Analysis and Usability Evaluation of Virtual Reality in Cultural Landscape Promotion Platform Application

A Case Study from Dongao Ding Village, Dongtou District

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***Abstract*—In order to improve the efficiency of analysing the application of virtual reality technology in cultural landscape promotion platform and enhance the accuracy of usability assessment, a feasibility assessment method based on MA-BiGRU for virtual reality technology cultural landscape promotion platform is proposed. Firstly, it analyses the application of virtual reality technology in cultural landscape promotion platform and designs the application feasibility assessment; secondly, it combines MA algorithm and BiGRU network, and proposes a usability assessment algorithm of virtual reality technology based on MA-BiGRU model; lastly, it analyses the feasibility and validity of the proposed method by using actual cases. The results show that, compared with other models conducted, the proposed method has a higher assessment and prediction accuracy, and it also effectively assists in completing the virtual reproduction of the cultural landscape promotion platform of Dongao Deng Village, Dongtou District, Wenzhou City, and improves the design effect of virtual reality technology in the cultural landscape promotion platform.**

Keywords*—Virtual reality technology; cultural landscape promotion platform; usability assessment algorithm; Mayfly algorithm

I. Introduction

With the continuous breakthrough of human science and technology, the visual experience of two-dimensional plane has slowly failed to meet the needs of people's life, so the three-dimensional virtual technology has gradually entered people's lives [1]. Virtual reality technology as one of the most promising technologies, with the development and improvement of hardware and software technology at this stage, has been widely used in a variety of industries, but virtual reality technology in the field of cultural landscape is lacking [2]. Currently, the main status quo of cultural landscape promotion research is reflected in the rigidity of cultural communication form, the lack of commercial profit model, combined with virtual reality technology to study the cultural landscape promotion platform not only improves the utilisation rate of cultural landscape resources, but also accelerates the speed of cultural landscape dissemination, but also realises the inheritance, innovation and development of cultural landscape [3]. The application of virtual reality technology in the cultural landscape promotion platform is mainly divided into three aspects: the application of virtual reality technology, the analysis of the application of virtual reality technology and the assessment of the usability of virtual reality technology [4].

The application of virtual reality technology in cultural landscape promotion platform is mainly the combination of virtual reality technology and cultural landscape promotion platform design; virtual reality technology application analysis is mainly to analyse the application of virtual reality technology in cultural landscape promotion platform index mention analysis; virtual reality technology usability assessment refers to the construction of virtual reality technology in cultural landscape promotion platform application analysis and assessment model, prediction and assessment of application situation. Cai and Jin [5] studied the combination of virtual reality technology and the protection and inheritance of village and town cultural landscape, and put forward the application strategy. Li and Wang [6] studied the application of virtual reality technology in cultural theme parks, and combined the elements of jin yong's martial arts world. Mo [7] studied the method of reproducing historical and cultural landscapes based on virtual reality technology. Yang and Sun [8] addressed the problem of virtual reality display in fuzimiao, and researched the historical humanistic landscape of cultural communication and tourism business promotion strategy. Dimitar et al [9] studied the usability assessment method of virtual reality technology based on machine learning, and at the same time for the machine learning algorithms fall into the local optimal problem using intelligent optimisation algorithms to find the optimal. By analysing the above literature, although there are some research results on the combination of virtual reality technology and cultural landscape promotion platform, there are some problems: 1) the role analysis of virtual reality technology on the design of cultural landscape promotion platform is not clear enough; 2) the extraction of indicators for the analysis of the application of virtual reality technology is not comprehensive and systematic enough; 3) the accuracy of the usability assessment of virtual reality technology is low; 4) the application of virtual reality technology fails to achieve the design efficiency [10].

In view of the above problems, this paper proposes a usability assessment method for cultural landscape promotion platform of virtual reality technology based on mayfly algorithm optimised two-way gated recurrent unit neural network. Focusing on the application of virtual reality technology in the design of cultural landscape promotion platform, the application process of VR in cultural landscape promotion platform is analysed, and the relevant usability assessment indexes are extracted; for the usability assessment of the cultural landscape promotion platform based on virtual reality technology,

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combining with the mayfly algorithm [11] to optimize the BiGRU neural network parameters [12], a MA-BiGRU-based feasibility assessment model of cultural landscape promotion platform based on virtual reality technology; through case study, the model proposed in this paper improves the feasibility assessment accuracy of cultural landscape promotion platform and verifies the feasibility of virtual reality technology in cultural landscape promotion platform.

This paper begins with a review of the status quo of cultural landscape promotion and how VR can address existing gaps. It then elaborates on the integration of MA and BiGRU for the usability assessment model, followed by an analysis of VR technology's impact on the design of cultural landscapes. The study incorporates actual case analysis from Dongao Ding Village, demonstrating the improved assessment and prediction accuracy of the proposed method compared to traditional models.

The paper is structured as follows:

- An overview of VR applications in cultural landscape promotion platforms.
- Explanation of the Mayfly Algorithm (MA) and the BiGRU model.
- The construction of a usability assessment method integrating MA and BiGRU.
- Application and evaluation of the proposed model using the Dongao Ding Village case.
- A discussion of results and performance improvements in the proposed approach.

