Design and Implementation of Intelligent Service Bracelet Supported by BDS and GIS

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Abstract: With the promotion of economic and social development, people have a greater demand for spiritual life, among which urban large amusement parks are an important place for people to enjoy life. Due to high pedestrian density and strong signal interference, traditional path planning models are not applicable in the environment of large urban amusement parks. The design and implementation of intelligent service bracelets supported by the Beidou satellite navigation system and geographic information system is an important step in improving personal quality of life. This innovative technology integrates GPS, sensors, and communication modules to provide real-time location tracking, health monitoring, and emergency response services. The intelligent service bracelet design is user-friendly, lightweight, and durable. It can be worn on the wrist, or hung on clothes or bags. This device collects data on users' heart rate, blood pressure, body temperature, and other vital signs. Information is transmitted to a cloud based platform for analysis and storage. In emergency situations such as falls or sudden illnesses, the device sends an alert message with user location information to the designated contact person. This bracelet also provides navigation assistance for users with impaired vision or difficulty finding their way in unfamiliar areas. Overall, this intelligent service bracelet has great potential in improving medical services and strengthening personal safety measures. Its design and implementation demonstrate how to utilize technology to create innovative solutions to real-world problems.

1 INTRODUCTION

With the development of the social economy, people have shifted from solving the problem of food and clothing to emphasizing the enjoyment of life. The most important entertainment point is the urban large-scale amusement park, represented by Disney, Happy Valley, Fonterra and other large-scale amusement park brands, which have been built and put into use one after another. However, so far, problems such as long queue times, mismatched flow of people and resources, and insecurity of tourist safety in amusement facilities still exist and are serious (Perin, Padrique, et al. 2021). The management of the amusement park has also proposed a series of solutions to the above problems, such as manual evacuation of passenger flow, scheduled equipment inspections, and the establishment of temporary child management places. However, these solutions are mostly manual processing, time-consuming and laborious, and cannot achieve the expected results, bringing negative gaming experiences to tourists (Han, Chen, et al. 2022). However, the research and use of the existing smart tourism system is also limited to the national A-level tourist attraction, natural scenic spots, historical scenic spots, etc., and it has not been used in large urban amusement parks. Therefore, it is urgent to research and design a smart system for large amusement parks. The above issues are divided into two categories in the article: the problem of tourists selecting the best amusement facilities, and the problem of tourists' own safety (Wu, 2022). In response to these two issues, an embedded module, wearable, and reusable intelligent service bracelet, as well as an intelligent cloud platform based on the Beidou positioning system and geographic information system, have been designed to provide real-time services such as crowd density display, personnel information matching, optimal facility selection, optimal play route design, warning of danger or overflow areas, and sending of help information for tourists, improving their gaming experience, Facilitate effective management of amusement park management (Mamodiya, Tiwari, et al. 2021).

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The China Beidou navigation satellite system (BDS) is a global satellite navigation system developed by China. It belongs to the active bidirectional ranging two-dimensional navigation system, which is solved by the ground center control system and provides users with three-dimensional positioning data. In addition to the function of GPS satellite positioning, communication function has also been added, and regional navigation, positioning, and timing capabilities have been provided. The positioning accuracy is 10 meters, and the speed measurement accuracy is 0 2 meters/second, with a timing accuracy of 10 nanoseconds. China successfully completed the deployment of the Beidou-3 basic system constellation on November 19, 2018, and announced on December 27 that Beidou-3 began providing global services, making the Beidou satellite navigation system more powerful and widely used. Geographic information system (GIS) is a spatial information technology that collects, stores, manages, operates, analyzes, displays, and describes data on geographical phenomena (Luo 2021). It focuses on location and geographic information as its core and foundation, solving problems related to geographic information.

The smart bracelet can also record the pulse wave signal of the human body through photoplethysmography (PPG). Real time heart rate signals containing a large amount of heart rate variability (HRV) information can be extracted from PPG, and the vast majority of the health monitoring functions of the bracelet are related to the characteristics of heart rate variability. When the human body is in different sleep stages, stress states, fatigue states, or certain disease states, the body's mechanisms will automatically adjust to adapt to changes, and these regulatory information will be reflected in heart rate variability (Wan, Dong et al. 2022). At present, most of the monitoring functions of smart bracelets are also achieved by monitoring changes in heart rate variability.

