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Research on the Dynamic Generation System of Coastal Elderly Cultural Tourism Brands Driven by Multimodal Perception

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Abstract

The dynamic generation of coastal elderly cultural tourism brands needs to comprehensively consider multi-dimensional factors such as the needs of elderly tourists, scenic environment, tourism resource characteristics, service quality rating, and geographical location advantages. The existing generation methods cannot fully meet these requirements, resulting in a decrease in the effectiveness of solution generation. In this regard, a dynamic generation system of coastal elderly cultural tourism brands driven by multimodal perception is designed. The hardware part includes a data processor and a multimodal perception driver, and the software part pre-processes the collected multimodal data. The data reuse rate, retrieval and storage efficiency are enhanced through a layered architecture, and the table structure of a coastal elderly cultural tourism brand database containing 8 tables is designed. Based on the core elements, a coastal elderly cultural tourism brand generation model is constructed, and a multimodal perception decision model is designed for coastal leisure areas and historical and cultural areas, and the corresponding scene processing flow is given. The core elements are extracted using the generation model, and the software design of the coastal elderly cultural tourism brand dynamic generation system is completed by continuously optimizing the brand symbols and color system. The test results show that the average value of the brand information perception fitting curve of the design system reaches 4.2, and when the data dimension reaches 300×10^3, the timeliness of brand dynamic response reaches 90%, which highlights that it can meet the high demand for brand dynamic generation when dealing with complex market environments.

Keywords: Multimodal Perception Drive, Coastal Elderly Culture, Tourism Brand, Dynamic Generation System, Brand Information Perception

Introduction

In the context of global population aging, the demand for elderly-oriented tourism has grown significantly. Coastal areas, with their pleasant climates, rich cultural heritage, and natural scenery, are becoming increasingly popular destinations among elderly tourists (Bellato et al., 2022). Elderly cultural tourism not only serves as a means of physical and mental relaxation for senior citizens but also facilitates intergenerational cultural transmission and stimulates local economic development. Therefore, the development of cultural tourism brands specifically tailored for the elderly in coastal regions holds both social and economic importance.

However, the rapid expansion of this sector has exposed a range of challenges. Many coastal elderly tourism brands lack a distinctive identity, relying on homogeneous content and outdated communication strategies. Moreover, the dynamic and diverse preferences of elderly tourists—such as varying mobility levels, cognitive styles, and cultural interests—are often neglected. This leads to a mismatch between brand representation and actual user needs, resulting in low engagement, weak brand loyalty, and limited sustainable growth of tourism destinations.

Despite an increasing interest in brand generation and dynamic design in related fields, current research lacks targeted solutions for the elderly cultural tourism market. For instance, Wang et al. (2024) explore dynamic graphic design in fast-moving consumer goods branding but do not account for the deeper cultural and experiential dimensions relevant to elderly tourism. Kuzmina et al. (2019) propose a framework for global wine tourism branding, but this is insufficient to address the multi-layered expectations and behavioral patterns of senior tourists in coastal contexts. Similarly, while Budiman (2021) investigates social media branding for Generation Y, the findings are not transferable to elderly groups, who typically engage with technology and media in markedly different ways.

Given these gaps, there is a pressing need to explore how coastal elderly cultural tourism brands can dynamically evolve in response to multimodal user input and real-time demand shifts. Multimodal perception technologies—integrating visual, auditory, and even emotional cues—offer powerful tools to bridge the divide between brand strategy and user-centered design (Liu, 2022). Through real-time data collection and analysis, these technologies can help brands more accurately interpret the cognitive, emotional, and behavioral characteristics of elderly tourists. This, in turn, enables more responsive, personalized, and emotionally resonant branding strategies. Hence, this study aims to develop a dynamic branding framework for elderly cultural tourism in coastal regions by integrating multimodal perception technologies.

The contribution of this study is as follows: (1) It will contribute to the theoretical advancement of brand generation systems, while also providing a scalable and replicable model for other regions facing similar challenges; (2) The outcomes of this research are expected to benefit a wide range of stakeholders, including policymakers, tourism planners, brand strategists, and—most importantly—the elderly travelers themselves, whose experience and satisfaction form the foundation for sustainable development in this emerging market.