II. Virtual Reality Application in Landscape Promotion

A. *Virtual Reality*

The use of Virtual Reality (VR) technology in cultural landscape promotion platforms is becoming more widespread, enabling users to experience cultural and tourism content in an immersive way through simulated environments.

1) VR technology: VR virtual reality technology can be regarded as a major development direction of simulation technology, which actually contains a variety of different technologies, such as human-computer interface, multimedia sensing, networking, etc. [13], as shown in Fig. 1. And the performance mode of VR virtual reality technology also contains several parts, such as environment simulation, external perception, natural skills, and sensing devices.

2) VR technology applications: According to the principle of VR technology, the application of VR technology in the cultural landscape promotion platform is mainly manifested in the following aspects [14]: 1) the construction of intelligent scenic spots; 2) the promotion of cultural and tourism virtual reality applications; 3) the digital promotion of national cultural industry parks; 4) the construction of digitally empowered cultural and tourism scenarios; and 5) the immersive tour experience of VR technology, as shown in Fig. 2.

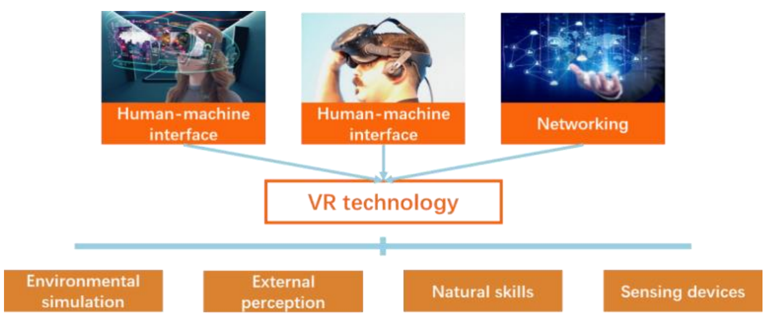

Fig. 1. Principle of VR technology.

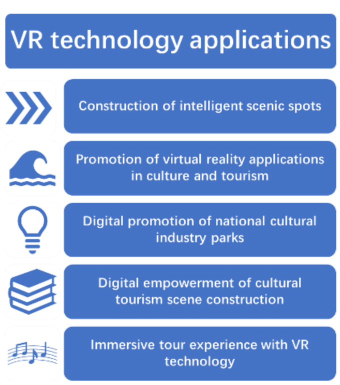

Fig. 2. Application of VR technology in the cultural landscape promotion platform.

3) Steps for the application of VR technology in cultural landscape promotion platforms: Virtual reality technology can not only bring visitors a rich and shocking visual impact, but also need to use virtual reality technology to clearly convey the information of the cultural landscape to the visitors. This paper takes the virtual reproduction of cultural landscape as a case study, based on the reality, adopts the multi-user interactive 3D modelling method of GIS, and applies the VR technology to the problem of cultural landscape reproduction [15], the specific steps are shown in Fig. 3.

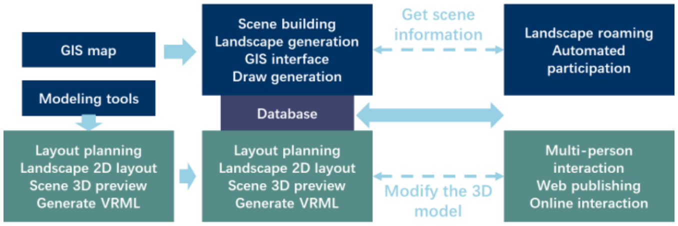

Fig. 3. Steps in reproducing the landscape virtual environment.

B. *Analysis of VR Application in Cultural Landscape Promotion Platforms*

According to the principles of demand, scientific, systematic and quantifiable (Fig. 4), by analysing the steps of applying VR technology in the cultural landscape promotion platform, this paper extracts the application analysis indicators from the four aspects of landscape environment, image, behaviour and spirit, as shown in Fig. 5. (1) Landscape environment includes indicators such as topography and geomorphology, climate, water bodies, flora and fauna, etc.; (2) Landscape image includes indicators such as residents, squares, historical sites, sculpture vignettes, etc.; (3) Landscape behaviour includes indicators such as daily behavioural habits, territorial construction methods, and landscape industry ideas, etc.; and (4) Landscape spirit includes feng shui, festivals and rituals, and symbolic images of the landscape, etc. [16].

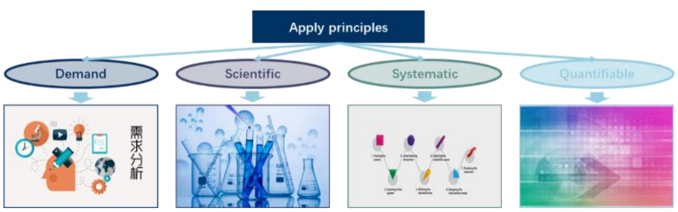

Fig. 4. Principles of application.

