refers to five viewpoints.

For the FKM model, it is necessary to summarize the elements (indicators) of user needs for VR interactive function. Therefore, a survey was conducted to address users' needs. The model defined three categories (interaction, landscape, and others) to which five to seven indicators belonged (Table 1). Each indicator was assigned to a code from I_1 to I_5, L_1 to L_5, and O_1 to O_6.

Each indicator was tested with the FKM for basic design requirements. The results are presented in Table 2. Among the indicators, I_2 (rotatable display), I_3 (first impression), I_4 (voice interaction), L_5 (vegetation), O_2 (role customization), O_3 (gamification), O_4 (muti-route guidance), and O_5 (applicability to a wearable device) were found to be important for the design of the app. These indicators' CS and DS scores were calculated, and the results are shown in Table 3.

Table 1
Categories and indicators defined by the FKM in this study.

Category	Code	Indicator
Interaction (I)	I_1	Touchable function
	I_2	Rotatable display
	I_3	First impression
	I_4	Voice interaction
	I_5	Route guidance
Landscape (L)	L_1	River
	L_2	Chinese architecture
	L_3	Multi-storied building
	L_4	Sculpture
	L_5	Vegetation
Others (O)	O_1	Head-mounted equipment
	O_2	Role customization
	O_3	Gamification
	O_4	Multi-route guidance
	O_5	Applicability to wearable device
	O_6	Campus culture

Table 2
Statistical table of the FKM classification results of design elements.

Code	Factors	M	O	A	I	R	Q	Type
I_1	Touchable function	18	13	59	14	0	2	A
I_2	Rotatable display	16	23	48	17	0	2	A
I_3	First impression	4	9	14	77	0	2	I
I_4	Voice interaction	10	59	23	12	0	2	O
I_5	Route guidance	64	21	17	2	0	2	M
L_1	River	58	23	14	9	0	2	M
L_2	Chinese architecture	10	19	18	57	0	2	I
L_3	Multi-storied building	69	15	11	9	0	2	M
L_4	Sculpture	19	17	27	41	0	2	I
L_5	Vegetation	26	50	15	13	0	2	O
O_1	Head-mounted equipment	19	24	50	11	0	2	A
O_2	Role customization	28	43	22	11	0	2	O
O_3	Gamification	17	21	41	25	0	2	A
O_4	Multi-route guidance	8	28	50	18	0	2	A
O_5	Applicability to wearable device	23	26	25	30	0	2	I

Table 3
Positive and negative satisfaction results of design elements.

Code	CS_i	DS_i
I_1	0.686	0.305
I_2	0.676	0.381
I_4	0.781	0.667
L_5	0.619	0.733
O_2	0.705	0.419
O_3	0.619	0.686
O_4	0.590	0.371
O_5	0.743	0.352

3.3 Determination of weight value of indicators

An expert evaluation was conducted on the selected indicators. For the evaluation, five experienced teachers in the VR design of the app were invited to score the importance of the indicators on a Likert scale (from 0 to 7). The results are shown in Table 4. According to Eqs. (6) and (7), the information entropy H_j and entropy weight ω_i of each indicator were obtained (Table 5). The weight decision matrix of standardized game design elements was obtained from Eq. (5), and the results are shown in Table 6. Using Eqs. (8) and (9), the positive ideal solution U^+ = [0.1043, 0.0923] and the negative ideal solution U^- = [0.0639, 0.0317]. According to the normalized importance decision matrix and positive and negative ideal solutions, the Euclidean and relative distances of the positive and negative ideal solutions for satisfaction with each design element were obtained using Eqs. (10) and (11). The results show that the importance of user demand is ranked as $O_4 > I_4 > O_3 > I_2 > O_2 > L_5 > I_1$. Among them, the demands for O_4, I_4, and O_3 are the most important. Therefore, the design methods for "multi-route guidance", "voice interaction", and "gamification" need to be added to the VR display of the campus culture app.