Hardware Design of Dynamic Generation System of Coastal Elderly Cultural Tourism Brands Driven by Multimodal Perception

Data Processor

In the dynamic generation system of coastal elderly cultural tourism brands driven by multimodal perception, the data processor is the core. The data processor mainly includes intelligent analysis host, brand data cloud storage cluster and edge computing node. The structure is shown in Figure 1.

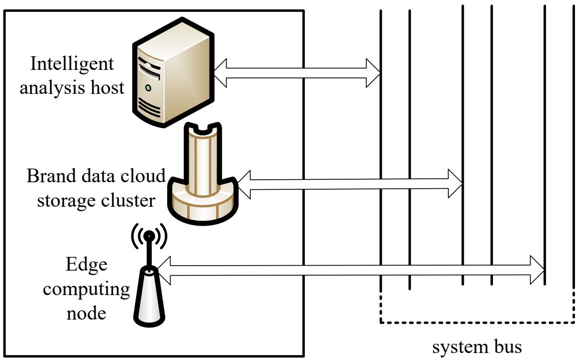

Figure 1. Data processor structure

The intelligent analysis host is the core of data processing, with strong computing power and advanced algorithm. Multimodal perception devices such as smart cameras, environmental sensors, and voice interaction devices in scenic spots will collect multi-source data such as the behavior of elderly tourists, scenic environment, and tourist feedback. The intelligent analysis host can quickly receive and integrate these data, use deep learning algorithms to conduct in-depth mining and analysis, accurately grasp their needs and interests, and provide key basis for dynamic brand generation.

The brand data cloud storage cluster is responsible for data security storage and management. It uses a distributed storage architecture, which is reliable and scalable (Wang, 2023). It can store brand promotional materials, tourist consumption records and other data safely and orderly, and also supports fast retrieval and call, which can be used by the system at any time to help the brand dynamically adjust and optimize. Edge computing nodes are distributed at key points in the scenic area and can process local data in real time. For example, the entrance of the scenic area can analyze the flow of tourists. If it exceeds the threshold, it will send an early warning to the intelligent analysis host to help the system respond quickly, adjust the publicity or divert tourists. It can also reduce the burden on the host and improve the system response and processing efficiency.

Multimodal Perception Driver

In the multimodal perception-driven coastal elderly cultural tourism brand dynamic generation system, the multimodal perception driver is the key to obtaining external information and can fully perceive various types of information related to elderly tourists and scenic spots. The multimodal perception driver consists of multiple modules, and its structure is shown in Figure 2.

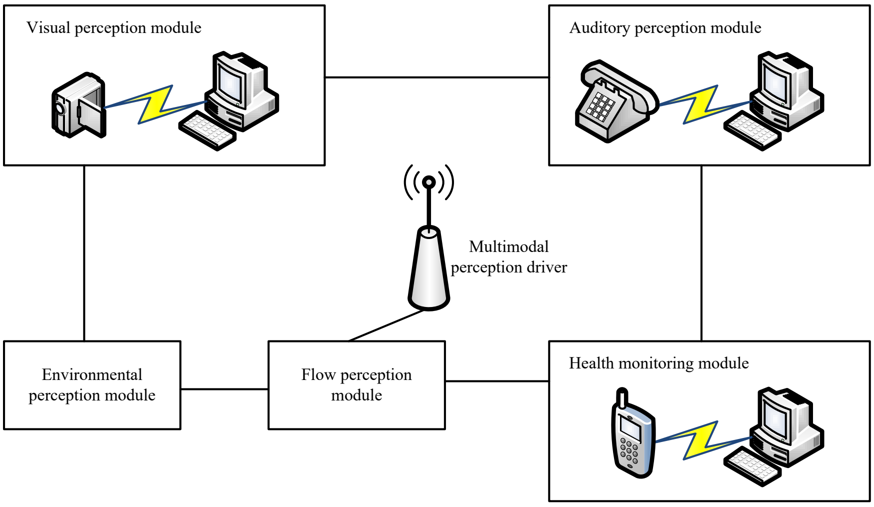

Figure 2. Multimodal perception driver structure

The visual perception module uses high-definition panoramic cameras and intelligent image recognition equipment to capture the elderly tourists' sightseeing pictures in all directions. The intelligent image recognition equipment can analyze in real time, identify tourists' expressions, movements and group behaviors, and judge the interest of scenic spots and whether the area is congested. The auditory perception module has a directional microphone array and voice recognition and analysis equipment, which can accurately capture the voices of elderly tourists in areas such as scenic area consultation points, quickly identify and analyze, and understand their needs, opinions and suggestions on catering, accommodation, tour guide services, etc.

