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ORIGINAL

Application of computer simulation technology in traditional building protection

Aplicación de la tecnología de simulación por ordenador en la protección tradicional de edificios

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ABSTRACT

Background: computer simulation technology, especially virtual reality (VR) technology, offers an innovative solution for participating in architectural design by providing an immersive and interactive experiences.
Aim: this research aims to provide the VR application for the protection of traditional buildings, focusing on how this technology can enhance stakeholder participation in the protection and preservation of historical structures. The aim is to evaluate the effectiveness of VR in facilitating a bottom-up approach to decision-making, thereby preserving cultural heritage.
Method: to gather data, a random sample of 136 participants, including both local residents and architectural professionals, were engaged in VR simulations of renovation for traditional buildings. The VR environment presented two design schemes: one reflecting a traditional architectural style and the other featuring a modern approach. Participants interacted with both schemes using VR, and their feedback was collected through structured surveys. Statistical methods were employed to evaluate the quality of VR experiences and their impact on participant preferences and decision-making.
Result: it indicate that VR technology significantly improves stakeholder engagement, with a majority of participants expressing a strong preference for traditional designs in terms of cultural protection. The immersive nature of VR was found to effectively replace traditional review methods, offering clearer insights into design intentions and facilitating informed decisions.
Conclusion: VR technology proves to be a valuable tool in the protection of traditional buildings by enhancing participant engagement and supporting informed decision-making processes.

Keywords: Computer Simulation; Virtual Reality (VR) Technology; Protection; Preservation; Statistical Analysis; Traditional Buildings.

RESUMEN

Antecedentes: la tecnología de simulación por ordenador, especialmente la de realidad virtual (RV), ofrece una solución innovadora para participar en el diseño arquitectónico al proporcionar experiencias inmersivas e interactivas.
Objetivo: esta investigación tiene por objeto la aplicación de la RV a la protección de edificios tradicionales, centrándose en cómo esta tecnología puede mejorar la participación de los interesados en la protección y conservación de estructuras históricas. El objetivo es evaluar la eficacia de la RV para facilitar un enfoque ascendente en la toma de decisiones, preservando así el patrimonio cultural.
Método: para recopilar datos, una muestra aleatoria de 136 participantes, entre los que había residentes locales y profesionales de la arquitectura, participaron en simulaciones de RV de renovación de edificios tradicionales. El entorno de RV presentaba dos esquemas de diseño: uno que reflejaba un estilo arquitectónico

tradicional y otro con un enfoque moderno. Los participantes interactuaron con ambos esquemas utilizando la RV, y sus opiniones se recogieron mediante encuestas estructuradas. Se emplearon métodos estadísticos para evaluar la calidad de las experiencias de RV y su repercusión en las preferencias y la toma de decisiones de los participantes.
Resultados: los resultados indican que la tecnología de RV mejora significativamente la participación de los interesados, y que la mayoría de los participantes expresan una marcada preferencia por los diseños tradicionales en términos de protección cultural. Se comprobó que la naturaleza inmersiva de la RV sustituye eficazmente a los métodos tradicionales de revisión, ofreciendo una visión más clara de las intenciones del diseño y facilitando la toma de decisiones con conocimiento de causa.
Conclusiones: la tecnología de RV demuestra ser una herramienta valiosa en la protección de edificios tradicionales al mejorar el compromiso de los participantes y apoyar los procesos de toma de decisiones informadas.

Palabras clave: Simulación por ordenador; Tecnología de Realidad Virtual (RV); Protección; Preservación; Análisis estadístico; Edificios tradicionales.

INTRODUCTION

Numerous cities and landscapes within an entity obtain value and attractiveness from the cultural heritage. The information from various sensors, including images, vibration, acceleration, and environmental characteristics, can be processed by the information systems. This presents wide potential for techniques that can provide sophisticated collective information, warnings, or operations without requiring direct human involvement.[1,2] The potential of the VR technology to create multilayered, three-dimensional (3D) experiences that fully immerse the user in a virtual world has received attention in the architectural, engineering, and construction (AEC) industry during the past few decades.[3] This is mainly caused by the sector's significant need for visual forms of communication during the employment processes associated with designing, engineering, building, and managing the built environment.[4,5]