4. Development of Campus Culture App

4.1 Development plan

To include the information on the selected indicators for the campus culture app, UAV-mounted sensors were used to obtain data necessary for 3D point cloud modeling to create real-time information maps based on campus field surveys. The purpose of developing the app is to

Table 4
Scores for the indicators selected by experts.

Code	A	B	C	D	E
I_1	7	6	5	7	7
I_2	5	6	7	5	5
I_4	4	5	4	3	5
L_5	7	4	7	6	7
O_2	6	6	4	4	3
O_3	5	6	4	4	5
O_4	4	3	3	3	6

Table 5
Entropy H_j and weight ω_i values.

Code	Type	H_j	ω_i
I_1	A	0.4344	0.1041
I_2	A	0.3061	0.1278
I_4	O	0.3821	0.1138
L_5	O	0.4389	0.1033
O_2	A	0.4303	0.1049
O_3	O	0.2690	0.1346
O_4	A	0.0394	0.1769
I_1	A	0.2690	0.1346

Table 6
Euclidean distance of positive and negative ideal solutions.

Code	D_i^+	D_i^-	υ_i	Type	Rank
I_1	0.0689	0.0404	0.3693	A	8
I_2	0.0472	0.0590	0.5556	A	5
I_4	0.0226	0.0623	0.7337	O	2
L_5	0.0437	0.0322	0.4243	O	7
O_2	0.0571	0.0434	0.4315	A	6
O_3	0.0210	0.0551	0.7236	O	3
O_4	0.0267	0.0831	0.7567	A	1
O_3	0.0452	0.0772	0.6309	A	4

transform text- and picture-based information into multi-dimensional information for live communication. The app is intended to provide an immersive tour of the university campus and guide users to various places on campus. By showing positive images of the university, the campus culture and the unique cultural environment can be publicized.

The planning process for the campus culture app is as follows. First, the design of the virtual tour of the campus was established with the concept of “top-level design from point to point.” Second, the specific framework and detailed research ideas were developed. Then, a survey was performed to collect detailed information on the campus using UAVs. We collected 3D point cloud data to lay a foundation for building a relevant, virtual 3D simulation. Moreover, we analyzed scenarios for the metaverse for the campus culture app. Finally, we proposed a model for the app based on the collected data and the established model. Using Unity3D software, we designed and implemented the simulation of the campus for mobile devices in the installation packages for Android and IOS mobile applications (Fig. 2).

4.2 Framework of app

For HUT, four key functional frameworks of the app were defined: virtual campus roaming, campus culture introduction, campus epidemic prevention information, and campus information inquiry. The app incorporated sensor data for visual, audio, tactile, and other senses to produce a strong sense of reality. The metaverse technology was used as a visual interface between the real and virtual worlds, combined with digital twinning and identification technology to construct a VR environment. The system was developed to enable multidimensional perception and accurate decision-making and allow users to interact with the system. It was an intelligent system to experience campus culture and support the campus life of faculty and students. The architectural landscape with unique cultural characteristics was chosen as the blueprint for the virtual campus culture app. The metaverse technology was used for the design and development of the app. The app was expected to promote campus culture effectively to gain popularity and reputation. Information on epidemic prevention was digitized on the basis of the collected information. The campus virtual tour system was developed to build a better campus environment, enrich campus culture, improve campus cultural literacy, and construct better campus culture (Fig. 3).

4.3 Information collection

As a new transportation means, the UAV can be used for convenient and practical observation to meet the needs of different tasks in various industries with diverse sensors on it. UAVs are

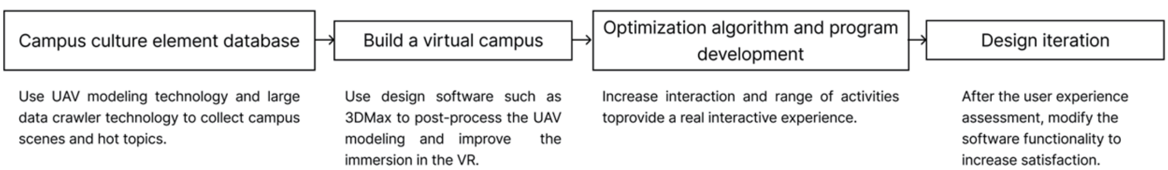


Fig. 2. Overall planning process for campus culture app development.