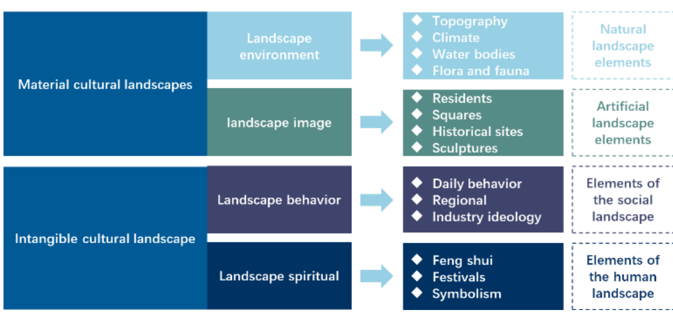

Fig. 5. Extraction of application analysis metrics.

C. *Application Analysis and Feasibility Assessment Programme*

By analysing the application of VR in the cultural landscape promotion platform, extracting the application analysis indexes, and after a series of data processing, the feasibility assessment model is constructed by adopting the feasibility assessment method of the cultural landscape promotion platform with improved data-driven algorithms to assess the feasibility of the application of virtual reality technology in the cultural landscape promotion platform, and the design of the scheme is specifically shown in Fig. 6. As can be seen from Fig. 6, the feasibility assessment study on the application of virtual reality technology in the cultural landscape promotion platform mainly includes key technologies such as the application analysis of VR technology, the collection of data processing, the construction of the feasibility assessment model, and performance analysis.

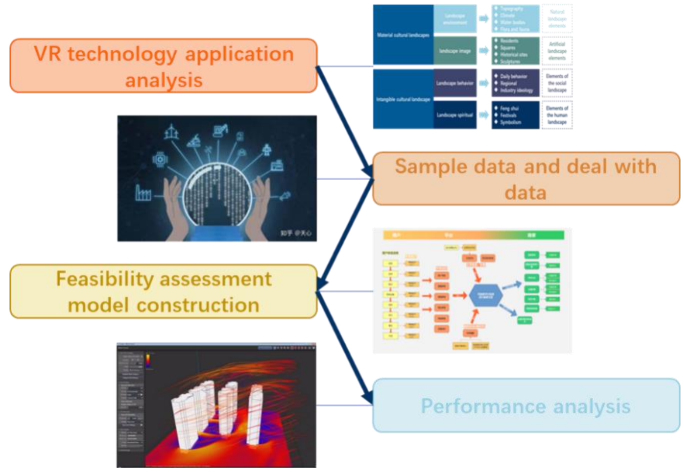

Fig. 6. Feasibility analysis assessment scenario for the application of virtual reality technology in a cultural landscape promotion platform.

III. Feasibility Assessment Algorithm for Virtual Reality Cultural Landscape Promotion Platform Based on MA-BiGRU Model

A. *Mayfly Algorithm*

Mayfly Optimization Algorithm (MA) [17] is an optimization algorithm that mimics the flight and mating behaviour of mayflies in nature. The Mayfly Algorithm is characterised by the fact that its population is divided into two parts: male mayflies move through the global optimum and their own historical optimum positions, while female mayflies move towards a mate that is superior to them, and perform a local search on their own if the mate is weaker than them. The algorithm generates new individuals by simulating the mating process of mayflies and retains the best individuals in the group through a selection mechanism [18].

1) MA algorithm optimisation strategy: The core optimisation strategies of the MA algorithm include the following:

a) Male Mayfly movement: The position update of male mayflies relies on their own speed and the experience of neighbouring individuals, and considering the specific behaviour of mayflies on the water surface, their speed update includes the influence of cognitive and social components, as shown in the following update model:

$$x_i^{k+1} = x_i^k + v_i^{k+1} \tag{1}$$

$$v_{ij}^{k+1} = g \cdot v_{ij}^k + a_1 e^{-\beta r_p^2}\left(p_{best_{ij}} - x_{ij}^k\right) + a_2 e^{-\beta r_g^2}\left(g_{best_{ij}} - x_{ij}^k\right) \tag{2}$$

$$p_{best_{ij}} = \begin{cases} x_i^{k+1} & f\left(x_i^{k+1}\right) < f\left(p_{best_i}\right) \\ p_{best_i} & f\left(x_i^{k+1}\right) \geq f\left(p_{best_i}\right) \end{cases} \tag{3}$$

$$g_{best} = \min\left\{ f\left(p_{best1}\right), f\left(p_{best2}\right), \cdots, f\left(p_{bestN}\right) \right\} \tag{4}$$

where x_i is the position of the ith male mayfly; v_i is the velocity of the ith male mayfly; k is the number of iterations; a_1 and are positive attraction coefficients, which measure the effect of experience gained from self and society, respectively, on the behaviour; g is the coefficient of gravitational force, which decreases with the number of iterations; $p_{best_{ij}}$ is the individual optimum; $g_{best_{ij}}$ is the global optimum; N is the total number of male mayflies in the swarm; r_g is the Cartesian distance between x_i and g_{best} ; r_p is the Cartesian distance between x_i and p_{best_i} :

$$\left\| x_i - X_i \right\| = \sqrt{\sum_{j=1}^{n} \left(x_{ij} - X_{ij} \right)^2} \tag{5}$$