The VR applications with realistic interactive visuals can be highly beneficial to the field of architectural heritage protection and preservation. Many museums and tourist destinations historically employ these types of applications. The use of these technologies educates many people about historical artifacts and sites in an engaging and visually appealing method.[6] There are numerous factors for significant safety threats for building workers, including the possibility of fatalities.[7] VR technology is developing as it is used to support several engineering fields, mainly based on the rapid advancements in the field of computers. VR technology has been shown to be effective for training and educational reasons. Its immersive experience allows individuals to interact with diverse virtual things in various conditions.[8,9]

By using computers, a virtual environment that is identical to reality is developed to enable users to experience it directly and develop natural abilities. Industries that at present utilize it largely include the military, computational sciences presentations, teaching and training, design and planning, virtual examination, virtual trips, retail, engaged recreation, engineering innovation, scientific and technological exploration.[10,11] Whereas marketing, sports, tourism, and education have all experimented with VR, gaming, and entertainment are the primary industries using VR. This technology has been not reliable and stable enough to fulfil the modern industrial requirements in the reality of life.[12] The people's quality of life and the economic performance of the nation have both significantly improved as a result of society's constant advancement and growth. People have become more conscious of the need to preserve the environment and develop landscapes.[13-15] Many digital and virtual technologies have been developed to preserve cultural heritage components in application, with an attention to the latest developments in the utilization of VR technology and digital techniques of documentation.[16,17]

This research aims to investigate how VR technology can be utilized to maintain and preserve traditional buildings by improving stakeholder participation in the process of decision making. It presents traditional and modern architectural design and the traditional design is improved more significantly. The objective of this research is to assess the facilities of VR technology for cultural heritage preservation by presenting involvement and interactive experiences. It intends to determine the performance of VR in enhancing reliable decisions in architectural protection by assessing the participant preferences and interaction with traditional and modern design ideas.

METHOD

This section provides the participants details, simulation of VR, questionnaire developments and statistical assessments to evaluate the traditional and modern architectural design preference of the participants.

Participants Description

The research gathers data from 136 participants, including archeologists (45 participants), architectural professionals (45 participants), and local residents (46 participants). The demographic data from three categories of participants are obtained. The local residents with age, gender, and years of living are obtained. The archeologist and architectural professional's demographic data like age, gender, and experiences in their fields are gathered. Table 1 provides information about the participants' demographics.

Table 1. Demographic data of the participants

Factors	Details	Percentage (%)
Local Residents (n=46)		
Age	25-45	-
Gender	Females (21)	45,65
	Males (25)	54,35
Years of living	35	76,08
Architects (n=45)		
Age	20-35	-
Gender	Females (20)	44,44
	Males (25)	55,56
Year of Experiences	10	22,22
Archeologists (n=45)		
Age	23-65	-
Gender	Females (23)	51,11
	Males (22)	48,89
Year of Experiences	15	33,33
DP	Traditional	69,23
	Modern	30,77
CS	Traditional	65,75
	Modern	34,25
DF	Traditional	66,67
	Modern	33,33
ER	Traditional	69,12
	Modern	30,88
DI	Traditional	69,01
	Modern	30,99

Representation of VR Simulation

The study explores two scenarios; in the initial scenarios, all the participants are allowed to visit both traditional designs. In the second scenario, participants are allowed to visit the modern design. The traditional architectural design, modern architectural design and the visual representations are shown in Figures 1(a and b). The 136 participants are allowed to visit both traditional and modern houses by utilizing VR devices for visualization. The feedback from the provided survey questions obtained from the participants is presented in the following phase.