In the health monitoring module, health data such as heart rate of elderly tourists are collected in real time, and portable detectors provide more comprehensive health testing services at medical service points in scenic areas. The environmental perception module has temperature and humidity sensors, air quality monitors and light sensors, which can monitor the environmental parameters of scenic spots in real time and provide data for brand promotion of comfortable and livable scenic spots. The flow perception module relies on the flow thermal sensing device and intelligent counter to accurately count the flow of people in scenic spots, helping the system to allocate resources and optimize brand promotion.

Software Design for Dynamic Generation System of Coastal Elderly Cultural Tourism Brand Driven by Multimodal Perception

Preprocessing of Coastal Elderly Cultural Tourism Brand Data Based on Multimodal Perception

In the research on coastal elderly cultural tourism brand data driven by multimodal perception, the multimodal data collected from various mobile smart devices and scenic spot sensing devices often have many problems, which will interfere with the subsequent brand feature extraction and classification analysis, so corresponding preprocessing must be carried out. The preprocessing work mainly covers three parts: interference signal elimination, abnormal data removal and data missing filling. Among them, abnormal data removal and data missing filling are driven by multimodal perception, and interference signal elimination is a special treatment for noise interference in multimodal sensor data.

Interference signal elimination processing is mainly for gyroscope data in multimodal sensors. When the gyroscope collects data, it is easily affected by environmental vibration and equipment electronic noise, generating high-frequency noise interference. These noise frequencies are usually higher than the normal activity signal frequency of elderly tourists, so the noise component is separated by a high-pass filter and then subtracted from the original data to obtain a pure motion signal (Melnychenko et al., 2021). Suppose the original gyroscope data is $G(t)$, the data after high-pass filtering is $G_e(t)$, and the transfer function of the high-pass filter is $H(f)$, then:

$$G_e(t) = F^{-1}H(f) + FG(t) \quad (1)$$

Where: F is the Fourier transform, F^{-1} is the inverse Fourier transform. The transfer function $H(f)$ of the high-pass filte rcan be designed according to actual needs. Usually, a first-order high-pass filter is used, which is in the form of:

$$H(f) = \frac{2\pi f}{2\pi f + \frac{1}{\tau}} \quad (2)$$

Where: f is the frequency, τ is the time constant, which is related to the cutoff frequency of the high-pass filter f_c and satisfies $f_c = \frac{1}{2\pi\tau}$.

In practical applications, a 5 to 10 Hz cutoff frequency is used to eliminate the high-frequency noise of the gyroscope data. The original sampling frequency is 200 Hz, and it can be calculated that the value range of τ is from 0.0016 to 0.0032 seconds. When removing abnormal data and filling missing data, the multimodal perception driver will dynamically adjust the window size, and then automatically adjust the weighting coefficient according to the data change trend to improve data quality.

Design the Database Table Structure of the Coastal Elderly Cultural Tourism Brand

Based on the pre-processed coastal elderly cultural tourism brand data, design the adapted database table structure and specifications. Adopt a layered architecture to separate data storage, computing and services to improve data reuse, retrieval and storage efficiency. Build a standard and unified data input and output interface to ensure data consistency and specification. Build a data computing middle platform to provide management and services with good interaction, stable performance, and safe controllable. At the same time, develop a unified data interface, use security policies, access control and log audit technology to make data service permissions controllable and call traces (Mirenda et al., 2022).

This coastal elderly cultural tourism brand database contains a total of 8 tables, namely, elderly tourist information table, elderly tour group information table, coastal characteristic hotel table, coastal scenic spot table, health and leisure project table, local characteristic souvenir table, traditional food table and elderly tourist evaluation table. Its specific structure is shown in Table 1.