The best male mayflies perform a unique nuptial dance step, moving up and down at different speeds. These male mayflies have a speed of:

$$v_i^{k+1} = v_i^k + d' \times r \tag{6}$$

where d' is the wedding dance coefficient and r is a random number between 0 and 1.

b) Female Mayfly movement: Female mayflies select mates during mating, and their positional updates depend on interactions with male mayflies. The velocity update of female mayflies takes into account attractive and random wandering factors to model their movement through the air. The position of the ith female mayfly is updated as:

$$y_i^{k+1} = y_i^k + v_i^{k+1} \tag{7}$$

Female mayflies and male mayflies are attracted to each other according to the principle of equal ranking of individual fitness, the position of female mayflies changes with the position of male mayflies with the same ranking, i.e.

$$v_i^{k+1} = \begin{cases} g v_{ij}^k + a_2 e^{-\beta r_{mf}^2} \left(x_{ij}^k - y_{ij}^k \right) & f\left(y_i\right) > f\left(x_i\right) \\ g v_{ij}^k + f_{f1} \times r & f\left(y_i\right) \le f\left(x_i\right) \end{cases} \tag{8}$$

where r_{mf} is the Euclidean distance between the ith female mayfly and the ith male mayfly; and f_{f1} is a random wandering coefficient used when the female mayfly is not attracted to the male mayfly.

c) Mayfly mating: The mating process involves the selection of male and female mayflies, usually based on their respective fitness values. Mating produces offspring that replace certain individuals in the population to maintain population diversity and facilitate the search process. The position of mated offspring is calculated as follows:

$$\begin{cases} o_1 = L \cdot m_{male} + \left(1 - L\right) \cdot f_{female} \\ o_2 = L \cdot f_{female} + \left(1 - L\right) \cdot m_{male} \end{cases} \tag{9}$$

where L denotes a random value; o_1 and o_2 initial values are set to 0; m_{male} and f_{female} are the position matrices of males and females, respectively.

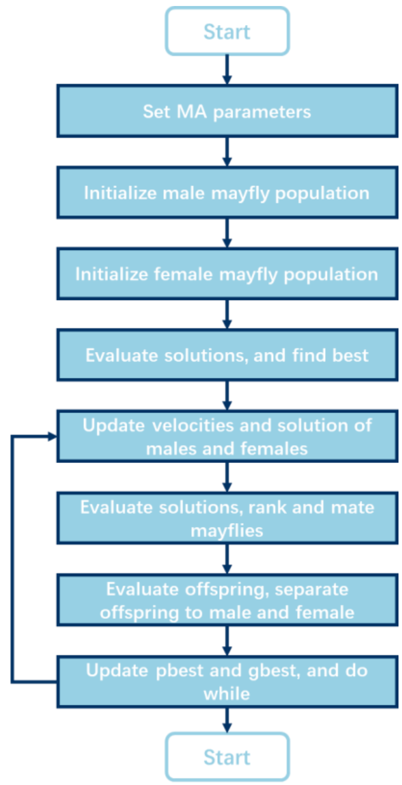

Fig. 7. Flowchart of MA algorithm.

d) Wedding dance and random wanderings: Wedding dance steps and random wandering make the algorithm search locally further, but fixed coefficients may make the mayfly iterate to a worse position later in the iteration. Therefore, make the dance step coefficients and random wandering coefficients decrease with the number of iterations, and update the arithmetic as:

$$\begin{cases} d_t = d_0 \delta \\ f_{fl_t} = f_{fl_0} \delta \end{cases} \tag{10}$$

Where, δ is a random factor with a value between 0 and 1.

e) Offspring variation: To deal with the case of premature convergence, so that the algorithm searches new regions of the space that have never been visited before, the offspring are randomly selected for the perturbed variant of the normal distribution, i.e.

$$o'_n = o_n + \sigma N_n(0,1) \tag{11}$$

where σ is the standard deviation of the normal distribution and $N_n(0,1)$ is the standard normal distribution.

2) MA algorithm flow: According to the optimisation strategy of MA algorithm, the flow of MA algorithm is shown in Fig. 7.

3) MA algorithm application: The mayfly algorithm can be applied to a wide range of optimisation problems, including engineering design [19], machine learning parameter optimisation [20], path planning [21], image segmentation [22] and other fields (Fig. 8). The strength of the algorithm lies in its ability to explore the search space efficiently and to improve search efficiency by simulating biological behaviour [19].