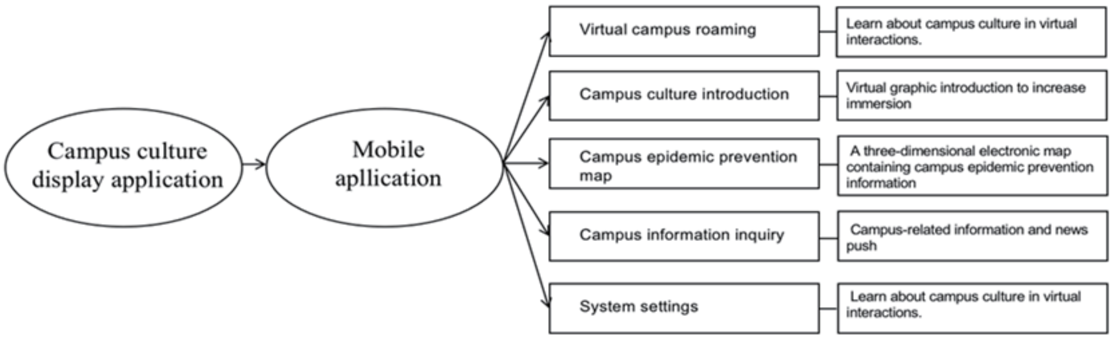


Fig. 3. Overall framework of the app.

Table 7
Sensors used for UAV surveys and their applications.

Sensor	Information	Processing Software	Digital products	Applications
Single-lens sensor	Single-angle image, video	Pix4D mapper, Smart 3D	DEM, DSM, DOM, DLG	Topographic mapping; land use status analysis; plant identification; depression, canopy, and tree height measurement; earth balance;3D green volume calculation; biodiversity evaluation; ecological evaluation
Multi-lens sensor	Multi-angle images, videos	Pix4D mapper, Smart 3D	Three-dimensional realistic model, DEM, DSM, DOM, DLG	All applications of single lens sensor, 3D model building and simulation analysis, digital model simulation hydrology analysis, private garden mapping, and heritage conservation
Small airborne LiDAR	Dense point cloud	TerraSolid, ENVI, LiDAR	DEM, DSM, three-dimensional model	All applications of single lens sensors, 3D model building and simulation analysis, digital model simulation hydrological analysis, garden mapping, and heritage conservation
Hyperspectral AI sensors	Full-band spectral information	ENVI, LiDAR	Hyperspectral imaging	Pests and diseases, plant nitrogen content, and leaf trait index
Multispectral Al sensors	Multi-band spectral information	ENVI, LiDAR	Multispectral imaging	Plant invasion, pests, diseases, and vegetation biomass

(DEM: digital elevation model, DSM: digital surface model, DOM: digital orthophoto map, DLG: digital line drawing)

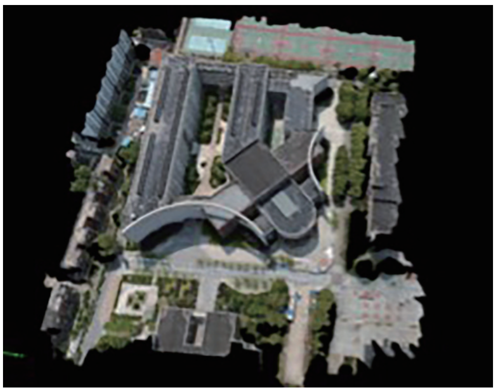
equipped with digital cameras, airborne LiDAR, multispectral imagers, thermal imagers, and other sensors[13] to carry out surveys, take photos, and construct digital elevation models (Table 7).[14]

