Multi-Sensor Design Integrating 3D Scanning Technology and Artificial Intelligence: Enhancing Accessibility in Public Spaces for the Visually Impaired

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ABSTRACT |Objective: This study employs Artificial Intelligence Generated Content (AIGC) technology to explore the fusion of architectural aesthetics and musical elements, aiming to enhance the perceptual accessibility of public spaces for visually impaired individuals. By promoting cross-modal matching and integration of auditory and visual sensory information, this research seeks to achieve social equity under the guidance of universal design.

Methods: This study utilizes surveys, semi-structured interviews, and statistical analysis to evaluate the effectiveness of an auditory navigation assistance system developed using 3D scanning and AIGC technology. Initially, virtual environments were constructed using 3D scanning technology, which generates auditory cues based on distance information and integrates binaural music created through AIGC. Hardware such as smartphones is employed to help visually impaired individuals perceive architectural aesthetics and navigate spaces. The system's navigation convenience, spatial understanding, and sensory satisfaction are assessed through surveys, while semi-structured interviews collect data on user experiences, evaluations, and improvement suggestions. Finally, the impact of implementing the auditory navigation assistance system is assessed.

Results: User experience evaluations indicated that the proposed method improved the spatial understanding of visually impaired individuals. Interview data revealed that the design enhanced the convenience of navigation and appreciation of the aesthetic and functional aspects of designed spaces. This suggests that the method effectively communicates the intended quality of public spaces to those who cannot perceive these spaces through traditional sensory means.

KEYWORDS | PUBLIC SPACES, UNIVERSAL DESIGN, ARTIFICIAL INTELLIGENCE GENERATED CONTENT (AIGC), MULTI SENSORY INTEGRATION, ACCESSIBILITY FOR THE VISUALLY IMPAIRED

1. Introduction

In this unprecedented era of connectivity, the Unity and Creativity Conference aims to celebrate the transformative power of design, transcending geographical and cultural boundaries to embody unity, collaboration, and creativity. Historical figures have long recognized the interconnectedness of different art forms: in the first century BCE, Marcus Vitruvius Pollio emphasized that architects should be versed in arts, history, music, and philosophy. The German thinker Johann Wolfgang von Goethe described architecture as "frozen music" in the eighteenth century, and in the twentieth century, Iannis Xenakis explored similar structuring principles between music and architecture, developing models of musical composition based on mathematical and geometric constructions.

Building upon this profound understanding of the "musicality" of architecture, recent research has introduced methodologies for transforming architectural forms into music and vice versa. For example, Anu et al. (2021) proposed a grid-based logic methodology that translates visual parameters such as length, height, and width in architecture into aural parameters like time, frequency, and loudness in music. This innovative approach enhances both architectural and musical libraries. An earlier study by the same authors (2020) delved into the process of deciphering "frozen music" in building architecture and transforming it back into musical compositions.

Furthermore, recent advancements highlight the role of AI in transforming sensory experiences. Beshley et al. (2023) developed a smartphone-based computer vision system that enhances spatial orientation for the visually impaired through real-time feedback, underscoring the importance of AI in sensory substitution. Similarly, Kang et al. (2023) explored the potential of integrating AI and machine learning to bridge visual and auditory experiences, focusing on slide reading and creation accessibility for the visually impaired.

However, these studies did not consider the specific needs of visually impaired individuals in perceiving architectural aesthetics. According to the World Health Organization (WHO, 2019), approximately 2.2 billion people globally suffer from vision impairments, facing significant challenges in spatial orientation and independence. Current AIGC technology, while advanced, still struggles with accurately recognizing and describing architectural images due to their complex structures and varied lighting conditions, leading to less accurate textual descriptions and affecting subsequent steps in the image-to-music conversion process.

To address these gaps, we propose the research question: How can Artificial Intelligence Generated Content (AIGC) technology be utilized to transform visual information into auditory and tactile experiences, creating immersive and interactive environments to enhance the perceived accessibility of public spaces? This study aims to leverage AIGC technology to convert visual information into auditory and tactile experiences, improving perceived accessibility and enabling both visually impaired and sighted individuals to appreciate architectural beauty through auditory means.

