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Article

Evaluating Cultural Landscape Remediation Design Based on VR Technology

Zhengsong Lin [1], Lu Zhang [2], Su Tang [3], Yang Song [4] and Xinyue Ye [4,*]

1 School of Art and Design, Wuhan Institute of Technology, Wuhan 430205, China; lzs2020@wit.edu.cn
2 School of Arts Communication, China University of Geosciences, Wuhan 430074, China; zl2015@cug.edu.cn
3 Foreign Language Department, Wuhan Huaxia University of Technology, Wuhan 430223, China; tstessie@hxut.edu.cn
4 Department of Landscape Architecture and Urban Planning, Texas A & M University, College Station, TX 77840, USA; yangsong@tamu.edu
* Correspondence: xinyue.ye@tamu.edu

Abstract: Due to the recent excessive pursuit of rapid economic development in China, the cultural heritage resources have been gradually destroyed. This paper proposes cultural recovery and ecological remediation patterns, and adopts virtual reality (VR) technology to evaluate the visual aesthetic effect of the restored landscape. The results show that: (1) the average vegetation coverage increased, providing data support for remediation design evaluation; and (2) the fixation counts and average saccade counts of the subjects increased after the remediation design, indicating that the restored cultural landscape reduced visual fatigue and provided a better visual aesthetic experience. Furthermore, the comparative analysis of the quality of the water environment shows that the remediation design project improved the ecological environment quality of the relics area. The results of this study will contribute to rural revitalization in minority areas in southwest China.

Keywords: VR technology; visual aesthetic experience; ecological remediation evaluation; Tujia settlement area

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1. Introduction

Cultural heritage was formally introduced at the 1972 UNESCO Convention for the Protection of the World Natural and Cultural Heritage, and includes mainly cultural relics, architectural complexes, and other relics [1]. In 2002, the 26th session of the World Heritage Committee adopted the Budapest Declaration, which juxtaposed cultural landscapes and intangible cultural heritage (ICH). It proposed to seek a balanced relationship between World Heritage conservation and sustainable development [2]. In 2015, the 39th World Heritage Committee initiated a strategy for World Heritage and Sustainable Development, emphasizing the techniques and methods of cultural heritage in sustainable conservation and development [3].

The research on eco-landscapes in cultural heritage mainly includes two aspects: the definition of the concept of cultural heritage and the study of its conservation and inheritance. Kurin [4] and Liu [5] gave the first clear definition of tangible cultural heritage, which was rapidly applied worldwide. Taylor, R et al. [6], Konkol, N et al. [7] analyzed the concept of cultural heritage, its connotation, and the sustainability of conservation and inheritance. Mitchell [8] and Munjeri [9] first introduced the concept of ICH, and described its social significance and the challenges in the process of sustainable development. Since the publication of the UNESCO Operational Guidelines for the Implementation of the World Heritage Convention, traditional settlements, monuments and arts, and cultural landscapes have been added to the cultural heritage list, leading to more complex conservation efforts [10]. Rapid economic growth, may result in divergence between cultural heritage conservation and development. Qiu, Q and Zhang, M [11] and Jung, K et al. [12] argue that cultural heritage conservation and development have a positive interaction, which is conducive to improving social and economic benefits, and scientific and reasonable development also positively helps cultural heritage conservation and inheritance. In addition, Ruan, Y [13] state that the two have a reverse interaction, and unreasonable development will cause secondary destruction of cultural landscape resources.

Therefore, there is still no consensus on the conservation and development of cultural heritage, especially in China. Domestic research on cultural heritage conservation and development has been abundant in recent years, but there are shortcomings. The perspectives mostly focus on the broad picture of the overall development of cultural heritage and lack specific discussions on single cultural landscape resources, especially in the minority populated areas [14,15]. In terms of content, the cultural tourism development process uses replication models and development risk assessment, but lacks any exploration of deeper issues such as respecting local topographical features, historical heritage and folklore [16–19]. Due to the application of technology, the need to battle poverty and the construction of "beautiful countryside", the development of cultural tourism projects in the Tujia settlement area has seen explosive growth. The application of technology and the need to battle poverty and construct "beautiful countryside" have contributed to explosive growth in the development of cultural tourism projects in the Tujia settlement area. However, residual waste such as paint, cement residues and metal compounds used in the development process is very likely to cause secondary pollution of water bodies and soil, adding a new workload to the work of cultural tourism development [20–22]. In terms of research methods, more qualitative methods are currently used to describe issues related to cultural landscape conservation, but they lack the data statistics and model validation components of quantitative analysis studies, which provide more objectivity and accuracy; thus, the proposed decision-making recommendations may lack relevance and practical significance [23,24].

This paper proposes a remediation design strategy including the activation of the "Linjun culture" and an eco-landscape remediation pattern to restore and recreate the cultural landscape resources in the study area, adopts VR technology to evaluate the visual aesthetic effect of the restored cultural landscape, and uses the water environment quality comparison method to verify the feasibility and effectiveness of the remediation design. The proposed method provides new technical paths for the conservation of cultural landscape resources in minority populated areas and provides an example of the integration of digital culture into the Revitalization Strategy and the construction of "Beautiful China".