We used the Da Jiang innovations (DJI) Inspire 2, which is an aerial vehicle with high-precision mapping capabilities. It was equipped with DJI first person view (FPV) sensors. A forward-and-down-looking binocular vision system was loaded to detect obstacles within 30 m. The system has reliable sensor redundancy, visual obstacle avoidance for accurate mapping operations, and good maneuverability with a maximum speed of 54 km/h. An infrared sensor was also loaded on the UAV to sense objects within 5 m and avoid collision with obstacles above it when ascending. The DJI Inspire 2 was equipped with a DJI X5S single lens. The lens acquires real images with spatial information from vertical and tilted multiple directions and angles to obtain ground information with a sensor size of 4/3 inch complementary metal-oxide-semiconductor (COMS), effective pixels of 24 million, and 3D data to reflect the original appearance of the campus.

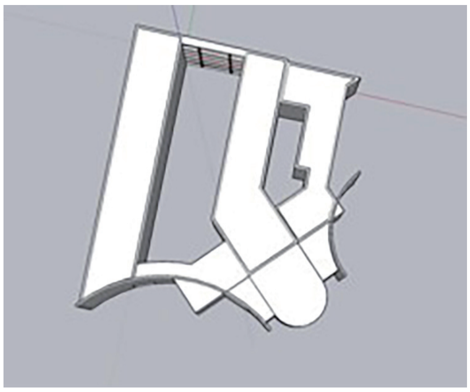
For the accurate position of collected images, the global navigation satellite system with real-time kinematics (GNSS-RTK) was used to acquire the image control points with the control point and image acquisition process for minimizing errors. A total of nine image control points were set up on the campus, and the distance between the image control points was no more than twice the relative flight height of the UAV. The actual flight height of the UAV for collecting information was 60 m, and the average distance between the control points was 100 m. The planning of UAV routes was set up with Pix4D capture software. The geometric feature data of the campus obtained by tilt photography with UAV sensors were used to create digital 3D models and render pertinent textures, and coordinate matching with the metaverse software and virtual effects were added. Point cloud 3D modeling for the VR environment was used to improve the user experience and various services.

The information collected for the app included the following, and Fig. 4 shows the model developed.

1) Geospatial data: Data on campus buildings, building layers, roads, waterfront pavilions, corridors, streams, and spatial attributes were included in the app. The same type of building or area was vectorized layer by layer according to the buildings' specifications and contours.
2) Tilt photography: The campus scene was photographed from multiple angles using a single-lens sensor and a UAV. Images and information on the location of ground objects were



(a)



(b)

Fig. 4. (Color online) Reverse modeling of 3D point cloud.

obtained in different orientations. The images captured by the UAV sensors were used to create visual 3D models from point cloud data to visually represent the current state of a site.

3) Real scene data: According to the type of building and the specific attributes of the space on the campus, real scene data required for 3D modeling was collected. The data contained types, styles, colors, wall colors, wall tile texture, decals, and other features. In addition, the spatial attributes and landscape layout of the pavement type, landscape style, water bodies, railings, streetlights, and billboards were collected.
4) Point cloud data processing: The 3D reconstruction of the image was required after the completion of aerial triangulation. Point cloud mesh data consisted of mesh model pre-processing, mesh model editing, and mesh model post-processing. We carried out the pre- and post-processing of the point cloud data using Smart3D capture software and model editing using Sketchup software. The main processes of point cloud data processing included model stretching, building structural unit refinement, attribute assignment (color, texture, size, etc.), model modification, and refinement. Obtaining detailed point cloud data based on the UAV production area compensated for the lack of analysis of complex areas and building spaces.
5) 3D virtual scene creation: Using a controlled single-lens sensor for tilt photography scanning, detailed images were obtained for optimization. A unified 3D model was used to create new scenes with basic geospatial data and libraries of font, symbol, style, and texture for the unified 3D base platform. The campus ground and vegetation models were then created on the basis of the geospatial data. Finally, the fine 3D model of the building was imported into the app with parameters including offset, scaling ratio, rotation angle, and others. The model parameters were adjusted according to actual photos of the scene and the environment. Streetlights, flower beds, cruise ships, signs, and road signs were used to decorate and beautify the scene and layout of the app. A detailed 3D model was established to provide users with an immersive user experience.