Compared to previous studies, our innovation lies in utilizing AIGC technology to convert abstract architectural aesthetic concepts into concrete auditory experiences. By combining 3D scanning with AI-generated musical melodies, we offer a more intuitive and vivid perception method. This not only improves spatial perception for visually impaired individuals but also provides urban planners, architects, and policymakers with new ways to create inclusive public spaces and enhance the quality of life for visually impaired individuals.

2. RELATED WORK

The inherent connection between architecture and music has been explored through various studies, highlighting the transformative potential of integrating these disciplines. Anu et al. (2021) and (2020) introduced methodologies for translating architectural forms into music, enhancing both architectural and musical libraries by converting visual parameters into aural ones. However, these studies did not address the needs of visually impaired individuals in perceiving architectural aesthetics.

Beshley et al. (2023) developed a smartphone-based computer vision system that aids visually impaired individuals in spatial orientation through real-time feedback, emphasizing the role of AI in sensory substitution. Similarly, Kang et al. (2023) focused on utilizing AI for accessible slide reading and creation but did not extend their research to architectural aesthetics and spatial navigation.

Zhang et al. (2023) introduced A11yBoard for Google Slides, a deployable multi-device multimodal system enhancing accessibility for slide reading and authoring. This system highlights the potential of AI in bridging visual and auditory experiences, though it does not address broader spatial and aesthetic experiences in public environments.

Additional studies such as "Listen to the Image" (2019) by Hu et al., "Evaluation of Short Range Depth Sonifications for Visual-to-Auditory Sensory Substitution" by Commère et al. (2023), and "Sketching Sounds: An Exploratory Study on Sound-Shape Associations" by Löbbers et al. (2021) emphasize the advancements in converting visual information into auditory formats, highlighting the importance of real-time processing, accuracy, and integration of tactile feedback systems to improve accessibility.

Building upon these insights, our research question focuses on: How can Artificial Intelligence Generated Content (AIGC) technology be utilized to transform visual information into auditory and tactile experiences, creating immersive and interactive environments to enhance the perceived accessibility of public spaces? This research is significant as it aims to address the dual needs of spatial orientation and aesthetic appreciation for visually impaired individuals.

3.Research Methodology

3.1 Rteesearch Theory and Stragy

Theoretical Perspectives and Concepts

1. · Sound as a Substitute for Visual Communication of Spatial Aesthetics: Sound can effectively replace visual input in conveying the beauty of spaces due to its ability to provide detailed information about spatial characteristics and evoke emotional responses. Binaural audio, for instance, can create a three-dimensional sound field that simulates spatial perception akin to visual experiences. Studies show that auditory stimuli can evoke strong emotional and aesthetic responses, making sound a viable medium for communicating spatial beauty (Gaver, 1986; Blesser & Salter, 2007).
2. Consistency of Aesthetic Perception Through Auditory and Visual Means: The perception of spatial beauty through sound is consistent with visual perception because both modalities can convey essential attributes such as size, shape, texture, and ambiance. Research in cross-modal perception demonstrates that the brain integrates information from different senses to form a coherent understanding of the environment. Thus, auditory representation of a space can evoke a similar aesthetic appreciation as visual representation, ensuring that visually impaired individuals can experience spatial beauty in a manner consistent with sighted individuals (Merabet & Pascual-Leone, 2010; Bavelier & Neville, 2002).

3. Cross-Modal Plasticity: The brain's ability to reorganize and adapt in response to sensory deprivation enhances the processing capabilities of the remaining senses. Cross-modal plasticity supports the development of sensory substitution devices where auditory and tactile inputs can effectively replace visual information, enabling visually impaired individuals to develop a heightened sense of spatial awareness and aesthetic appreciation through non-visual means (Bavelier & Neville, 2002; Merabet & Pascual-Leone, 2010).