2. Data Sources and Processing

2.1. Study Area

The Tujia are an ethnic group with a long history, located in the high mountainous areas adjacent to Hubei Province, Hunan Province, Chongqing City and Guizhou Province, with a DEM between 1000–1500 m. The area reaches the Fanjing Mountains and the Wu River in Guizhou to the west, the Jianghan Plain to the east, the Wushan Yangtze River to the north, and the Lanli and Zhiyuan to the south, covering an area of about 100,000 square kilometers (108°23′15′′–111°21′43′′, and 29°12′45′′–31°12′56′′ N). The heart of China is located in the area at 30° N, with a land-use classification and an average vegetation cover of 62.56%. The topographical features of the study area are complex and varied, and the settlement areas are mainly distributed along rivers and roads. The Tujia nationality has a population of about 8,353,900, and are the eighth largest ethnic minority in China. The study area has a typical subtropical monsoon climate with an average annual temperature of 13.5–17.5 °C and an average annual rainfall of 1200–1500 mm [25]. According to a Google map search, there are hundreds of cultural relics in the study area. There is a popular proverb, "Xiangwang Tianzi has a horn that blows a clear river" and the local Tujia people take the image of Xiangwang Tianzi as the collective memory for protecting the water environment [26]. The three major functions of the Linjun Temple, Bagong Temple and Xiangwang Temple in Linjun include interacting with the environment, i.e., "worship", "lighthouse" and "cohesion", and they were also used to promote social stability during the Emperor Kangxi and Emperor Qianlong period. Since reform and opening-up in China, residents have pursued rapid social and economic development and made large investments in local high-speed railroads and highways. The functional influence of ancestral temple relics distributed on the ancient Sichuan Salt Road and Ten-Thousand-Mile Tea Road, and the role of ancestral relics in reminding people to protect the ecological environment has slowly faded in the last 40 years. As a result, cultural landscape resources are gradually destroyed and disappear. Therefore, strengthening the conservation and inheritance of cultural heritage resources in the study area is of significance as a practical example of the digital culture Revitalization Strategy and the construction of Beautiful China, as shown in Figure 1.

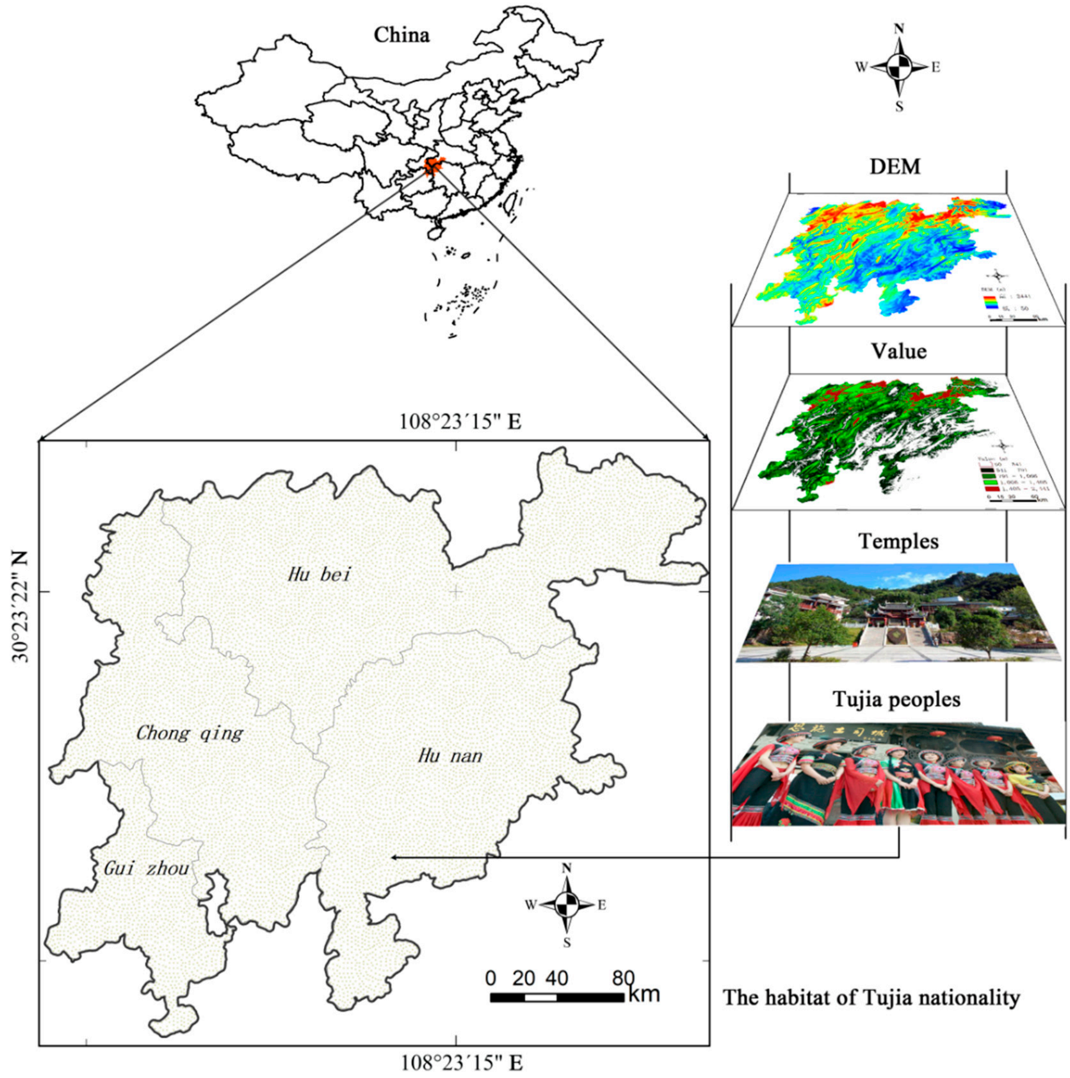


Figure 1. Tujia settlement area.

2.2. Data Sources and Pre-Processing

Three main sources of data regarding the design of ecological remediation of cultural landscape resources were used. Firstly, remote sensing image data were obtained from the remote sensing image taken by GF-2 with a resolution of 2 m, and were pre-processed by geographic alignment, geometric correction, radiation correction and image fusion using ENVI5.2 and Arc GIS10.2 software to obtain data for the natural environment of the cultural landscape area. Secondly, social and environmental data such as water, soil, gas, and solid waste in the cultural landscape area were obtained from the National Bureau of Statistics (NBS), and the pollution limits were determined based on national evaluation standards. Thirdly, samples were taken through field surveys, and the corresponding data were obtained by field and indoor experiments as a way of supplementing data sources other than the NBS, as shown in Table 1.

Table 1. Data sources and processing statistics.