Figure 1 (a). Traditional architectural designs using VR technology

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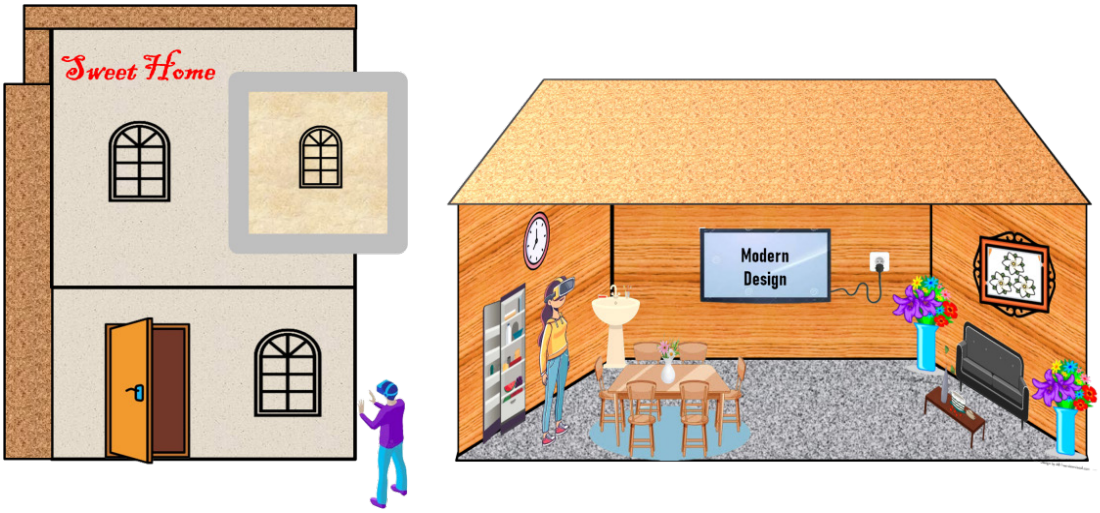

Figure 1 (b). Modern architectural designs using VR technology

Survey Questionnaires to obtain the feedbacks

The survey questionnaires are gathered from the participants based on five variables related to the VR technology in the protection of traditional buildings and the variables are design preference (DP), cultural significance (CS), design features (DF), emotional responses (ER) and design intentions (DI). There are two questions acquired from each variable, the obtained survey questions are represented in Table 2. Gathering feedback from the participants about the traditional design based on the initial design and gathering feedback from all the participants about modern design based on second scenario are explored. 5-point Likert scales are used to quantify responses to each question. Participants assess their opinion or level of agreement on a scale that usually goes from I-Strongly Disagree, II-Disagree, III-Neutral, IV-Agree, V- strongly agree. This scale aids in the measurement of personal convictions and makes statistical analysis easier.

Table 2. Survey Questionnaires

Variables	Questions
DP	What is your design preference: traditional and modern houses?
	Rate the importance of traditional objects in the house.
CS	What is the cultural significance of traditional buildings?
	How well do the traditional designs represent cultural significance?
DF	Which design features do you like the most in both designs?
	Rate the efficiency of modern design features for cultural identity.
ER	What emotions did you feel with the traditional design?
	What emotions did you feel with the modern design?
DI	How clear is the intention of the design in the traditional design?
	Did the modern design have any significant preservation message?

Statistical Assessment

The research demonstrates the statistical analysis techniques for the performance by using the Kruskal-Wallis Test and inferential statistics techniques. The statistical evaluation employs the SPSS software to implement the analysis performance. A statistical test called the Kruskal–Wallis test is used to compare multiple categories for a constant or discrete variable. Non-parametric analysis is similar to one-way analysis of variance (ANOVA) in that it involves no specific data distribution. The one-way ANOVA on ranks or the Kruskal Wallis one-way ANOVA are common names for the Kruskal Wallis test. The distribution of the data is thought to be altered or irregular. For data with a normal distribution, one-way ANOVA could be utilized. When the relevant variable is discrete or continuous, this method needs to be applied. An analysis of random samples is used to infer characteristics related to the population, known as inferential statistics. Establishing generalizations on an estimated population is the objective of inferential statistics. A statistic is extracted from the sample data in inferential statistics. Since it has the ability to make generalizations on the population without requiring all available data, inferential statistics can be highly beneficial and economical.

RESULTS

In this section, the evaluations of traditional and modern architectural design by using the Kruskal-Wallis Test and inferential statistics analysis techniques are examined.

Evaluation of Kruskal-Wallis Test Analysis

This test analysis was performed based on variables like DP, CS, DF, ER, and DI to estimate the traditional and modern architectural designs. Table 3 and Table 4 illustrate the outcomes of traditional and modern architectural designs by employing this statistical technique. Two or more independent groups could exist for the variable of importance. The test is most frequently applied when analyzing numerous categories. When this test is significant, it means that at least a single instance is sequentially more dominant than the other. The test cannot determine where its dominance occurs or how many group pairs it affects.