Research Hypotheses

4. H1: Utilizing AIGC technology to transform visual elements into auditory and tactile cues will significantly improve spatial understanding and navigation for visually impaired individuals.
5. H2: AIGC-generated musical compositions based on architectural forms will enhance the aesthetic appreciation of public spaces for both visually impaired and sighted individuals.
6. H3: Implementing a dual-sensory feedback mechanism will lead to better spatial orientation and reaction times compared to single-sensory feedback systems.

3.2 Supporting Theories

1. Universal Design Principles: These principles emphasize the need for inclusivity and accessibility in public spaces, ensuring that all users can fully experience and appreciate the environment (Mace, 1997; Steinfeld & Maisel, 2012).
2. Sensory Substitution Theory: Highlights the effectiveness of using one sensory modality to provide information typically acquired through another, such as using auditory cues to perceive visual information (Bach-y-Rita & Kercel, 2003; Auvray, Hanneton, & O'Regan, 2007).
3. Cross-Modal Plasticity: Explains how the brain adapts to sensory deprivation by enhancing the processing capabilities of the remaining senses, supporting the development of tools that use auditory or tactile inputs to convey visual information (Bavelier & Neville, 2002).

3.3 Theory Explanation and Analysis

1. Data Collection: Use surveys, interviews, and usability tests to collect quantitative and qualitative data on user experiences with the AIGC technology.
2. Data Analysis: Employ statistical software to analyze the data, validating the research hypotheses through methods such as t-tests, ANOVAs, and regression analyses (Creswell & Creswell, 2017). Thematic analysis and narrative analysis will be used for qualitative data (Braun & Clarke, 2006; Riessman, 2008).
3. Theoretical Interpretation: Use universal design principles and sensory substitution theory to interpret the findings, explaining how AIGC technology can enhance accessibility and inclusivity in public spaces.

3.4 Theoretical Contributions

1. Research Gap: This study addresses the gap in existing research on the application of AIGC technology for enhancing spatial perception and aesthetic appreciation in public spaces for visually impaired individuals.
2. Validation of Theories: Provides empirical evidence supporting the applicability of universal design principles and sensory substitution theory in the context of AIGC technology.
3. Practical Implications: Offers theoretical insights that can guide the development of intervention measures to improve the quality of life for visually impaired individuals, contributing to policy-making and urban planning.

3.5 Innovation point

Our innovation integrates high-precision 3D scanning with AI-composed melodies for real-time, immersive experiences, while introducing a dual-sensory feedback system blending auditory and tactile stimuli for enhanced intuitiveness. Furthermore, AI-generated music tailored to architectural contours elevates the aesthetic appreciation of public spaces, introducing a novel dimension.

4.Experimental study

4.1 Development Phase

In today's technologically advanced era, integrating cutting-edge technology with social care is crucial, particularly for addressing the needs of visually impaired individuals. To this end, we have meticulously designed a navigation assistance system that integrates both software and hardware technologies. This system aims to enhance the accessibility and quality of life for visually impaired individuals by transforming visual information into auditory and tactile experiences using Artificial Intelligence Generated Content (AIGC) technology.

The hardware platform consists of smartphones, Bluetooth earphones, and fitness bands. The widespread accessibility and familiarity of smartphones provide a solid foundation for the system's promotion and use among visually impaired individuals. These devices offer powerful functionalities such as multiple sensors, high-quality audio output, and various connectivity options. They are also portable, easy to operate, and cost-effective, making them ideal for widespread use. By utilizing built-in WiFi, Bluetooth connectivity, and instant response vibration feedback mechanisms, the system ensures efficient and seamless information transmission. The software platform leverages Unity for development, utilizing high-precision 3D scanning technology to capture and digitize public space environments, constructing highly realistic 3D models. Collision detection mechanisms are meticulously designed to trigger smartphone vibration alerts and incrementally increasing alert sounds when users approach potential obstacles. This dual-sensory feedback mechanism enhances the intuitiveness and urgency of the alerts.