S/N	Classification	Monitoring Contents	Data Sources
1	Waste pollutants	water, soil, gas and solid pollutants	Field and indoor experiment method
2	Natural environment	geological landscape, elevation (DEM), slope gradient and direction	Processing by ENVI5.2 and Arc GIS10.2 software
3	Social environment	number of people, floor area, and land use in the relics area	Field surveys

Note: The evaluation of waste pollutants was carried out with reference to China's minimum standard limits (Grade III).

3. Methodology of Design and Evaluation

This study has three analytical components: firstly, the remediation design for the "Linjun Culture" through the collective memory of the Tujia family and the unique characteristics of the Tujia settlement area, which also proposes an "activation + remediation" scheme to ensure the integrity of the national ecological barrier [27,28]; secondly, the VR evaluation uses VR technology to quantitatively analyze the visual aesthetic effect of the remediation design; and finally, a field environmental data comparison, which collects water data for environmental quality comparison analysis to verify the feasibility of the method, as is shown in Figure 2.

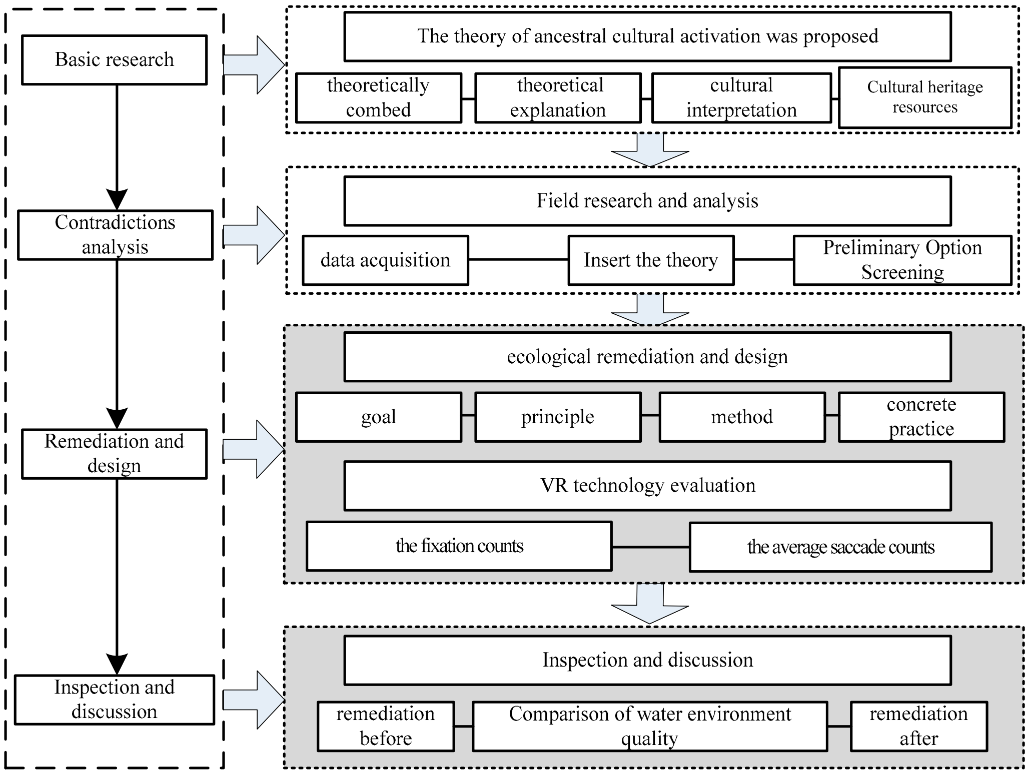


Figure 2. Evaluation methods and steps of VR technology evaluation.

3.1. Remediation Design Process

3.1.1. Conceptual Foundation

The ancient indicates that Linjun held high status in the Tujia region in literatures such as "The predecessors of Linjun have always come from a wizard family", "Since the five families competed to become the leader and Wuxiang remained aloof, so they elected him as the leader, calling him Linjun.", and "Xiangwang Tianzi has a horn that blows a clear river", which. A large number of temple relics related to Linjun were built during the Emperor Kangxi and Emperor Qianlong period, and these became an important contemporary cultural heritage resource [29]. Following the destruction caused by geological and geomorphological disasters in the Wuling Mountains and the expansion of towns and villages, as well as the rise of the local high-speed railroads and highways, the cultural relics distributed along the ancient Sichuan Salt Road and the Ten-Thousand-Mile Tea Road lost their unique functions of "worship", "lighthouse" and "cohesion", and their role in warning people to protect the ecological environment has gradually faded [30]. Therefore, this study aims to rebuild the image of Linjun and restore the unique functions of "worship", "lighthouse" and "cohesion" of the cultural relics, carries out ecological landscape remediation design for the cultural relics area, and build the original "worship" function into the settlement's public ritual activity area and recreational gathering square, etc. This could serve as protection against mountain fires during important holidays and as a recreational relic for the settlement during leisure time.

The "Internet+" model was used to transform the "lighthouse" function into an "online popular ancient road" and a map navigation marker was used to enhance the identification of the settlement by self-drivers and tourists. The "cohesion" function was used to restore the "Linjun Mausoleum" at the birthplace of Linjun, making it a hub for millions of Tujia people to trace their roots, prompting the memory of Linjun to turn "waste" into "treasure" and "ugly" into "beautiful" in the process of "activation", and extending new ecological protection benefits, economic benefits and social welfare benefits.

3.1.2. Ecological Landscape Remediation Design Methods and Technical Tools

The ecological remediation design of the cultural landscape was carried out by reference to the national Law on the Protection of Cultural Relics, the Technical Specification for Bare Slope Revegetation and Technical Requirements for Relics Utilization after Stabilization in Municipal Solid Waste Landfill (GB/T25179—2010), and other remediation design guidelines to restore the unique functions of cultural heritage relics of "worship", "lighthouse" and "cohesion", and to guide the remediation design of cultural heritage areas in terms of architecture, vegetation, ancient roads, water bodies and rituals, etc., as well as to develop an operation mechanism for the restoration practice. The specific restoration process was as follows.