Therefore, the quality of PPG real-time heart rate signals has a significant impact on the accuracy of intelligent bracelet related functions. There are many factors that affect the quality of real-time heart rate signals in PPG wristbands, including hardware devices, ambient light, motion artifacts, etc. Therefore, before launching any smart wristband or a new feature based on real-time heart rate signals, a detailed quality evaluation of the real-time heart rate signals in PPG wristbands should be conducted to ensure the quality of the signals and the accuracy of the features extracted from the signals, To support subsequent related analysis and research (Ghavidel Maalandish et al. 2021).

At present, the standard real-time heart rate signal is extracted from the electrocardiogram (ECG) signal. The operation of medical grade ECG devices is complex, and wearable ECG devices are more convenient to use. However, they are still not as convenient and easy to operate as smart wristbands. Therefore, people tend to use smart wristbands in daily life to monitor real-time heart rate related physical states and functional indicators (He, Zhang, Zhang, 2021). In the quality evaluation of real-time heart rate signals of PPG smart bracelets, the real-time heart rate signals extracted from electrocardiogram can be used as standard real-time heart rate signals (i.e. reference values). In daily life, wearing wearable electrocardiographic devices and smart bracelets at the same time and comparing the real-time heart rate signal of the bracelet pulse wave with the standard real-time heart rate signal should be the most direct and accurate quality evaluation method.

2 RELATED WORK

2.1 Intelligent Bracelet Service Module

The core solution of this design is to display the density of pedestrian flow, providing tourists with the best playing facilities and paths. The data involved in this plan include amusement facility points, accessible roads, all signal points obtained from BDS, and tourist body signal points. The main steps are as follows:

(1) Perform kernel density analysis using all signal points and output the analysis results;

(2) Utilize amusement facility points for European allocation to obtain various facilities

Based on the service range of the point, partition and count the results of step 1 based on this service range to obtain the average pedestrian flow value of each service area (Yalcin Yazici, et al. 2022). Establish a waiting time function based on the number of passengers carrying the amusement facility once, and determine the waiting time required for each facility;

(3) Perform network analysis using tourist body signal points, amusement facility points, and accessible roads to obtain the shortest time path from the body signal point to each facility point. Extract the time spent on this path, compare it with the waiting time in step 2, and obtain the maximum value. Use this value to establish a new field, namely cost time,

compare and obtain the minimum value of all cost time, and output the facility point corresponding to the minimum value as the optimal facility point, Set the optimal facility point as the main signal point and delete it (Genuth-Okon and Knights 2023);

(4) Perform a loop through step 3 until all amusement facility points have been traversed, and output all the best facility point numbers in order to obtain the order of path docking points. Then, perform the shortest path analysis to output the best amusement path. Taking Chengdu Happy Valley as an example, 1000 signal points and 1 tourist body signal point were obtained throughout the entire park. Remote sensing images were used as data sources, and ArcGIS was used to obtain park boundary vector data, road vector data, and amusement facility point vector data (Güllü, Demirdelen et al. 2022). Based on the actual situation, certain attribute values were assigned to the data, such as walking speed and road passage time.

Among them, according to the existing signal point data, nuclear density analysis data and facility point service area data statistics, two groups of data, the actual number of people and the estimated number of people, were obtained (Monteverde Llorens et al. 2022). MATLAB was used to perform function fitting analysis on the two groups of data, and found that the linear function function relationship fitting precision was the best, which met the fitting precision conditions, and the functional relationship between the actual number of people and the estimated number of people was obtained:

$$y = 0.001x - 0.0361 \quad (1)$$

By consulting information, it was found that the time required for the amusement facility to operate once and the number of people it can carry were obtained. Similarly, it was found that the cubic function relationship had the best fitting accuracy and met the fitting accuracy conditions (Zhou Du, Kim, 2022). The functional relationship between waiting time and the number of people it can carry was obtained:

$$y = 0.0001x^3 - 0.0148x^2 + 0.6671x - 3.047 \quad (2)$$

The calculation method for ApEn is as follows:

1) Assuming there is a time series x (x), x=1,2,..., n, with the embedding dimension m as the window length, m is usually taken as 2 or 3, the time series x (x) is divided into K=n-m+1 subsequences.

$$X_i = \{x_i(t), x_{i+1}(t), \ldots, x_{i+(m-1)}(t)\}, i = 1,2,\ldots,K \quad (3)$$