Table 1
Structure of the database table of coastal elderly cultural tourism brands

Serial Number	Table Name	Field Types
1	Elderly Tourist Information Table	Tourist ID, Name, Age, Gender, Contact Information, Health Status
2	Elderly Tour Group Information Table	Tour Group ID, Tour Group Name, Departure and Return Dates, Guide Name, Contact Number
3	Coastal Characteristic Hotel Table	Hotel ID, Hotel Name, Address, Star Rating, Special Services
4	Coastal Scenic Spot Table	Scenic Spot ID, Scenic Spot Name, Location Area, Scenic Spot Type, Natural Landscape
5	Health and Leisure Project Table	Project ID, Project Name, Location, Suitable Population, Price
6	Local Specialty Souvenir Table	Souvenir ID, Souvenir Name, Material, Price, Origin
7	Traditional Cuisine Table	Cuisine ID, Cuisine Name, Taste, Recommended Restaurant, Price
8	Elderly Tourist Evaluation Table	Evaluation ID, Tourist, Evaluation Object Type, Evaluation Object ID, Evaluation Content, Evaluation Time, Rating

In terms of data association analysis, in order to measure the attractiveness correlation of different tourism elements to elderly tourists, let the attractiveness index of scenic spots i be A_i, the number of elderly tourists participating in health projects j be B_j, the number of elderly tourists jointly participated by both parties be N_{ij}, and the total number of elderly tourists participating in related tourism activities be N. Then the attractiveness correlation R_{ij} of scenic spots i and health preservation projects j can be expressed as:

$$R_{ij} = \frac{N_{ij}}{N} \times \frac{A_i + B_j}{2G(t)} \quad (3)$$

This formula comprehensively considers the number of tourists participating in the event and the attractiveness index of the two, and can be used to analyze the correlation between different tourism elements, providing data support for the construction of a generation model for coastal elderly cultural tourism brands.

Constructing a Generation Model for Coastal Elderly Cultural Tourism Brands

Based on the core elements such as elderly tourists' preferences, tourism resource characteristics, service quality ratings, and geographical location advantages, business logic analysis and modeling are carried out. Following the designed database table structure of coastal elderly cultural tourism brands, the system scenario modeling focuses on two typical application scenarios: coastal leisure areas and historical and cultural areas. The generation model of coastal elderly cultural tourism brands is shown in Figure 3.

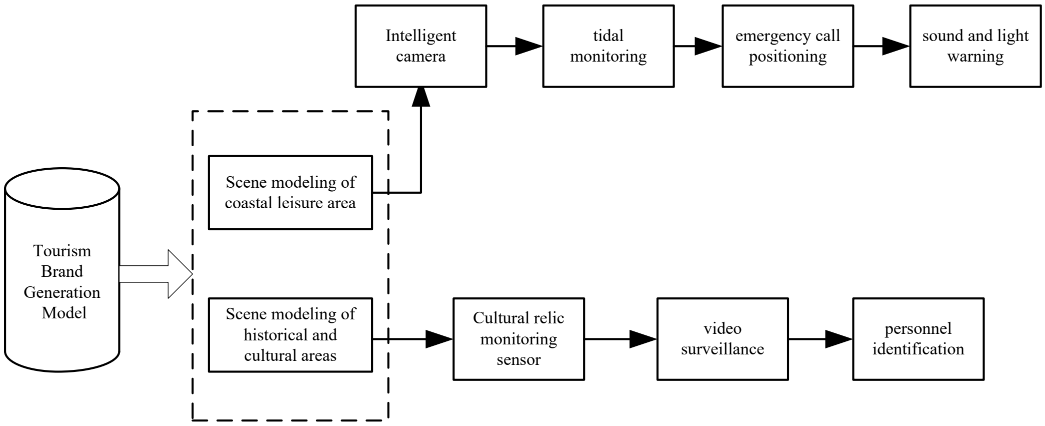

Figure 3. Generation model of coastal elderly cultural tourism brand

In view of the threats that elderly tourists may encounter at the seaside, such as accidental falling into the water and staying in dangerous areas for a long time, the coastal leisure area designs a multimodal perception decision model of "intelligent camera + tidal monitoring + emergency call positioning + sound and light warning", which can effectively improve the accuracy of safety warning and the speed of emergency response, and reduce false alarms caused by natural factors such as waves and sea fog (Ahmad et al., 2023). The scene modeling process of the coastal leisure area is as follows:

1) Real-time identification of elderly tourist targets in the surveillance video of the coastal leisure area and analysis of their movement trajectory.
2) Receive and cache various types of safety equipment alarm information, including alarm time, equipment number, specific location, alarm category, etc.
3) In the alarm information list, find whether other safety equipment has generated alarm records during the period. If the time match is successful, proceed to the next step.
4) Retrieve the video image recognition results at the time near the alarm point for confirmation. If it is found that the elderly tourists are in a dangerous state, proceed to the next step.
5) If the alarm location does not match the positioning information of the smart bracelet worn by the elderly tourists, the alarm caused by the normal activities of the elderly tourists can be excluded, and the location is confirmed to have safety hazards, and a comprehensive warning information is sent.
6) Select the rescue equipment closest to the alarm point, determine the rescue parameters, generate a rescue plan and issue instructions.

With the advantage of the commanding heights of the historical and cultural area, a multimodal perception decision model of "cultural relics monitoring sensor + video surveillance + personnel identity recognition" is designed to realize early warning and disposal of illegal destruction and theft by real-time monitoring of cultural relics status and personnel behavior. The scene modeling process of the historical and cultural area is as follows:
Receive cultural relics monitoring sensor data, including cultural relics vibration frequency, temperature and humidity changes, etc.; receive video surveillance recognition results, including personnel behavior characteristics, stay time, etc.

2) If the cultural relics monitoring data exceeds the "cultural relics safety threshold rule" or the personnel behavior meets the "abnormal behavior rule", proceed to the next step.
3) Match the personnel information identified by the video surveillance with the "tourist whitelist". If the match fails, send an alarm message and start the corresponding security measures according to the "Cultural Relics Protection Rules".
4) According to the damage to the cultural relics and the location of the personnel, combined with the emergency disposal cost C and the rescue effect evaluation value E , the formula is:

$$\begin{cases} C = \alpha S + \beta T \\ E = \frac{HR_{ij}}{C} \end{cases} \quad (4)$$

Where: S is the damaged area of the cultural relics, T is the emergency response time, α and β are the weight coefficient, and H is the degree of restoration of the cultural relics.Optimize the emergency disposal plan to ensure the best rescue effect at the minimum cost. At this point, the construction of the coastal elderly cultural tourism brand generation model is completed.

Dynamically Generate Coastal Elderly Cultural Tourism Brands

Dynamically generate coastal elderly cultural tourism brands. It is necessary to use relevant generation models to deeply explore the coastal geographical features, elderly tourism resources and regional cultural connotations, and turn these unique elements into attractive and recognizable brand symbols. Designers should consider the visual preferences, information reception and understanding habits of elderly tourists, so as to make the brand image vivid, easy to understand and full of vitality. This dynamic generation system is based on the model and has two sections: core element extraction and communication application expansion. The structure is shown in Figure 4.

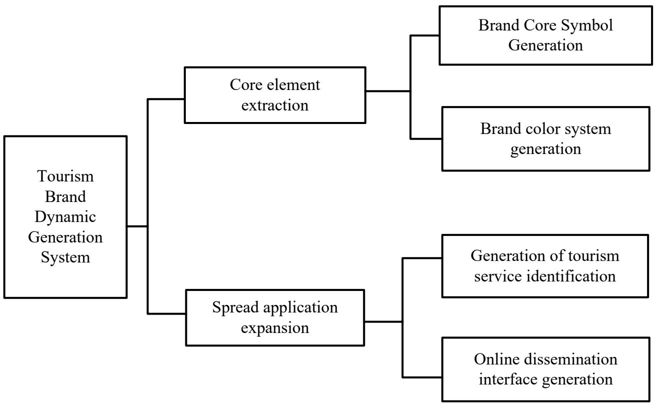

Figure 4. Main structure of the dynamic generation system of coastal elderly cultural tourism brand

Brand core symbol generation: According to the characteristics of the coastal area's marine landscape, health resources and folk culture, representative image elements are extracted, such as wave lines, shell shapes, health herbal patterns, etc. These elements are matched with text and color to form a recognizable and communicative brand core symbol, showing the unique charm of coastal elderly cultural tourism (Diem et al., 2021).