The remediation design of the "worship" function was implemented with the help of drones, total station and TITAN360 imaging technology. The overall and local effects of "architecture–vegetation–ritual" was created, reflecting an atmosphere of solemnity and reminding people to protect the ecological environment. The first method was to restore the buildings, ritual platforms and public facilities in the relic areas that are well preserved, have a flat terrain and occupy a large area, so as to provide public ritual activity areas and recreational gathering squares for the settlement, which could serve as protection against mountain fires during important holidays and as a recreational relic for the settlement during leisure time. The second method was to create a solemn atmosphere in the landscape of the ancestral temples by using a linear planting method in accordance with the historical lineage of the cultural relics. The third method used VR technology in the design of ritual restoration to simulate the ritual scene and to achieve virtual immersion in the ritual scene, as shown in Figure 3.

Figure 3. Scene simulation in the process of landscape reconstruction design.

The remediation design of the "lighthouse" function was implemented with the help of remote sensing image, GIS and LIM model technology, and carried out in the form of "ancient road + vegetation", with a focus on the functional role of modern practical subjects. Specifically, the first method used the "Internet+" model to include the ancient roads, which have lost their original functions with the rise of high-speed railroads and highways, in the List of Cultural Heritage, for example, the "Ancient Tea-Horse Road", to invite a "network anchor" to strengthen the publicity, and transform the ancient roads into a tourism-oriented "online popular ancient road". Based on the complex topographic features of the Wuling Mountains area combined with the pace of beautiful countryside construction, the second method was to transform the cultural landscape area into map navigation identification markers for settlements and administrative villages to strengthen the identification function of the settlement areas for self-drivers and tourists, as shown in Figure 4.

Figure 4. Field survey and data collection scenarios.

The remediation design of the "cohesion" function focused on restoring the Linjun Mausoleum at the birthplace of Linjun, making it a hub for millions of Tujia people to trace their roots, and at the same time making the ritual area, the online popular ancient road and the Linjun Mausoleum into a tourism industry chain that attracts both Tujia people to trace their roots and foreign tourists.

3.2. Evaluation and Analysis of Ecological Landscape Remediation Design Effects

3.2.1. Statistics for Landscape Patches after Ecological Remediation Design

The specific operational steps of the ecological landscape restoration project were as follows. Firstly, the geospatial data cloud was used to extract the remote sensing image of Gaofen-2, and ENVI 5.2 software for atmospheric correction and human eye supervision to classify and extract the land class data; secondly, Arc GIS10.2 software was employed to classify and extract the geographical type information, and the LIM model was used for landscape patch data collection so as to understand the changes in the cultural landscape pattern after ecological remediation. This reflects the visual changes in the cultural landscape such as construction, vegetation and water bodies in the relics area before and after the remediation design project, providing data to support the visual aesthetic evaluation. Table 2 shows the conceptual renderings and design after ecology remediation design and the landscape patch data.

Table 2. Cultural landscape pattern after the remediation design project.

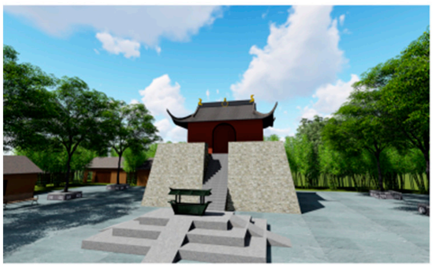
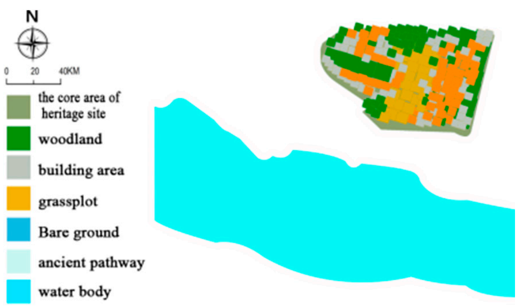
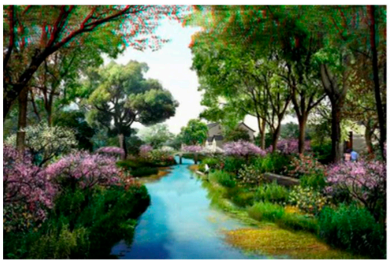
S/N	The Landscape Spatial Pattern	The Cross-Section Data Statistics
A. Xiangwangjie Temple		
B. Wulingshan Temple		
C. Shizhuguan Temple		

Table 2. *Cont.*

S/N	The Landscape Spatial Pattern	The Cross-Section Data Statistics
D. Wuluozhonglishan Temple		
E. Hanyangqiao Temple		

Note: Groups B, C and E images are being built.

According to landscape patch data extracted by the LIM model, the new completed area based on our remediation design has increased the vegetation cover in the restored relics area from 46.57% in 2016 to 65.44% in 2019. Among them, the vegetation cover of the Shizhuguan Temple, Wuluozhonglishan Temple and Hanyangqiao Temple increased the most, by 21.25%, 18.94% and 16.21%, respectively, followed by Miaolingshan Temple and Xiangwangjie Temple with 14.59% and 11.34%, respectively. Moreover, the remediation and reconstruction design of the buildings, gatehouses and ancient roads in the core area of heritage relics has increased the number of local Tujia people and domestic and foreign tourists traveling and sightseeing, providing a reference for the practice of the digital culture Revitalization Strategy and the construction of Beautiful China in the minority areas of southwest China.

3.2.2. Evaluation and Analysis of the Visual Aesthetic Effect of the Landscape

Unlike traditional questionnaire interview methods [31], hierarchical analysis methods [32] and fuzzy comprehensive evaluation [33], VR technology, which has emerged in recent years, can take people into immersive experiences in virtual or realistic environments by simulating environments, sensing nature and sensing devices. The use of VR technology to evaluate the visual aesthetic effect of the cultural landscape after ecological remediation design not only provides visual comfort to the audience or visitors, but also serves to reduce people's aesthetic fatigue and perceive the natural beauty [34,35].