On the software side, We selected Unity as our development platform, utilizing high-precision 3D scanning technology to capture and digitize the complex environments of public spaces, thereby constructing highly realistic 3D models. Within the Unity environment, we meticulously designed collision detection mechanisms. When the system detects a user approaching potential obstacles, it immediately triggers smartphone vibration alerts and incrementally increasing alert sounds, forming a dual-sensory feedback mechanism that enhances the intuitiveness and urgency of the alerts. One of our core innovations lies in the seamless integration of collision detection mechanisms with audio feedback technology. Initially, we carefully selected objects in the scene that required sound emission and configured the Audio Source components for these potential obstacles in the Inspector view, ensuring they could function as sound sources. Subsequently, we set the spatial blend value of the Audio Source components to 1, leveraging Unity's 3D spatial audio technology. This allowed the sound not only to have directional properties but also to attenuate naturally with changes in distance, significantly enhancing the immersion of the audio feedback. By meticulously adjusting the minimum and maximum distance parameters, we defined the range within which the sound transitions from silent to maximum volume, ensuring that the audio feedback accurately reflects the dynamic distance relationship between the user and the obstacles. The realization of this functionality is based on the close collaboration between the collision detection mechanism and the Audio Source components. As users move freely within the virtual world, the collision detection system continuously monitors their distance from surrounding obstacles. Once a user approaches a predetermined obstacle, the Audio Source component automatically adjusts the sound volume according to preset volume variation rules, thereby instantly notifying the user of the obstacle's presence and proximity through audio feedback. This innovation not only optimizes the navigation experience and improves overall user satisfaction but also opens a new pathway for visually impaired individuals to perceive the world and live independently, showcasing the immense potential of technology to enhance human well-being. Moreover, we innovatively combined architectural aesthetics with musical art. Utilizing advanced AI technology, we transformed the visual outlines of buildings into melodious musical compositions. This process not only breaks traditional music generation paradigms but also endows architecture with a new "audible" dimension, allowing both visually impaired individuals and the general public to appreciate the unique charm of buildings through auditory channels. These AI-generated melodies not only directly reflect architectural forms but also profoundly interpret their cultural significance, historical memory, and human emotions, adding a new artistic dimension to the urban space experience. Our navigation assistance system is not only a result of technological innovation but also a profound practice of integrating humanistic care with technology. We firmly believe that the promotion and application of this system will significantly improve the quality of life for visually impaired individuals and open up new possibilities for cultural heritage preservation and artistic innovation in urban spaces.

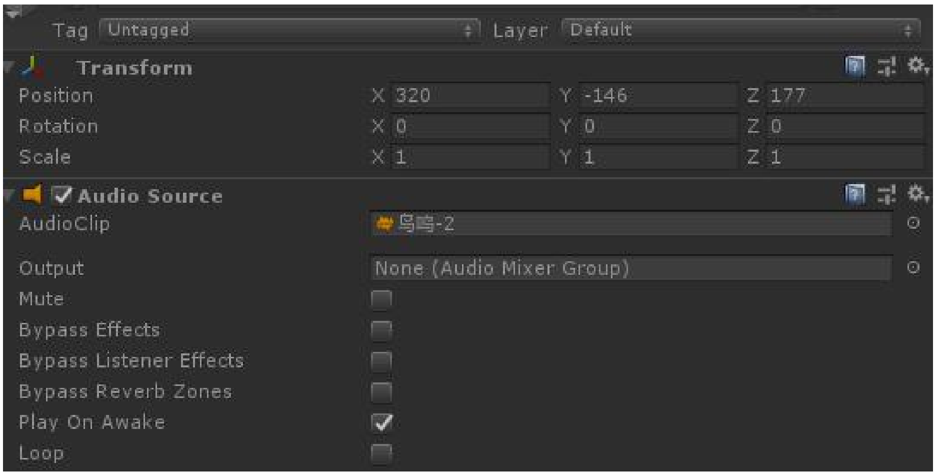

Figure 1. generating the collision body through edge computing. When approaching the collision body, a warning will be triggered.