In the app, the following elements were included on the basis of the data:

1) Interaction (Fig. 5): The background of the app's first page shows a promotional video of the campus. The interface was designed to meet various browsing needs by showing relevant function keys. The main functions are found in the "virtual campus roaming" part of the app.

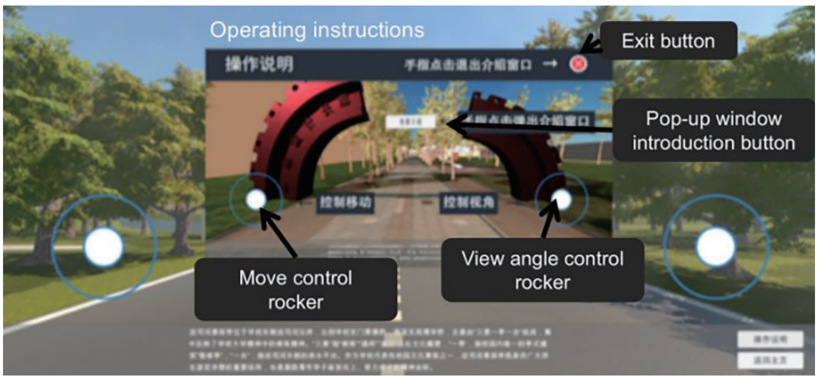


Fig. 5. (Color online) Operating instructions.

With the roaming feature, users can observe a scene as if they were walking on campus in real time and having a realistic and robust sensory experience. After displaying the detailed information for each scene, the “operation description” and “return to home page” commands appear on the right side of the screen. The interface is clear and eye-catching, with a click-jump trigger mechanism in line with the normal operation habits of users. The metaverse virtual campus allows users to browse scenes conveniently. Users can return to a previous scene or switch to a new one at any time. As they browse and interact with the campus culture app, they better understand campus culture as they link each scene to a cultural element.

2) Social media platform (Fig. 6): The metaverse transforms simple online communication into online interaction. On the basis of the information exchanged and the knowledge-based framework, new campus scenes are created. Users can interact in the metaverse to exchange and expand their knowledge and information to create new communities on campus. A key component of the app with meta-universal online social networking is a collaborative control technology. To realize online social networking, one-to-many and one-to-one control methods based on client/server and client/client are provided as follows: the MS Word Standard toolbar to select correct columns from the selection palette, listening mode using application programming interface (API) listen for users requests, connection to the server using API connect, and exchanging data through APIs.

The operating system automatically completes the data confirmation and retransmits the data to ensure their accuracy. Whenever a user closes the connection using API close, the system closes the connection.

4.4 User interface

The VR system of the app was based on 3D point cloud modeling that comprised the main interface and several interfaces. The user interface (UI) framework in Unity3d software was used for the interface. The important information is presented in the best location, the secondary information is shown at the bottom so the primary and secondary information levels may be

Fig. 6. (Color online) Metaverse campus culture app.

effectively differentiated. After clicking on the main interface, the campus walking mode initiates, and the secondary level selection button floats along the road. After pressing the button, the interface opens the corresponding text description interface and displays a VR animation to display campus information. When the level 2 interface is opened, two buttons are available in the lower right corner of the interface to return to the level 1 interface or to link to the whole browsing process.

The buttons have an irregular blue border, and the built-in text has a white font. The font size is set according to the primary and secondary levels with a sharp contrast. The color of icons reflects the cultural characteristics of the campus for the more effective transmission of cultural information. Considering the spirit of campus culture and the color preference of the main user groups, four chromatograms (cyan, sky blue, cold gray, and warm gray) were used with low saturation (Fig. 7).