(1) Experimental design

This study explores whether the visual aesthetic effect can be enhanced after the restoration of cultural landscape design by employing a subject design with a single factor and two variations. The independent variable is the change before and after the cultural landscape restoration design, and the dependent variable is the result of the evaluation of the landscape's visual benefit.

(2) Experimental equipment and materials

A Tobii X2-30 virtual eye tracker from Germany and THUNDEROBOT III computer operating platform were used as the experimental instruments. The ErgoLAB man-machine environment synchronization platform from Beijing Jinfa Technology Company was used as the software. The combination of hardware and software ensures the scientific and reasonable assessment of the visual aesthetic effect of the landscape.

According to the preliminary interviews, 18 cultural heritage protection experts and students interested in VR technology were randomly invited from the research area as subjects, with an average age of 35. The subjects were assigned to the expert group and student group, with 9 people in each group and a male/female ratio of 1:1. The hearing and sight, and sight-corrected visual acuity of all subjects were normal.

The experimental stimulus material was taken from the image of the cultural site section before ecological restoration, which was extracted in the research area by Adobe Illustrator software, the image of the current situation after restoration design, and the simulated image in the construction. The experimental stimulus materials total 5 groups of 10 units.

(3) Experimental process

The head of the experiment organized the subjects to get them familiar with the experiment environment, procedures and instructions at the experiment site, so as to ensure the accuracy and reliability of the experimental process and eliminate the possible interference factors in this process. Before the experiment, the instructions were repeated to ensure that the subjects entered the experiment quickly, and to alleviate the influence of emotional factors such as anxiety and excitement on the experimental results. The whole experimental process included three stages: the pre-test stage, experimental stage and post-test stage.

In the pre-test stage, all subjects provided demographic information (including gender and age), and were divided into groups based on job attributes. All devices were then calibrated on the ErgoLAB human–computer environment synchronization platform to ensure that the error of the five sight points was within 20 pixels. After the mapping function generated by the eye movement parameters has been determined, the test could proceed. The test time was limited to 1 min to ensure the integrity of the experimental program.

In the experimental stage, the head of the experiment required the subjects to independently read the 5 groups of stimulus image materials before and after the restoration design in accordance with the instructions for 3 min, and recorded the values of various eye movement parameters in real time and mapped the gaze points. The above steps were repeated until the 18 subjects finished the experiment, the experimental scenario is shown in Figure 5.

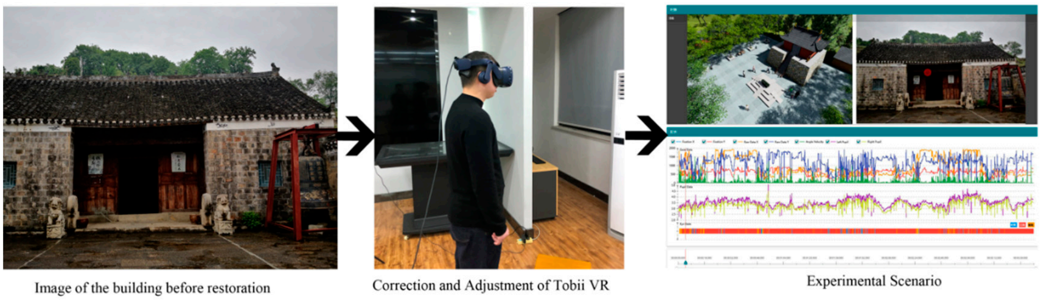


Figure 5. Experimental scenario of the ErgoLAB human-machine environment synchronization platform.

In the post-test stage, the head of the experiment imported the experimental data into EXCEL, eliminated 1 piece of datum with a large error in each group, and obtained 16 pieces of saccade tracking data. Then, SPSS21 was used to analyze the reliability of the experimental data, and the results showed that the α value was 0.882, $0 < \alpha < 1$, indicating that the data were reliable.

4. Results

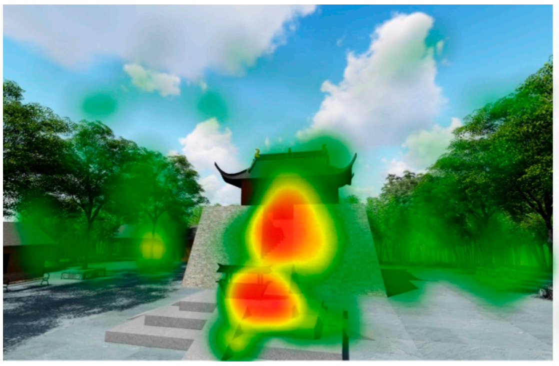
4.1. VR Experimental Results and Evaluation and Analysis

VR technology was used to compare and analyze the changes in the visual effects before and after restoration, which reflected the practical significance of the visual aesthetic evaluation. Through the instructions of the head of the experiment and repeated tests, the two groups of experimental data showed a good degree of fit. According to the statistical results of the fixation counts and the average saccade counts during the experiment, the subjects were usually focused on the restored cultural landscape on the left side first during the experiment, accounting for 86.29% of the total saccade counts, indicating that this area received the highest degree of attention from the subjects. The saccade counts for the cultural landscape before restoration only accounted for 13.71%, indicating that the subjects were immersed in the process due to visual aesthetic fatigue or low interest level, as shown in Table 3. According to the distribution of the subjects' fixation hot spots (Figure 6), the subjects might choose the areas with better visual benefits to focus on according to their own interests or visual aesthetic effects, which is conducive to improving visual aesthetic interests on one hand, and to reducing subjects' feelings of visual fatigue and improving aesthetic interests on the other hand.

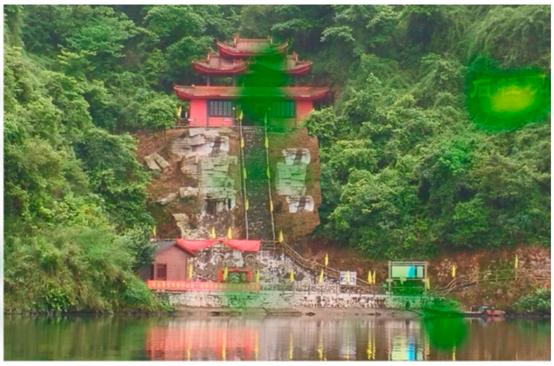
Table 3. Statistics on the fixation counts and average saccade counts of subjects after cultural landscape remediation.