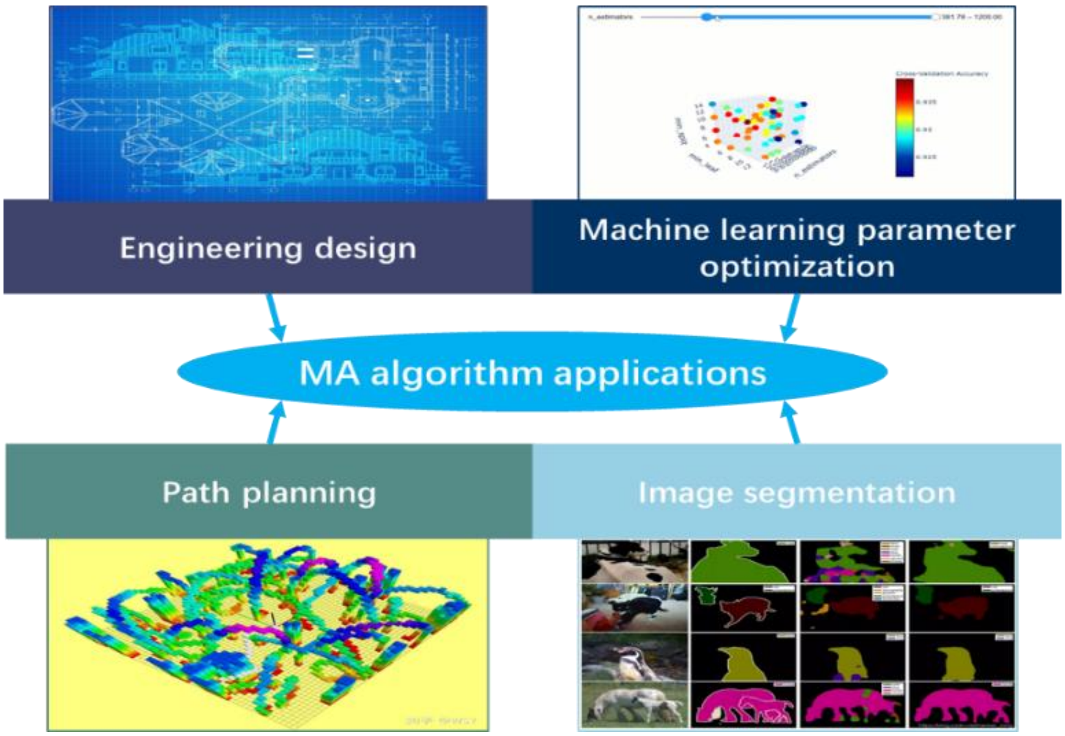

Fig. 8. Application of MA algorithm.

B. The MA-BiGRU Model

1) BiGRU network

a) BiGRU network fundamentals: BiGRU (Bidirectional Gated Recurrent Unit) network [23] is a special form of Recurrent Neural Network (RNN) that combines two directional GRU (Gated Recurrent Unit) layers to process sequence data. Compared to unidirectional RNNs, BiGRU is able to take into account both past and future information of sequence data to better understand contextual dependencies in the data, and the structure is shown in Fig. 9. The output of each time step depends not only on the information before that time point, but also on the information after, which makes BiGRU very useful in tasks such as text analysis, speech recognition, and natural language processing.

b) Characteristics of BiGRU: According to the structural principles of BiGRU network, its characteristics are as follows: i) Bidirectional structure: BiGRU consists of two GRU layers, one processing left-to-right information and the other processing right-to-left information; ii) Gating mechanism: the GRU unit contains reset gates and update gates, which control the flow of information and help the network to capture long-range dependencies; iii) Reducing the gradient vanishing problem: in comparison with the traditional RNN, GRU mitigates the gradient vanishing problem through the gating mechanism, enabling the network to learn long-distance dependencies more efficiently; iv) Parameter efficiency: although BiGRU is able to capture bi-directional information, it usually has fewer parameters than BiLSTM (Bidirectional Long Short-Term Memory), which may result in faster training speeds and lower memory requirements, as shown in Fig. 10.

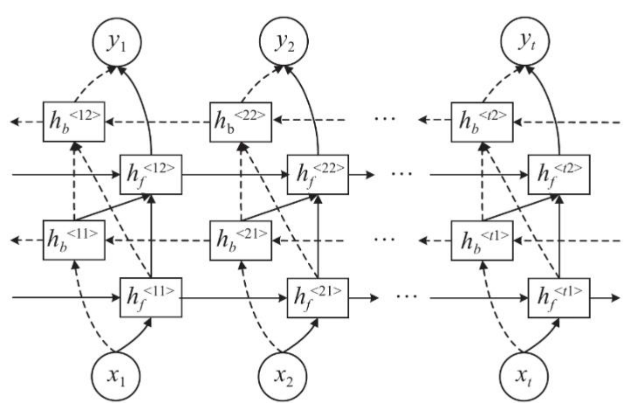

Fig. 9. Structure of the BiGRU model.

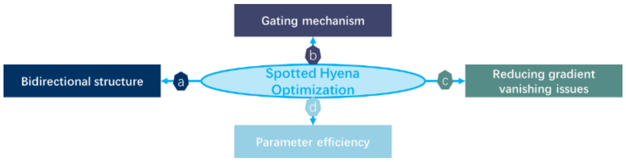

Fig. 10. BiGRU characteristics.

c) Application of BiGRU: BiGRU network is widely used in a variety of deep learning tasks due to its ability to process sequence data efficiently. For example, it can be used in natural language processing tasks such as text sentiment analysis, named entity recognition, and machine translation, as well as in the fields of time series prediction and speech recognition [24] (Fig. 11).