Brand color system generation: According to the natural colors and cultural atmosphere of the coastal area, the main and auxiliary colors of the brand should be determined. For example, sea blue represents the vast tranquility of the ocean, and warm yellow reflects the warmth and vitality of elderly tourism, creating a comfortable and pleasant visual experience. The color selection should be consistent with the brand connotation and meet the aesthetic taste of elderly tourists.

Tourism service logo generation: When designing, the visual characteristics and information needs of elderly tourists should be considered. Use concise and clear graphics and text to clearly mark the location and function of tourism service facilities, such as elderly care service centers, medical emergency points, etc. The logo should be integrated with the core elements of the brand and consistent with the overall brand image.

Online communication interface generation: When designing web pages and mobile APP interfaces, we should pay attention to user experience, with a simple interface layout and convenient operation. At the same time, we should integrate the core elements of the brand to create an online communication platform with the characteristics of coastal elderly cultural tourism.

In the process of brand dynamic generation, use brand attractiveness X and brand communication effect Q to improve brand attractiveness. The formula is:

$$\begin{cases} X = \alpha D + \beta K \\ Q = \dfrac{M}{tE} \times XC \end{cases} \quad (5)$$

Where: D is the brand symbol uniqueness index, K is the color system harmony index, M is the number of people covered by the communication channel, t is the communication time, and by continuously optimizing the brand symbol and color system, the brand attractiveness is improved, and then the software design of the coastal elderly cultural tourism brand dynamic generation system is completed.

System Test

Test object

The research test was conducted in a coastal area with longitude and latitude between 119°30' E-120°15' E and 37°20' N-37°55' N. It faces the sea to the east and faces the surrounding islands across the sea. It is connected to the land transportation hub to the west and is connected to the inland city. It is a key place for regional transportation and cultural integration. The terrain here is mainly low mountains and hills, and there are also coastal plains. The coastline is tortuous, and there are many natural harbors and characteristic bays. The natural landscape and cultural relics complement each other, and the tourism resources are unique. The landform features are obvious, the coastal karst landform and sea erosion landform are well developed, the geological stratification is clear, and the ecology is diverse. There are also many historical and cultural heritages and folk villages in the area, which provide a profound cultural heritage for elderly cultural tourism. With the help of multimodal sensing technology, its ecological footprint is shown in Table 2.

Table 2
Ecological footprint of the coastal test area

Ecological Footprint Type	Specific Sub-item	Value (Unit: Global Hectares per Person·Year)	Proportion (%)
Biological Resource Footprint	Agricultural Product Consumption	0.35	28
	Forest	0.08	6.4
	Aquatic	0.22	17.6
	Livestock	0.30	24
Energy Resource Footprint	Coal Consumption	0.10	8
	Petroleum	0.15	12
	Natural	0.05	4
Total Ecological Footprint	-	1.25	100

The total ecological footprint of the coastal test area is 1.25 global hectares/person/year, and the area of land used for the construction of elderly cultural tourism facilities in this area is second only to the sea area, and far exceeds the unused land. This is mainly due to the booming local elderly cultural tourism market in recent years and the surge in demand for the construction of related supporting facilities.

Test Preparation
In the test phase of the multimodal perception-driven coastal elderly cultural tourism brand dynamic generation system, the activity of the coastal elderly cultural tourism market, the completeness of tourism service facilities, as well as the typicality of cases and the feasibility of data acquisition are comprehensively considered. The data is collected from the authoritative national elderly tourism market research report, the coastal city tourism development white paper, and the annual statistical data released by the cultural and tourism departments of each city, providing a solid data foundation for system testing. The structure of the multimodal perception-driven sensor used is shown in Figure 5.