2) Calculate the distance d between each sequence and another K-1 sequence, taking the maximum absolute value of the pairwise distance.

$$d_{ij} = \max \mid x_{i+k}(t) - x_{j+k}(t) \mid, k = 1,2,\ldots,K \quad (4)$$

3) Get the distance matrix d as shown in Figure 1:

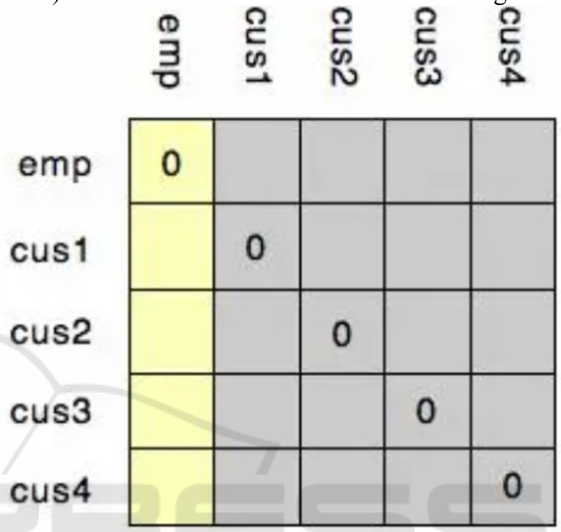

Fig. 1. Distance matrix

3) Define a threshold D:

$$D = r * SD \quad (5)$$

Among them, r is the scale, the range of r is usually 0.1-0.2, and SD is the standard deviation of the time series x (x).

5) Count the number of d in each row that is less than D, calculate the ratio C (r) that exceeds the threshold, and calculate the logarithmic average of K C (r):

$$\phi^m(r) = \frac{1}{K}\sum_{i=1}^{K} InC_i^m(r) \quad (61)$$

6) Change the window length m by one to m+1, repeat the above steps, and then calculate the difference between the two to obtain the approximate entropy:

$$ApEn(t) = \phi^m(r) - \phi^{m+1}(r) \quad (7)$$

Out of consideration for tourist safety issues, the intelligent service bracelet has designed a security service module for tourists. The main steps of this plan are to use Beidou positioning technology to set up an electronic fence around the park, and delineate a safe area range at the corresponding boundary on the map (Lilo, Mashhadany, et al. 2021). The obtained tourist body signal point is input to determine the range of the point. If it is within the designated range, no feedback information will be provided and monitoring will continue; If it is not within the designated range, send a danger warning signal.

2.2 Calculating Heart Rate Variability Using Real-Time Heart Rate Signals

With the popularity of smart bracelets, more and more people are using them to monitor their health. However, due to the storage of important information such as user health data and personal privacy in smart bracelets, the security issues of smart bracelets have also received widespread attention. In order to ensure the security of user data, smart bracelet manufacturers need to add security modules for protection.

The smart bracelet stores important information such as user health data and personal privacy. Therefore, a reliable data storage solution must be adopted to ensure the integrity, confidentiality, and availability of the data. Common solutions include data encryption storage, backup and recovery mechanisms, etc. The security of smart bracelets is the key to ensuring user data security. Smart bracelet manufacturers need to design and implement a series of security measures to ensure the security and legality of user data (Dai, Wang, et al. 2021). With the continuous development of technology and the Internet of Things, the security issues of smart bracelets also need to be constantly updated and upgraded to maintain technological leadership and foresight.

Heart rate variability is an important, non-invasive and convenient index to evaluate the regulation of the human autonomic nervous system and human health. It is also used in most smart bracelets in the market. When the external environment is stimulated or the human body changes, the autonomic nervous system regulates the heart sinoatrial node, and the heart rate changes irregularly. Therefore, HRV reflects the ability of the human body to autonomously regulate and is one of the important methods used to monitor the physiological and psychological conditions of the human body. In previous studies, there were many methods for analyzing HRV, mainly including time-domain analysis, frequency-domain analysis, nonlinear analysis, etc. The specific methods are as follows:

The time-domain feature of HRV is to describe real-time changes in heart rate using statistics from the perspective of the timeline. The common HRV time-domain indicators are as follows:

(1) Mean RR: The average level of R-R interval over a certain period of time. The calculation method is shown in equation (1):

$$MeanRR = \sum_{i}^{N} \frac{RR_i}{N} \quad (8)$$

Among them, N represents the number of normal R-R intervals, and RR□ represents the i-th R-R interval.