S/N		ST		XT		WT		MT		HT	
		Average Saccade Counts	Fixation Counts (N)	Average Saccade Counts (N/s)	Fixation Counts (N)	Average Saccade Counts (N/s)	Fixation Counts (N)	Average Saccade Counts (N/s)	Fixation Counts (N)	Average Saccade Counts (N/s)	Fixation Counts
Experts	1	6.33	492	5.78	524	6.45	524	6.54	546	6.46	468
	2	5.62	501	5.89	503	6.03	522	6.68	523	6.68	487
	3	7.12	495	6.47	509	5.98	523	5.58	517	6.46	502
	4	6.45	501	6.52	501	6.01	511	5.89	523	6.04	511
	5	6.78	523	5.77	503	6.02	486	6.47	501	4.65	495
	6	6.35	496	5.87	499	5.78	499	6.48	535	5.46	489
	7	7.07	497	6.34	487	5.68	526	6.33	537	6.34	479
	8	7.22	531	6.12	512	6.34	507	6.04	504	6.33	478
Students	1	7.04	531	6.87	493	5.95	503	5.89	544	5.87	495
	2	6.14	514	6.43	532	5.76	498	6.23	522	5.88	492
	3	7.06	533	6.11	522	6.11	538	5.56	536	6.23	523
	4	6.76	521	5.78	546	5.78	577	6.04	567	6.21	545
	5	5.89	534	6.79	568	6.23	581	5.66	549	6.32	548
	6	6.54	545	6.03	534	6.55	544	5.67	578	6.04	498
	7	6.56	567	5.98	589	5.87	602	5.59	584	6.56	509
	8	7.47	678	6.03	524	5.97	514	6.26	519	6.32	493

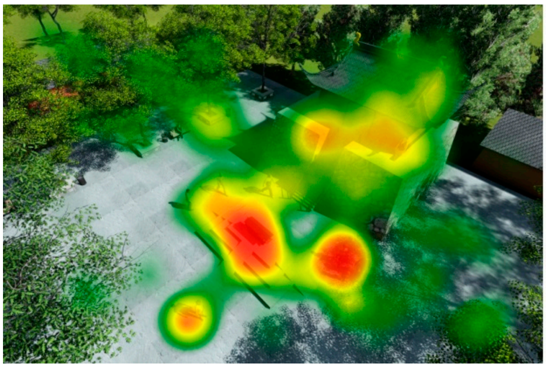
Note: Groups ST, XT, WT, MT and HT come from Shizhuguan Temple, Xiangwangjie Temple, Wuluozhonglishan Temple, Miaolingshan Temple, and Hanyangqiao Temple.