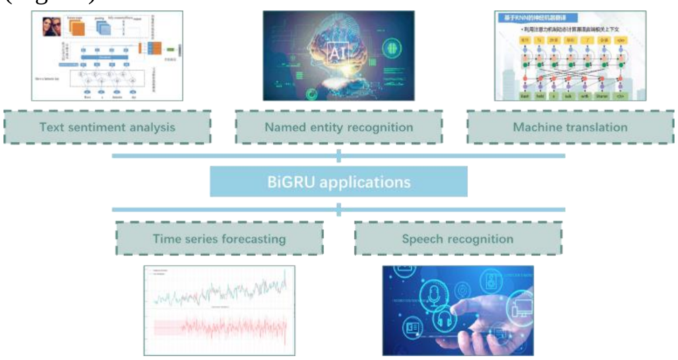

Fig. 11. BiGRU application.

2) MA-BiGRU model

a) Optimising variable coding: In the optimisation variables section, this paper uses real number coding for Update Gate, Reset Gate and Candidate State Weights and Bias of BiGRU network as shown in Fig. 12.

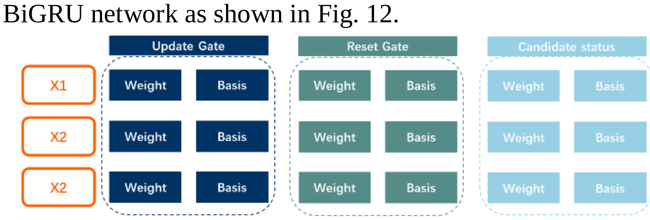

Fig. 12. Optimising the coding structure of decision variables.

b) Adaptation function setting: The MA algorithm is introduced mainly to improve the mapping accuracy of BiGRU model, so in this paper, RMSE, MAPE, MAE, R2 are selected as the fitness function in the optimisation process of MA algorithm (Fig. 13), and the specific fitness function is calculated as follows:

$$F(x) = w_1 f_{RMSE} + w_2 f_{MAPE} + w_3 f_{MAE} + w_4 \left(1/ f_{RMSE}\right) \tag{12}$$

where w_1 , w_2 , w_3 and w_4 are the weights of RMSE, MAPE, MAE, and R2 , respectively.

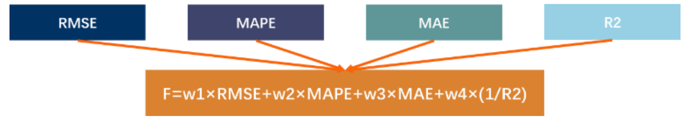

Fig. 13. Structure of the fitness function.