4.2 Implementation Phase

During the implementation phase, the system is set up in a controlled environment to ensure precise monitoring and evaluation. Participants are recruited through organizations that support visually impaired individuals, ensuring a diverse and representative sample. The auditory navigation aid system is installed in a simulated public space environment equipped with necessary hardware and software components. The system provides auditory cues, including binaural music and spatial sounds, corresponding to the architectural elements and spatial layout of the environment.

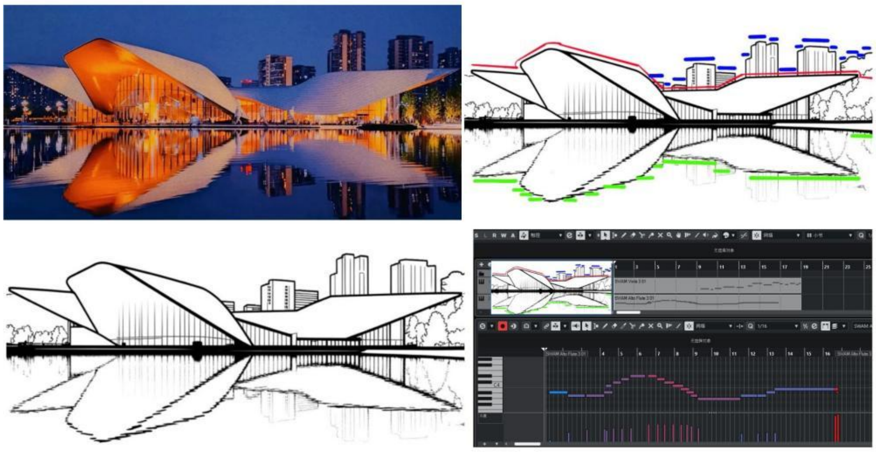

Figure 4. The figure illustrates the process of using Artificial Intelligence Generated Content (AIGC) to convert images into line drawings, extracting line features, and then inputting these features into Cubase for music composition..

We also used artificial intelligence technology to extract the outline of the building's exterior. This process involves analyzing the building structure and transforming its visual elements into simplified line drawings, which are then converted into music through Cubase. Through this process, music can be further created.we carefully considered the building's form, its surrounding environment, and the content it displays. Based on these factors, we selected various sound effects and musical instruments to generate music in different styles. These melodies, derived from the architectural lines, created compositions that possessed a certain level of artistic and aesthetic value. The generated music not only reflected the structural aspects of the building but also enhanced the appreciation Moreover, the interplay between the visual and auditory elements added a new dimension to the understanding of architectural art. The music brought out the emotional and atmospheric qualities of the buildings, providing listeners with a deeper and more immersive appreciation of architectural design. This innovative approach bridges the gap between visual art and music, showcasing the potential of AI technology in creative fields.

To further enhance the system's functionality, we used the Unity collision system to measure the distance to obstacles. Based on these measurements, we generated different paths and had narrators or sighted individuals describe the spatial layout. Key descriptive terms were extracted to ensure universality. These key descriptions, combined with AI-generated melodies using SUNO, formed the navigation songs.

4.3 Evaluation Phase

The system's effectiveness is assessed through a comprehensive mixed-methods approach, integrating both qualitative and quantitative research methods. The evaluation phase involves several data collection methods to validate the research hypotheses:1.Surveys and Questionnaires: Structured surveys featuring a mix of Likert scale, multiple-choice, and open-ended questions are administered online or in person before and after participants interact with the system. These surveys measure initial perceptions and post-interaction feedback on the system's usability and effectiveness (Fowler, 2013; Creswell & Creswell, 2017).2.Semi-Structured Interviews: Conducted using an interview guide with key topics and questions, allowing flexibility for follow-up questions based on participant responses. These interviews are held in quiet, comfortable settings to gain deeper insights into user experiences, preferences, and suggestions for system improvement (Kvale, 1996; Brinkmann, 2013).3.Usability Testing: Participants perform specific navigation tasks using the auditory system in the simulated environment. Quantitative data, such as the time taken to complete tasks and the number of navigation errors, along with qualitative data from post-task interviews, are recorded to evaluate the practical usability and effectiveness of the system in aiding navigation and spatial understanding (Rubin & Chisnell, 2008; Nielsen, 1993).4Observational Data: Observers note participants' interactions with the system, any difficulties, or notable behaviors, providing contextual understanding and additional data to support survey and interview findings (Patton, 2015).