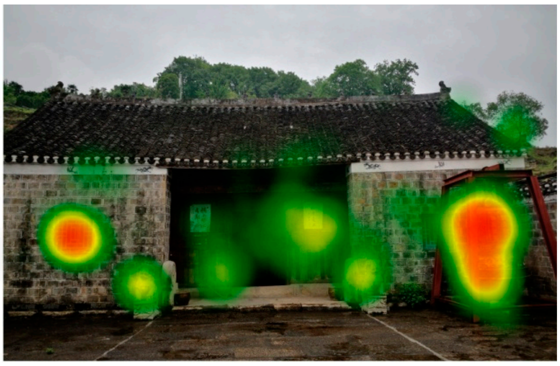
A1. After remediation



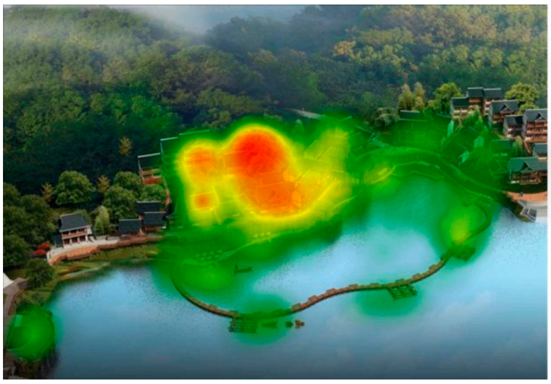
A2. Before remediation



B1. After remediation



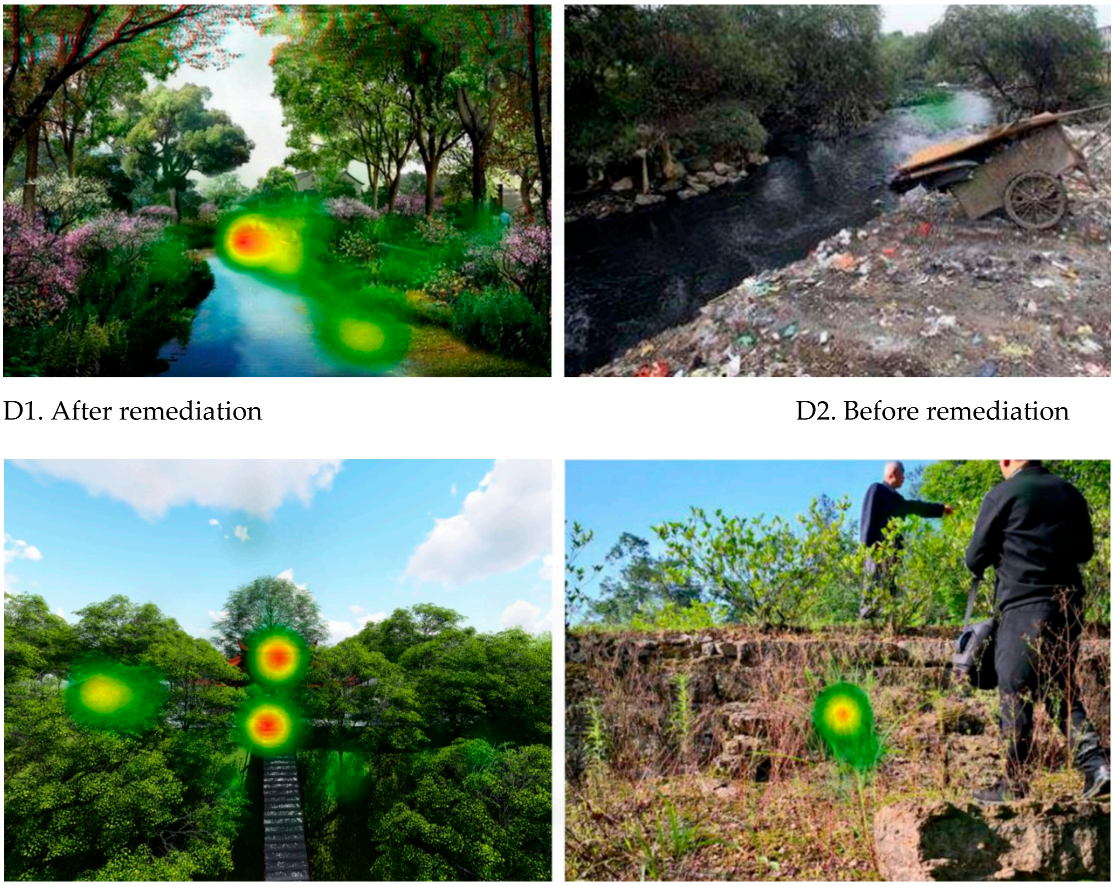
B2. Before remediation



C1. After remediation

C2. Before remediation

Figure 6. *Cont.*



D1. After remediation D2. Before remediation

E1. After remediation E2. Before remediation

Figure 6. Distribution of fixation hot spots of subjects before (**right**) and after (**left**) the remediation design project. Group (**A**–**E**) images come from the distribution of fixation hot spots before and after the restoration of cultural relics cross-sections of Shizhuguan Temple, Xiangwangjie Temple, Wuluozhonglishan Temple, Miaolingshan Temple, and Hanyangqiao Temple.

Through VR technology evaluation analysis, it was found that the fixation counts and the average saccade counts increased by 61.19% and 59.23%, respectively, after the remediation design was applied. The heat map of saccade counts is mainly concentrated on the nodes after the restoration design, and the more successful the restoration is, the better the directivity of the saccade fixation effect, indicating that the restored cultural landscape increased the subjects' visual interest. This reflects a good visual aesthetic effect, and reduces the visual fatigue of the subjects with a more pleasant visual experience. Moreover, our visual aesthetic evaluation of the restored cultural landscape enhanced our understanding of ecological environmental protection in the relics area.

4.2. Water Environment Quality Comparison Analysis and Effect Test

The Tujia settlement area is mainly distributed along watersheds, and water pollution is one of the typical factors reflecting the ecological and environmental quality of the study area. In this paper, data on water pollutants were extracted from the Environmental Quality Report (2016–2019) of the Environmental Protection Bureau of the study area to further examine the effects of the ecological remediation design project of the landscape on the improvement of ecological quality. The changes in pollutant concentrations in water bodies in the cultural landscape areas before and after the ecological remediation design (2016, 2019) of the landscape were compared and analyzed by reference to the Environmental Quality Standard for Surface Water (GB3838-2002) [36–39], as shown in Table 4.

Table 4. Comparison of changes in pollutant concentrations and statistics of water quality.

Classification	S/N	Monitoring Item	Monitoring Points					Limits in Standards for Grade III Water Bodies
			WT	MT	XT	ST	HT	
After remediation (2019)	1	pH	7.9	7.7	7.8	7.5	7.7	6~9
	2	DO (mg/L)	4.47	4.43	3.45	4.58	4.02	≥5
	3	NH_3-N (mg/L)	1.08	0.37	1.01	0.57	1.27	≤1
	4	COD_{Mn} (mg/L)	2.10	2	2.10	1.90	2.20	≤6
	5	BOD_5 (mg/L)	0.73	0.68	0.79	0.68	1.69	≤4
	6	F^- (mg/L)	1.13	1.13	1.13	1.13	1.13	≤1.0
	7	TP (mg/L)	0.32	0.13	0.32	0.31	0.41	≤0.20
	8	COD_{Cr} (mg/L)	25.78	12	23	11	15	≤20
	9	TN (mg/L)	1.78	1.72	1.82	1.58	2.03	≤1.0
Before remediation (2016)	1	pH	7.9	7.7	7.8	7.6	7.7	6~9
	2	DO (mg/L)	4.52	3.89	4.96	4.02	4.43	≥5
	3	NH_3-N (mg/L)	1.27	1.07	1.13	1.07	1.34	≤1
	4	COD_{Mn} (mg/L)	1.08	1.02	2.10	1.04	2.14	≤6
	5	BOD_5 (mg/L)	0.76	0.82	0.69	0.82	0.68	≤4
	6	F^- (mg/L)	1.14	1.14	1.14	1.14	1.14	≤1.0
	7	TP (mg/L)	0.32	0.23	0.29	0.31	0.25	≤0.20
	8	COD_{Cr} (mg/L)	21	18	23	21	19	≤20
	9	TN (mg/L)	1.82	1.77	1.94	1.67	1.72	≤1.0

Note: Groups WT, MT, XT, ST and HT come from Wuluozhonglishan Temple, Miaolingshan Temple, Xiangwangjie Temple, Shizhuguan Temple, and Hanyangqiao Temple.

According to the statistical results in Table 4, it was found that the pollution concentrations of DO, NH_3-N and TN indexes in all relic areas were significantly reduced after the remediation design, indicating that the remediation works on buildings, vegetation and water bodies in the cultural landscape area have improved the efficacy of water-containing forests, and that the dirt-holding capacity of rivers was conducive to the degradation and dilution of some pollution source concentrations, leading to better water ecosystem functions and improved water environment quality, as shown in Figure 7. In some of the relic areas, COD_{Mn}, BOD_5, TP, COD_{Cr} and other pollution index concentrations before and after remediation showed uneven changes, indicating that residual household waste, cement ash and debris and other residues in some of the relic areas in the remediation process have caused secondary pollution of the water body, requiring secondary clean-up. F- and pH remained essentially unchanged, indicating that both have relatively little impact on the relics area. Overall, the water qualities were better than before, which proves that our design intervention effectively improved the eco-environmental quality.