(2) Standard deviation of normal to normal intervals (SDNN): The standard deviation of normal RR intervals after excluding abnormal RR intervals. The calculation method is shown in equation (2):

$$SDNN = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(RR_i - \bar{RR})^2} \quad (9)$$

Among them, (RR) ̅ represents the average value of the normal R-R interval. The normal reference range is 141 ± 39, in milliseconds (ms).

(3) The standard deviation of the average R-R intervals calculated every five minutes (SDANN) reflects the relatively slow changes in HRV. The calculation method is shown in equation (10):

$$SDANN = \sqrt{\frac{\sum_{i=1}^{K}(\bar{RR}_\iota - RR_5\bar{m\iota n})^2}{K}} \quad (10)$$

Among them, (RR) ̅_ L is the mean R-R interval of the i-th 5-minute, (RR) ̅_ ("5" min) is K RRs_ The mean of l, where K represents K 5-minute windows in this signal segment.

(4) The standard deviation (SDSD) of the difference between all adjacent R-R intervals.

(5) The root mean square (rMSSD) of the difference between adjacent R-R intervals reflects the rapidly changing part of HRV. This indicator reflects the regulation of the parasympathetic nervous system. If the parasympathetic nerve is dominant, rMSSD will rise. The calculation method is shown in Formula (11):

$$rMSSD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(RR_{i+1} - RR_i)^2} \quad (11)$$

(6) The percentage of adjacent R-R intervals with a difference greater than 50ms in the total number of R-R intervals (pNN50) reflects a sudden change in R-R intervals. The calculation method is shown in equation (12):

$$pNN50 = \frac{NN50}{N} \times 100\% \quad (12)$$

Among them, $N\ N\ 50$ is the number of adjacent R-R intervals greater than 50ms.

3 DESIGN OF INTELLIGENT SERVICE BRACELET SUPPORTED BY BDS AND GIS

3.1 Principle and Application of Information Similarity Algorithm

At present, the commonly used assessment of pulse wave heart rate quality mainly uses pulse wave waveform characteristics or qualitatively evaluates its quality through the correlation between pulse wave HRV indicators and electrocardiogram HRV indicators. This project will use time series symbolization coding and sorting statistics to calculate the similarity index of dynamic change patterns between pulse wave real-time heart rate signals and electrocardiogram standard real-time heart rate signals, in order to quantitatively evaluate the quality of real-time heart rate signals.

Yang et al. believe that complex physiological signals may contain unique dynamic characteristics, which may be related to the underlying mechanisms behind them. Based on this, a symbolic sequence method was proposed to study the change patterns and dynamic characteristics of signals, and a new algorithm for calculating signal similarity was proposed. This algorithm is also known as the IBS (Information Based Similarity) algorithm.

The specific steps of the IBS algorithm are as follows:

(1) Assuming there is a continuous interval signal $X_i = \{x_0, x_1, \dots, x_n\}$, where x□ is the k-th interval value. Starting from x□, take two consecutive intervals $\{x_k, x_{k+1}\}$ as a group. A set of interval pairs can have two variation modes, one is x_{k+1} ratio x_k is small or equal, one is x_{k+1} ratio x_k is large. Represent these two change modes with 0 and 1, as shown in equation (13):

$$I_k = \begin{cases} 0, & x_k \le x_{k+1} \\ 1, & x_k > x_{k+1} \end{cases} \quad (13)$$

(2) According to the conversion rule in (1), the continuous interval signal is converted into a binary symbol sequence S, m symbols are taken as a group, and the long sequence is divided into multiple sets of symbol sequences with a length of m. Each symbolic sequence with a length of m represents a pattern of change, denoted by $W_t = \{I_1, \dots, I_m\}$represents. After obtaining the set, count the number and frequency of occurrences of various patterns in the set, and sort the various symbolic sequences in reverse order according to their frequency. The first ranked symbolic sequence indicates that the change pattern it represents most often appears in the original signal; On the contrary, the symbolic sequence at the bottom of the ranking indicates that the change pattern it represents is least commonly present in the original signal. If a symbolic sequence with a length of m is set, there are two change modes. With the increase of m, the types of change patterns increased exponential growth. Therefore, when the original signal length is short, m should not be too large. Choosing an appropriate m based on the length of the original signal is a question worth exploring.