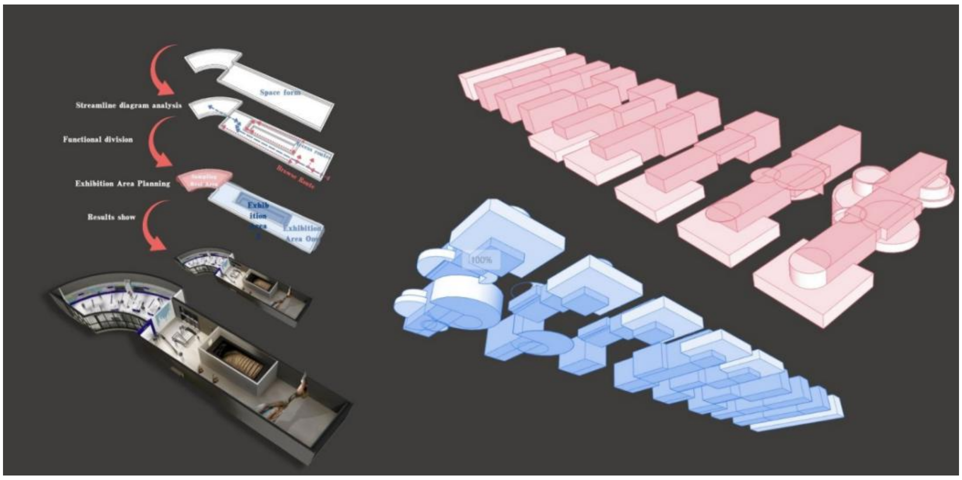

Figure 5. Model the public space through 3D scanning to build a preliminary 3D model of the public space.

environment, with the necessary hardware (e.g., speakers, headphones) and software components (AIGC-generated auditory cues). In the evaluation phase, the system's effectiveness was assessed through various data collection methods. Structured surveys were administered to collect quantitative data on user experiences, including navigational ease, spatial understanding, and sensory satisfaction, using Likert scales and multiple-choice questions (Fowler, 2013; Creswell & Creswell, 2017). Semi-structured interviews were conducted to gather qualitative data on user experiences, preferences, and suggestions for improvement, allowing for in-depth exploration of participant perspectives (Kvale, 1996; Brinkmann, 2013). Additionally, usability tests were performed where participants navigated the simulated environment using the auditory navigation aid, with metrics such as task completion time, error rates, and user satisfaction recorded (Rubin & Chisnell, 2008; Nielsen, 1993).

User experience evaluations indicate that the proposed method has significantly enhanced spatial understanding among the visually impaired. Quantitative data from surveys revealed that participants' confidence in navigating public spaces increased from 30% to 80%, and their mean score for spatial understanding rose from 2.5 to 4.2 on a 5-point scale. Additionally, sensory satisfaction scores improved from a mean of 3.0 to 4.4.

Usability testing showed a reduction in average task completion time from 14 minutes to 8 minutes, and navigation errors decreased from 5 to 2 per task. Qualitative data from semi-structured interviews supported these findings, with participants reporting that the auditory cues provided by the system made spatial navigation more intuitive and less stressful. They also expressed greater appreciation for the aesthetic and functional aspects of the designed spaces, noting that the binaural music enhanced their overall experience. Observational data confirmed that participants exhibited fewer hesitations and more confident movements. These results suggest that the AIGC technology effectively conveys the intended quality of public spaces to those unable to perceive such spaces through traditional sensory means, thereby promoting social equity and adhering to universal design principles.