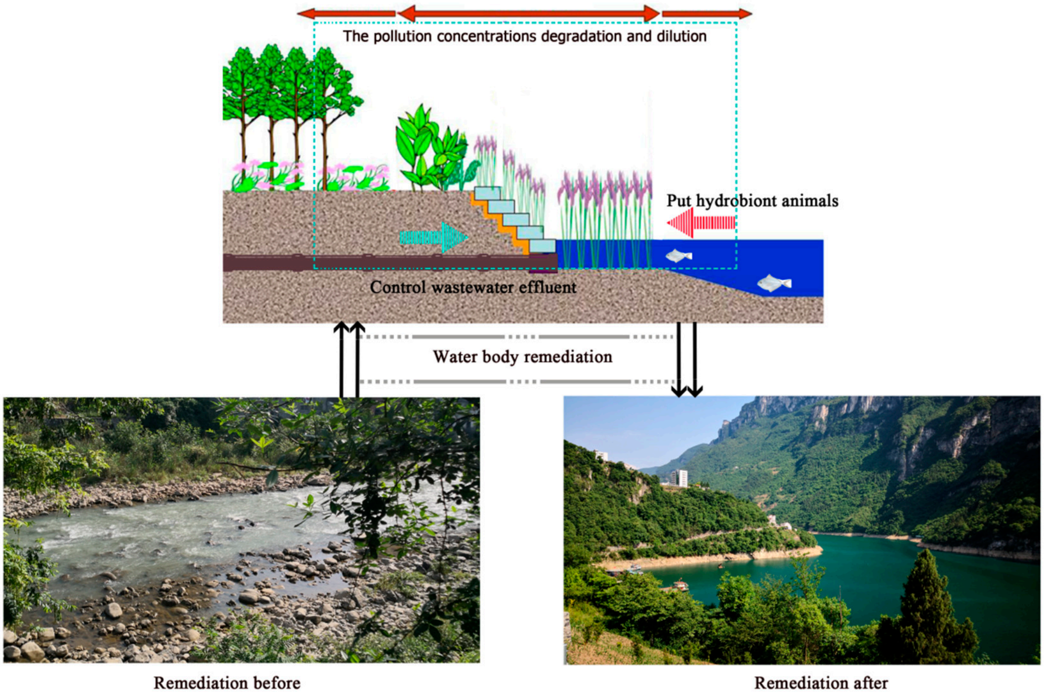


Figure 7. Visualization of the water body remediation process and results.

5. Discussion and Conclusions

By proposing an activation and eco-landscape remediation pattern to preserve the cultural landscape resources in the study area and using VR technology to evaluate the visual aesthetic effects of the remediation design, this study investigated the restoration of the Linjun Culture through the collective memory of the Tujia family based on the characteristic culture of the Tujia population, and introduce the theory of "activation" into the disappearing cultural landscape resources with the support of China's digital culture Revitalization Strategy and policy on the construction of Beautiful China to achieve the goal of cultural heritage protection and inheritance.

Applying the VR technology evaluation method to the conservation and inheritance of cultural landscape resources is, on the one hand, conducive to "activating" the characteristic culture of the Tujia settlement and enhancing people's awareness of the conservation of the cultural heritage around them; and on the other hand, the environmental restoration and landscape remediation design of the cultural landscape resources on the verge of destruction in the study area is not only conducive to turning "waste" into "treasure" and "ugly" into "beautiful", but also to improving the ecological environment quality of the study area.

This research shows that the proposed VR technology evaluation method is not only conducive to exploring new paths to protect cultural heritage resources through the inheritance and innovation model in order to achieve the benefits of the beauty in the human landscape and natural environment, but also to achieve the goal of harmonious coexistence between humans and the environment through the practice of ecological environmental protection [40]. The experimental procedure in this study may have affected the accuracy of the data because only 16 subjects were randomly invited to participate. The next step will be to increase the number of subjects, and this will help to improve the accuracy of the evaluation results.

Extracting landscape patch information through the LIM model [41] is beneficial to the overall statistics of land use changes in the study area and provides data support for the VR technology evaluation of the visual aesthetics of the cultural landscape. In the next step, the group will also form a cultural heritage protection association in the relics area in conjunction with local ethnic departments to provide image data, subjects and evaluation tools for the visual evaluation of the landscape. The introduction of the LIM model and VR technology to the evaluation of landscapes' visual aesthetics is a new breakthrough in both research technology and method, which can be further applied to the conservation of cultural landscape resources in the ethnic minority settlement areas in Southwest China. Additionally, we could also invite "net celebrities" to go to the cultural heritage relics in the study area for live streaming promotions and to create a number of online popular scenic spots, which will not only help attract domestic and foreign tourist groups but will also realize the internal circulation of protected resources.

Moreover, the water environment quality was compared before and after the restoration, which showed that the pollution concentrations of DO, NH_3-N and TN in the water environment were significantly reduced after the remediation design. The research results showed the effectiveness of VR technology for evaluating the visual beauty of cultural landscapes after ecological remediation design. It was shown that the landscape ecological remediation design improved the ecological environment quality in the research area, and the crossover study of landscape ecology [42] and environmental science together with ecological environment management is significant in practice to protect the cultural landscape resources of ethnic minority settlement areas in poor mountainous areas. It also provides a reference for the practice of the Rural Revitalization Strategy and the construction of Beautiful China.

The application of VR technology in cultural heritage protection and construction effectively verifies the changes of the cultural landscape before and after restoration through the quantitative assessment method. In the next step, the research team will extend the method to study areas with different location characteristics, explore the heterogeneity characteristics of different locations, and summarize the evaluation indicators to promote the protection of cultural heritage, to finally form a scientific and reasonable evaluation system.

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