c) Analysis of model steps: According to the decision variable coding and fitness function settings, the MA-BiGRU model is constructed by determining the parameters of the MA algorithm, generating the initial population, updating the update gates, reset gates, and candidate state weights and biases of the BiGRU network by using the optimisation strategy of the MA algorithm, comparing the values of the fitness function, and obtaining the optimal update gates, reset gates, and candidate state weights and biases of the BiGRU network, and thus constructing the MA-BiGRU model, and the pseudo-code is shown in Fig. 14. Fig. 15 shows the schematic diagram of SHO-LSTM structure.

```
Algorithm 1: BiGRU based on MA
Determine optimized variables, including weights and basis;
Set MA algorithm parameters;
Encode mayfly population;
Calculate fitness, and update best mayfly;
Do While stop criteria are not met
    Update velocities and solutions of males and females;
    Evaluate solutions;
    Rank the mayflies;
    Mate the mayflies;
    Evaluate offspring;
    Separate offspring to male and female randomly;
    Replace worst solutions with the best new ones;
    Update pbest and gbest;
End While
Output best parameters of BiGRU;
Build MA-BiGRU model.
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Fig. 14. MA-BiGRU pseudo-code.

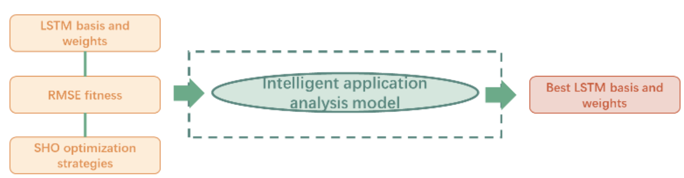

Fig. 15. Schematic diagram of SHO-LSTM structure.

IV. Example Analyses

A. (1) Introduction of Examples

In order to verify the application of VR technology in cultural landscape promotion platform analysis and usability assessment algorithm effectiveness, this paper takes Dongao Ding Village in Dongtou District, Wenzhou City as a case study. Dongao Ding Village is located in the southeast end of Dongtou Island. Dongao Ding village coastline reefs are strange and strange, and the sandy beach is broad and soft, which has an important economic location advantage (Fig. 16).

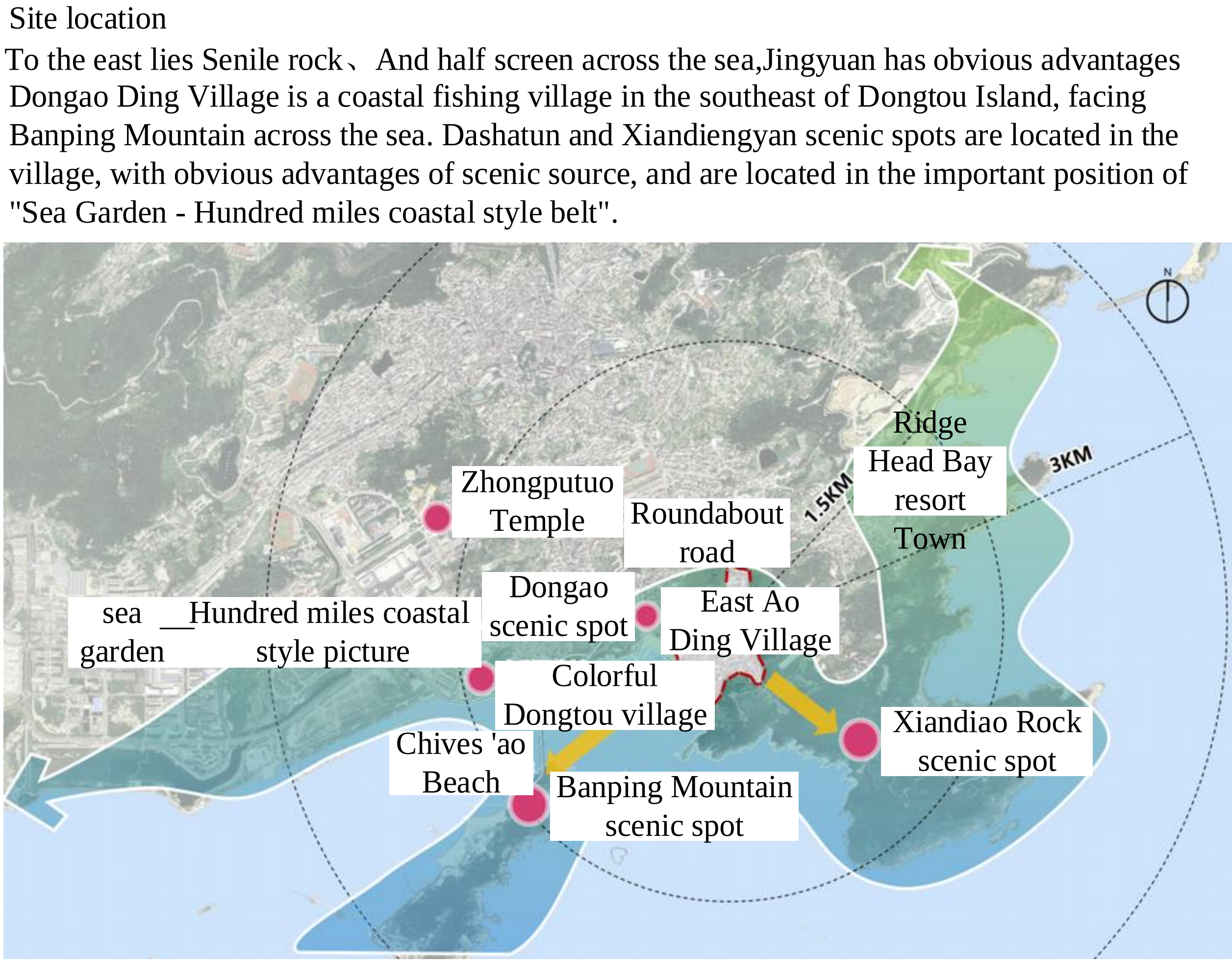

Fig. 16. Dongao Ding Village, Dongtou District, Wenzhou City, China.

In the usability evaluation algorithm experiments, this paper adopts LSTM, GRU, BiGRU, MA-BiGRU models as the analysis and comparison algorithms; LSTM, GRU, BiGRU are optimised iteratively using Adam's algorithm, the activation function is the Relu function, and the number of nodes in the hidden layer is 50; the NP of MA algorithm is set to 100, and the Max_iteration is set to 1000.

B. Example Analysis

1) Application results: Taking the landscape of Dongao Teng Village as an example, this paper uses VR technology in the cultural landscape promotion platform application analysis to extract the landscape elements of various cultural landscapes, and the specific results are shown in Fig. 17.

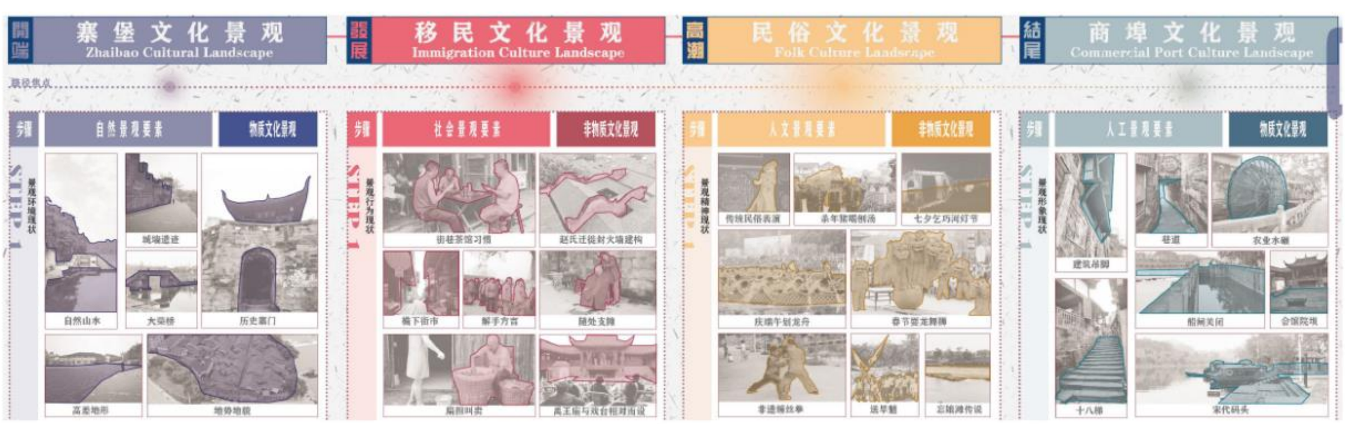