Table 3. Outcomes of Traditional Architectural Design

Variables	H-statistics	Median	P-value
DP	15,23	4,5	0,0001
CS	14,78	4,8	0,0002
DF	12,45	4,6	0,0005
ER	13,89	4,7	0,0003
DI	11,67	4,9	0,0007

Table 4. Outcomes of modern architectural design

Variables	H-statistics	Median	P-value
DP	5,12	2,0	0,024
CS	6,78	2,5	0,010
DF	4,55	2,3	0,034
ER	5,90	2,1	0,018
DI	3,67	2,2	0,042

The outcomes of the assessment determined that the traditional architectural design provides improved performance than the modern architectural design in terms of H-statistics, p-value, and median values. The median represents the median score for each variable in architectural design. The H-statistics shows the Kruskal-Wallis test that indicates the range of variance among two categories. The P-value indicates the significant difference between the two categories and the significant value is less than 0,05.

Inferential Statistics Analysis

Generalizations of the participants in both modern and conventional architectural designs are made possible by inferential statistics, which are applied to the sample data using statistical methods. Based on the variables (DP, CS, DF, ER, and DI), the performance of traditional and modern architectural design is evaluated through inferential statistics analysis. The results of traditional and modern architectural designs are illustrated in tables 5 and 6. The outcomes of (a) mean and (b) standard deviation (SD) are represented in figures 2 and 3 (a and b) for modern and traditional designs.

Table 5. Results of traditional design in inferential statistics

Variables	SD	Mean	Test Statistics	P-value
DP	0,75	4,3	8,45	0,0003
CS	0,70	4,6	7,89	0,0004
DF	0,60	4,5	6,75	0,0002
ER	0,65	4,0	6,90	0,0001
DI	0,50	4,2	5,65	0,0006

Table 6. Results of modern design in inferential statistics

Variables	SD	Mean	Test Statistics	P-value
DP	0,80	3,5	3,20	0,0015
CS	0,85	3,7	2,75	0,0050
DF	0,75	3,4	3,10	0,0020
ER	0,70	3,2	2,90	0,0045
DI	0,75	3,8	3,50	0,0008