(3) Based on the frequency and ranking of the symbolic sequence with a length of m in the two original signals, select the sequence of change patterns that appear in both original signals, and substitute it into equation (14) to calculate the similarity between the two signals. D□ represents the IBS distance indicator (i.e. similarity indicator) of the two signals. The larger the distance, the lower the similarity between the two signals, and vice versa, the higher the similarity.

$$D_m(S_1, S_2) = \frac{\sum_{t=1}^{2^m} | R_1(w_t) - R_2(w_t) | F(w_t)}{(2^m - 1)} \quad (14)$$

$$F(w_t) = \frac{1}{Z}[-p_1(w_t)logp_1(w_t) - p_2(w_t)logp_2(w_t)] \quad (15)$$

$$Z = \sum_t [-p_1(w_t)logp_1(w_t) - p_2(w_t)logp_2(w_t)] \quad (16)$$

Among them, $p_1(w_t)$ and $R_1(w_t)$ represents the symbolic sequence w_t in S, respectively_ 2. Probability and ranking of occurrence. Similarly, p_2 (w_t) and R_2 (w_t) respectively symbolize the sequence w_ T represents the probability and ranking of its occurrence in S_2. The absolute difference in ranking is divided by the normalization factor Z and $(2^m - 1)$ to ensure that the range of D is between 0 and 1.

3.2 Software and Hardware Design

3.2.1 Hardware Design

The core modules of this intelligent bracelet are the Beidou navigation and positioning module, Beidou communication module, and Bluetooth module. These three modules are integrated to form the most core integration block of the intelligent service bracelet. The Beidou navigation and positioning module is the core of the intelligent service bracelet implementation service module, using the Hexin Xingtong UM220-IIINLBD2/GPS dual mode positioning module under Xingtong Industry. This module is currently the smallest fully domestically produced BDS/GPS module in the market, with high integration and excellent positioning and navigation functions, supporting single system and multi-system joint positioning. The Beidou communication module is the core module of the intelligent service bracelet to achieve safety warning. It adopts the GYM2002A Beidou RDSS communication basic module from Beijing Guoyi Hengda Navigation Technology, which is small in size, low in power consumption, and reliable in performance. The Bluetooth module is an important module that connects smart service bracelets with smartphones, enabling tourists to access services on the smart cloud platform. It adopts the SKB369 (A) module of Shenzhen Tiangong measurement and control technology. The selected modules can operate normally in more extreme environments and have a longer service life, which meets the needs of the intelligent bracelet design. Connect the core processing board, three core modules, battery, electronic display screen, buttons, and other components through bottom board wiring to obtain the integrated circuit board of the smart bracelet. The hardware structure diagram of the intelligent bracelet terminal is shown in Figure 2.

Based on the above core solution design, the intelligent cloud platform system is designed and developed using C # and ArcGISEngine development libraries. The software has designed two core business classes, ServiceModule and SecurityModule, which correspond to the service module and security module, and contain the required methods for each module.

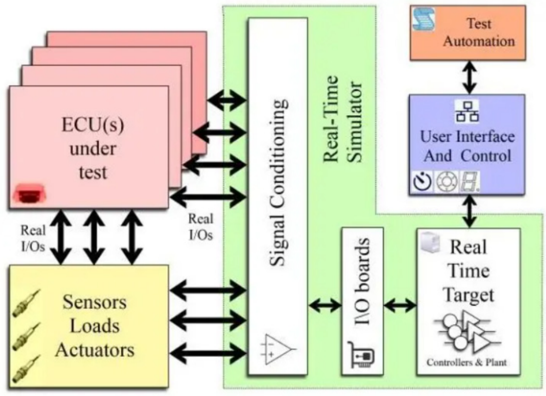

Figure 2: Hardware structure diagram of intelligent bracelet terminal

3.2.2 Software Design

This involves connecting the BDS module and transmitting signals back, analyzing coordinates and performing layer display, kernel density analysis, Euclidean allocation, partition statistics, shortest path analysis, cost time calculation, optimal facility point extraction, facility point play order extraction, spatial topology query, and other core methods. The calculation results of the software operation are the same as the case of Chengdu Happy Valley mentioned earlier.