Fig. 17. Cultural Landscape Elements of Dongao Ding Village.

Fig. 18 gives the effect of promoting the historical and cultural landscape of Dongao Ding Village. Fig. 19 gives the effect of virtual reproduction of cultural landscape based on VR technology.

Fig. 18. Historical and Cultural Landscape Promotion Effect of Dongao Ding Village.

Fig. 19. Effect of virtual reproduction of the historical and cultural landscape of Dongao Ding Village.

2) Usability evaluation algorithm analysis: In order to test the effectiveness of the usability evaluation algorithm, this paper uses 73 samples for training and tests on samples 73-80, and the analysis results are shown in Fig. 20 and Fig. 21. Fig. 20 demonstrates the comparison of the evaluation level results of the usability evaluation algorithms based on LSTM, GRU, BiGRU, and MA-BiGRU models.

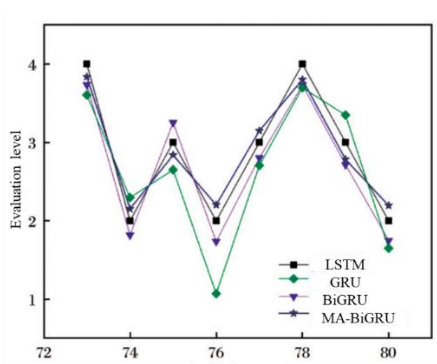

Fig. 20. Assessment level results.

The absolute errors of the usability evaluation algorithms based on LSTM, GRU, BiGRU, and MA-BiGRU models are plotted in Fig. 21. From Fig. 21, it can be seen that MA-BiGRU has the smallest absolute error.

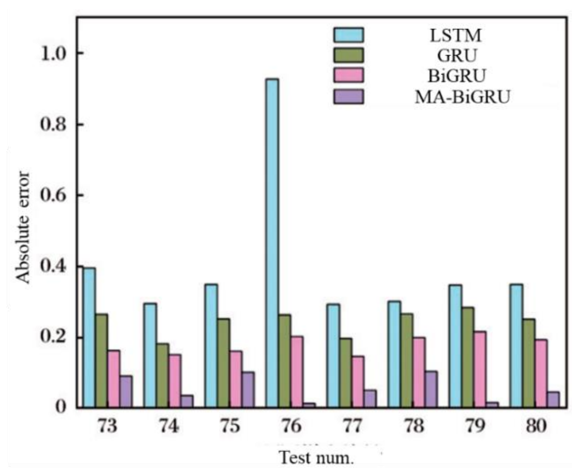

Fig. 21. Comparison of absolute error results.

V. Conclusion and Outlook

This paper proposes an application analysis and usability assessment algorithm of VR technology in cultural landscape promotion platform based on MA algorithm and BiGRU network. Taking the application of VR technology in the cultural landscape promotion platform as the research object, analysing the application situation, designing the application feasibility assessment scheme, and combining the MA algorithm and BiGRU network, an application analysis and usability assessment method based on the MA-BiGRU model is proposed. Taking Dongao Ding Village as a case study for analysis, the results show that the assessment method based on MA-BiGRU model has the best assessment and prediction accuracy and can improve the application effect.

Despite these promising results, the study has some limitations. First, the focus on a single case study limits the generalizability of the findings. Second, the computational complexity of the MA-BiGRU model may pose challenges for real-time usability in larger-scale projects.

Future research could explore three key directions: 1) Expanding the usability model to encompass a broader range of cultural landscapes across different regions. 2) Developing a more computationally efficient version of the MA-BiGRU model to facilitate real-time usability. 3) Integrating other machine learning models or algorithms to enhance the robustness and flexibility of the assessment framework. By addressing these areas, future work can further refine VR technology's role in cultural landscape promotion and its practical applications.

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