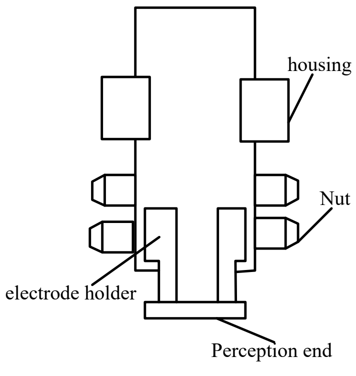

Figure 5. Multimodal perception-driven sensor structure

In this study, in the context of coastal elderly cultural tourism, tourists were asked to wear multimodal perception-driven sensors to collect data for about 1.5 hours, including physiological and behavioral data. To ensure the accuracy of activity labels, the research team first removed some unclear data, and then preprocessed the outliers and missing values. The physiological data became 180,000 × 3 dimensions, and the behavioral data was 270,000 × 4 dimensions. In order to improve data processing efficiency and system performance, the location coordinate information in the behavioral data was simplified, and the behavioral data became 135,000 × 4 dimensions after processing. The training set used the first 90,000 × 3 physiological data and 90,000 × 4 behavioral data continuous samples, and the validation set used the remaining samples. When collecting data, the researchers drew the real activity labels of tourists, subdivided the activities of elderly tourists into 7 states, and the on-site staff recorded them in real time and combined them with video review to ensure the accuracy of the labels. Table 3 shows the training set and validation set after data preprocessing.

Table 3
Correlation between training set and validation set after data preprocessing

Data Type	Data Dimension (Training Set)	Data Dimension (Validation Set)	Number of Samples (Training Set)	Number of Samples (Validation Set)	Examples of Data Features
Physiological Data	90000×3	90000×3	90000	90000	Heart Rate (beats per minute), Blood Pressure (Systolic/Diastolic), Step Count (steps)
Behavioral Data - Movement Trajectory	90000×2	45000×2	90000	45000	Longitude Coordinate, Latitude Coordinate
Behavioral Data - Dwell Time	90000×1	45000×1	90000	45000	Dwell Time at a Scenic Spot (seconds)
Behavioral Data - Movement Speed	90000×1	45000×1	90000	45000	Walking Speed (meters per second)
Behavioral Data - Direction Information	90000×1	45000×1	90000	45000	Movement Direction Angle (degrees)

In order to verify the actual effectiveness of the multimodal perception-driven coastal elderly cultural tourism brand dynamic generation system designed in this paper, the relevant systems were selected as the control group. By conducting a comparative experiment on brand information perception fitting curves, the trend of the brand information generated by each system and the expected image under multimodal perception of elderly tourists was analyzed; at the same time, a comparative experiment on brand dynamic response timeliness was conducted to record the response time of each system when the behavior preferences of elderly tourists changed. In this way, the advantages of this system in brand building and dynamic adjustment were comprehensively and objectively evaluated.

Test Result Analysis

Based on the actual score distribution of multimodal perception data collected during the system test, professional data analysis tools and methods were used to draw the brand information perception fitting curves of the five systems, as shown in Figure 6.