4.5 Metaverse

The metaverse replicates the actual campus and provides users with a more intuitive experience of campus culture on a mobile platform.(15) Depending on the mobile device, users can choose different forms of experiences, such as virtual campus roaming, campus culture introduction, campus epidemic prevention map, VR campus, AR campus, and others. The relevant building information and cultural landscape of the university can be offered. The new high-quality campus culture can be experienced with the ideological consensus, endogenous motivation,(16) and promotion(17) of the tradition and spirit of the university. The metaverse provides immersive virtual campus navigation. The observation angle during roaming can be controlled freely so virtual roaming around multiple locations is possible by clicking several buttons. Information on landmark buildings can be given by virtual characters at each location with text explanations or animations with background music. Users can share interesting or meaningful things about the campus and mark and store them in special places to increase their interactive experience and sense of belonging and responsibility to the campus culture (Fig. 8).

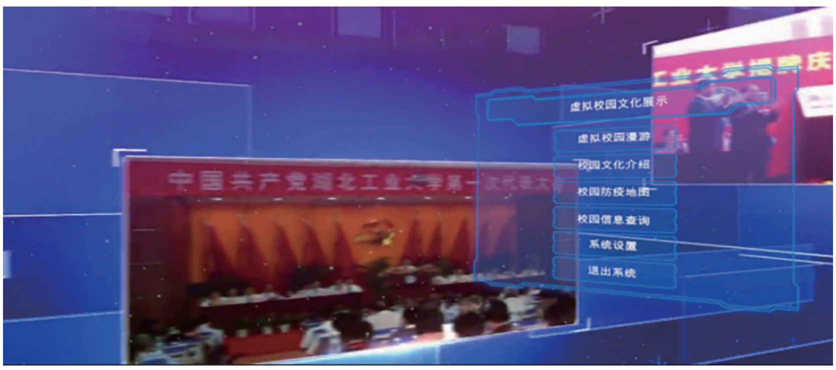


Fig. 7. (Color online) Home page of campus culture app.

Fig. 8. (Color online) Overall map of the virtual campus.

5. Conclusion

Today, metaverse technology is gaining momentum with the rapid development of internet technology.[18] We researched and developed a campus culture app based on the metaverse to display and promote campus culture. The app provides an interactive means for recruitment by, promotion of, and informatization about colleges and universities. It also helps campus culture be reconstructed in the new era more realistically and effectively. A new 3D model of campus culture in the metaverse promotes the spread of campus culture and enhances its vitality.[19] The model and app are a new way to provide appropriate information, develop campus culture, and support decision-making processes in the era of 5G network technology. The new model of the metaverse plus campus culture provides users with new ways to experience campus culture.[20]

The app was developed on the basis of the indicators defined through user demand analysis using the FKM, EW method, and TOPSIS, and with data and information from sensors and UAV technology. Out of 20 defined indicators through interviews with experts and a survey questionnaire, the following indicators were found to be important in developing the campus culture app: a rotatable display, user's first impression of the app, voice interaction, inclusion of vegetation, role customization, gamification, muti-route guidance, and applicability to a wearable device. To reflect the demand for these indicators, relevant information and data were collected with various sensor technologies such as DJI FPV sensors, DJI X5S single lens, and GNSS-RTK on the DJI Inspire 2 model UAV. The data and information were used to create a 3D point cloud model for a VR environment and develop the campus culture app based on the model that included geospatial data, tilt photography, real scene data, point cloud data, 3D virtual scene, and other sources. The app allows interaction with users and is applicable to various social media platforms. We created a user interface and metaverse, which enable users to browse, communicate, and exchange information interactively.

In the future, more innovative applications of campus culture apps can be developed by adding 2D game scenarios and integrating auxiliary psychological elements such as music and intelligent features based on 5G and the Internet of Things technologies.

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