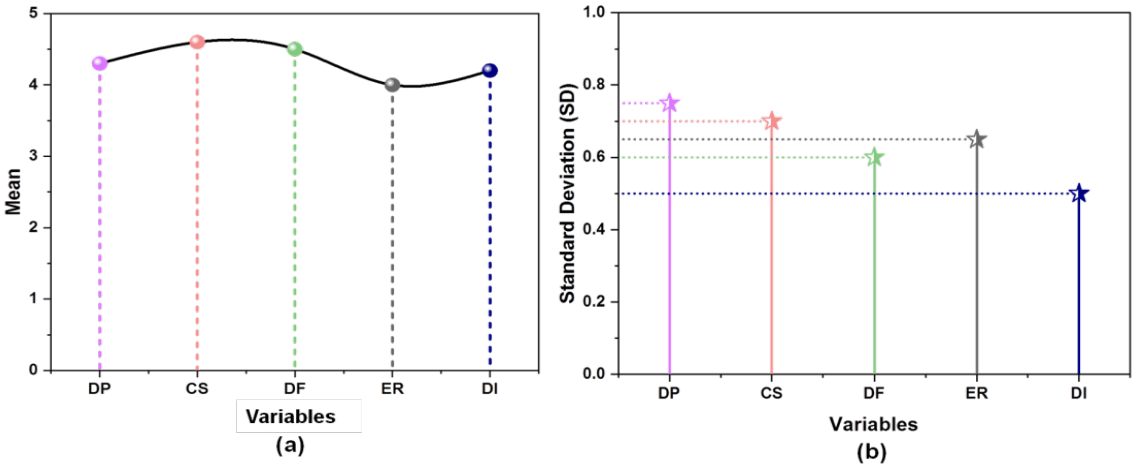

Figure 2. Visualization of (a) mean and (b) SD for traditional design

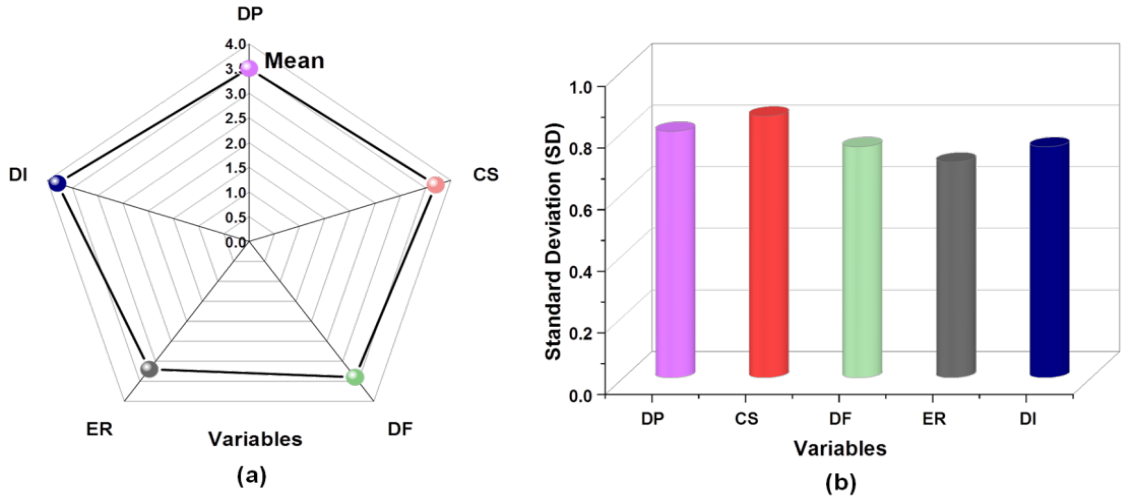

Figure 3. Graphical illustration of (a) mean and (b) SD for modern design

DISCUSSION

The study' limited ability for integration and practical application across several disciplines is a significant flaw. it concentrated on developing an easy-to-use website for vacation planning that is connected to cultural assets, it does not provide a thorough strategy for sustained participation or quantifiable effects on preservation. Similar to this, they presented virtual reality (VR) as a platform that crosses disciplines, but it did not thoroughly examine its drawbacks or real-world application issues in other industries. It emphasized the development of generative language and BIM, they did not discuss the practical obstacles of implementing these advances in heritage sites. Lastly, they used virtual reality (VR) for ecological remediation and visual aesthetics. Their study concentrated mostly on theoretical results without exploring the difficulties or constraints encountered when implementing these technologies in actual restoration operations.

The average amount for every variable in the design of the building is displayed by the mean. The variance in scores within each group is called SD. Significant values are indicated by a P-value of below 0,05. Test statistics is the outcome of an applied statistical test. The traditional architectural design explores more significant performance compared to the modern designs.

The two categories, such as modern and traditional architectural designs, were assessed by using the statistical method called Kruskal-Wallis test analysis and inferential statistics. The traditional architectural design shows better performances than the modern design. It showed the cultural values, emotions of the participants, and their preferences about the traditions, intentions and features of the traditional design.

The limitations of the research, including its small sample size and limited geographical emphasis, could limit the generalizability of the findings, particularly with the positive outcomes. To demonstrate the efficacy of VR in various environments, future investigations are needed to assess a wider range of cultural circumstances and involve larger participants. The integration of modern technologies has the potential to enhance the deep involvement more significantly, providing more thorough evaluations and determining more applications in the wider preservation of traditional buildings.

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CONCLUSIONS

The VR innovation's potential for conserving historic structures is investigated in this study. It focuses on its potential to enhance stakeholder participation in the conservation and preservation of historical structures. The VR simulations of typical building renovations were used to collect data from 136 participants, including professionals in architecture and local inhabitants. The VR environment showed two distinct design schemes: modern and traditional. Participants interacted with the VR systems and structured surveys were used to gather feedback. The results showed that VR technology significantly improved stakeholder involvement, and most participants strongly supported traditional designs for cultural preservation. The interactive quality of VR replaced conventional assessment techniques, providing detailed perspectives on design objectives and facilitating effective decision-making. By increasing participant engagement and facilitating comprehensive decision-making processes, VR technology appears to be an efficient method for preserving traditional buildings.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

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Research: Yanjun Wang, Ajmera Mohan Singh.
Drafting - original draft: Yanjun Wang.
Writing - proofreading and editing: Yanjun Wang, Ajmera Mohan Singh.