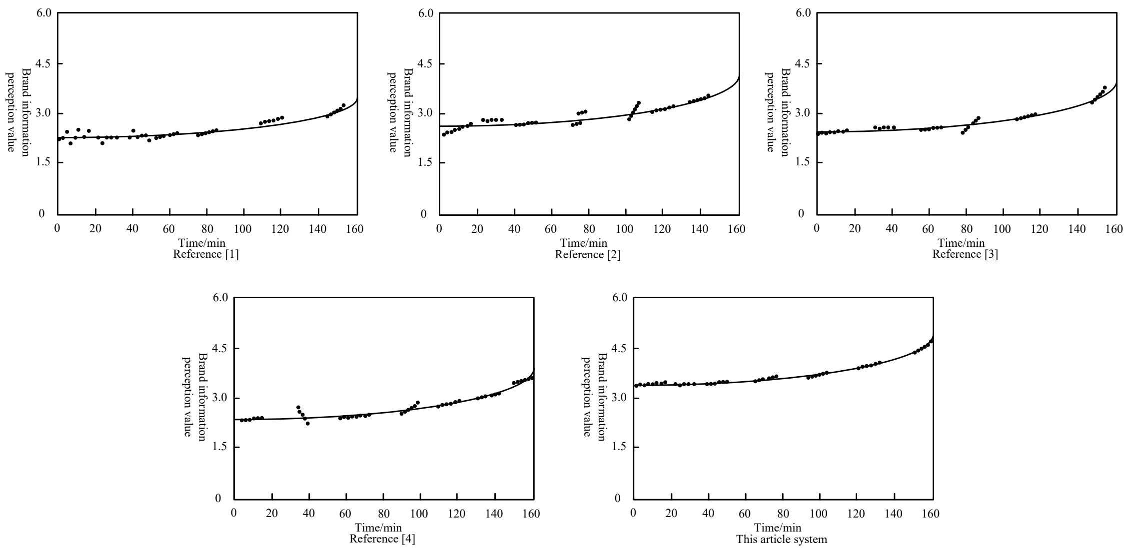

Figure 6. Brand information perception fitting curves of five systems

As shown in Figure 6, the brand information perception fitting curve of the proposed system fluctuates in the range of 3.5-4.8 points, with an average value of 4.2. The average values of references are 3.6, 3.8, 3.5, and 3.7, respectively. The proposed system is significantly better. Visually, the brand logo and other elements generated by the system fit the aesthetic and cognitive habits of elderly tourists and can quickly attract them. Auditorily, background music and voice explanations can create an atmosphere of coastal elderly cultural tourism, making people feel as if they are there. In terms of comprehensive multimodal perception dimensions, the proposed system is ahead of other reference systems in terms of brand information perception fit, can more accurately grasp the needs of elderly tourists, and enhance brand attractiveness and influence, proving that the system design is effective and has great advantages.

In the face of equipment upgrades, business expansion, etc., the system adopts technologies such as unified data interfaces to ensure compatibility, maintainability, and scalability. The timeliness of brand dynamic response of the five systems is shown in Figure 7.

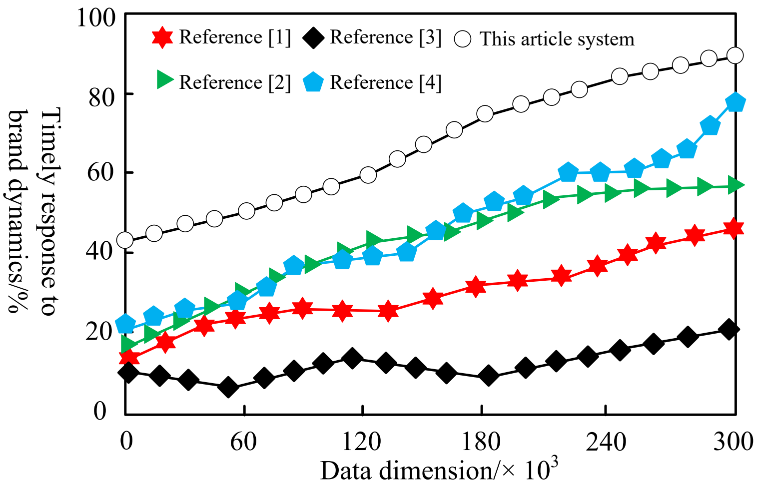

Figure 7. Timeliness of brand dynamic response of five systems

As can be seen from Figure 7, the response timeliness of this method in the initial stage reached 45%. As the data dimension increases, the advantage becomes more obvious. When the data dimension is 300×10^3, the response timeliness of this method reaches 90%, while references are all lower than 60%. This shows that in the face of the complex and ever-changing coastal elderly cultural tourism market, this method can perceive brand dynamics and respond faster. This is due to the efficient decision-making mechanism driven by multimodal perception, which can quickly integrate information and accurately judge needs. The response speed of other reference systems is slow and it is difficult to meet the needs of fast dynamic generation. Therefore, this method is more practical and reliable.

Conclusion

This study focuses on the dynamic generation system of coastal elderly cultural tourism brands driven by multimodal perception. On the theoretical level, it enriches the theoretical system of the integration of elderly cultural tourism brand construction and multimodal perception technology, and provides new perspectives and ideas for subsequent research. In practice, the constructed system can accurately capture the needs and behavioral characteristics of elderly tourists through multimodal sensing technology, realize dynamic generation and personalized push of brand information, and enhance the attractiveness and competitiveness of coastal elderly cultural tourism brands. However, the research has limitations, the data collection scope and sample size are insufficient, which affects the universality and accuracy of the system. In the future, the system performance will continue to be optimized, and more advanced multimodal sensing technologies and data analysis methods will be introduced to make brand dynamic generation more efficient and effective.

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