4 EXPERIMENTAL SIMULATION ANALYSIS

Before the formal scientific testing of the system, a survey was conducted on the user selectivity of software and hardware. A questionnaire survey was conducted on 1000 scattered tourists around Chengdu Happy Valley and Shenzhen World Window, including teenagers aged 10-50 and middle-aged and young people, with the majority being young people. 73.5% of people are willing to use the system and believe that it has practical value for use; About 45% of people believe that the system can be implanted into commonly used mobile apps such as WeChat, making it convenient for tourists to use.

Convert the real-time heart rate signal into a binary 0-1 symbolic sequence according to equation (13), as shown in Figure 3. Triangles are labeled as real-time heart rate signals, and dots are labeled as corresponding converted binary sequences. Figure 3 shows the conversion process of standard real-time heart rate signals, and Figure 4 shows the conversion process of E4 bracelet real-time heart rate signals.

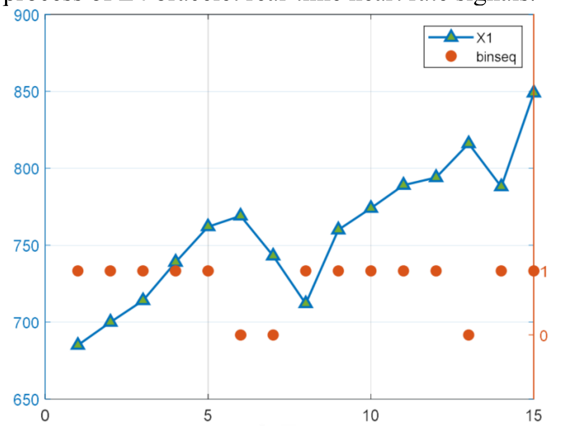

Figure 3: The Symbolic Sequence Conversion Process of Standard Real Time Heart Rate Signal

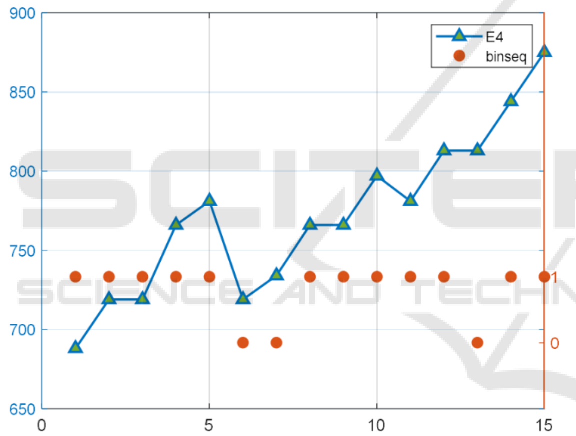

Figure 4: The Symbolic Sequence Conversion Process of Real Time Heart Rate Signal for E4 Bracelet

The frequency and ranking of the 8 change modes in the standard real-time heart rate signal and the real-time heart rate signal of the bracelet are shown in Table 1.

Table 1: Frequency and ranking of each change mode

Standard real-time heart rate signal			Real time heart rate signal of the bracelet		
Change mode	Frequency of occurrence	ranking	Change mode	Frequency of occurrence	ranking
000	0.20069	1	000	0.21107	1
001	0.16263	2	001	0.15571	2
100	0.15917	3	100	0.15225	3

From the table, it can be seen that there are some differences in the ranking of each mode, but the difference is not significant. At this point, the IBS indicator calculation result is 0.0581. However, in the standard real-time heart rate signal, there are already two change modes that have not appeared. Considering that when m is taken as 5, there will be more missing change modes, so m=4 will be used in subsequent research in this project. In 4.4.2, the data from the second resting state of participant 3 was used and based on experience, m=5 was used to demonstrate the method process. Due to the longer duration of the resting state task (500s) compared to the deep breathing task (300s), taking m=5 has little impact on the results. However, considering the data of the three time periods (300s, 360s, 500s), taking m=4 is more appropriate.

5 CONCLUSIONS

A solution was proposed by combining BDS and GIS, and small-scale experiments were conducted using ArcGIS to validate the solution. For this purpose, an intelligent service bracelet and its corresponding intelligent cloud platform were designed. Desktop software design and development were carried out using C # and ArcGIS Engine development libraries, and actual testing was conducted in Chengdu and Shenzhen. The test results indicate that this scheme can effectively alleviate issues such as personnel congestion and safety in amusement parks, while providing services for tourists to play and park management, reducing waiting time for tourists, and improving the management efficiency and effectiveness of park managers.

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