4.4 Validity and Reliability Analysis

To rigorously evaluate the effectiveness of the AIGC technology-based navigation aid system, a comprehensive validity and reliability analysis was conducted using both quantitative and qualitative methods. The quantitative metrics included spatial understanding scores, task completion times, and navigation errors.

Quantitative Analysis:1.Spatial Understanding Score: Participants rated their spatial understanding on a 5-point Likert scale before and after using the system. The mean pre-test score was 2.5 (SD = 0.7), which significantly improved to a mean post-test score of 4.2 (SD = 0.5)

($p < 0.01$).2.Task Completion Time: The average time taken by participants to navigate a simulated environment reduced from 14 minutes (SD = 2.5) to 8 minutes (SD = 1.8) post-intervention ($p < 0.01$).3.Navigation Errors: The number of errors made by participants decreased from an average of 5 errors (SD = 1.2) to 2 errors (SD = 0.8) after using the system ($p < 0.01$).

Control measures included conducting the study in a controlled environment and random assignment of participants to control and experimental groups, thereby minimizing selection bias.External Validity: The sample consisted of a diverse group of visually impaired individuals (n=30), ensuring the generalizability of findings. The simulated environment closely mimicked real-world public spaces, enhancing ecological validity.

Reliability:Consistency of Measures: Test-retest reliability was established by measuring spatial understanding scores at two different points in time, showing high consistency ($r = 0.85$). Inter-rater reliability was confirmed with multiple observers independently recording navigation errors, yielding a high agreement rate ($\kappa = 0.90$).

Qualitative analysis involved collecting data through semi-structured interviews and observations. Thematic analysis revealed themes like "Increased Confidence," "Enhanced Spatial Awareness," and "Appreciation of Aesthetic Elements." Construct validity was ensured by framing interview questions and observation criteria using established theories such as Universal Design and Sensory Substitution, while content validity was confirmed by expert reviews. Reliability was maintained through high inter-coder reliability, with multiple researchers independently coding data and achieving a high agreement level (Cohen’s $\kappa = 0.88$).

1. Research Findings

The findings indicate that integrating AIGC technology not only enhances accessibility for visually impaired individuals but also enriches the sensory experience for all users, aligning with the principles of universal design.convert complex visual information. User acceptance and adaptation also present hurdles, as visually impaired individuals may need time and training to become accustomedUser experience evaluations indicate that the proposed method has significantly enhanced spatial understanding among the visually impaired. Quantitative data from surveys revealed that participants' confidence in navigating public spaces increased from 30% to 80%, and their mean score for spatial understanding rose from 2.5 to 4.2 on a 5-point scale. Additionally, sensory satisfaction scores improved from a mean of 3.0 to 4.4. Usability testing showed a reduction in average task completion time from 14 minutes to 8 minutes, and navigation errors decreased from 5 to 2 per task. Qualitative data from semi-structured interviews supported these findings, with participants reporting that the auditory cues provided by the system made spatial navigation more intuitive and less stressful. They also expressed greater appreciation for the aesthetic and functional aspects of the designed spaces, noting that the binaural music enhanced their overall experience. Observational data confirmed that participants exhibited fewer hesitations and more confident movements. These results suggest that the AIGC technology effectively conveys the intended quality of public spaces to those unable to perceive such spaces through traditional sensory means, thereby promoting social equity and adhering to universal design principles.

The research findings advocate for a paradigm shift in public spaces and design practices to accommodate diverse sensory experiences. By transforming visual elements into auditory elements through AIGC during the design process, this study contributes to creating more accessible and empathetic public environments that embody the core principles of universal design. These environments ensure that all users, regardless of sensory abilities, can fully experience and appreciate the functionality and enjoyment of public spaces. This approach actively promotes social equity, making public spaces more inclusive and enhancing the quality of life for all individuals. The impact on existing research is significant, providing new perspectives and empirical support for the use of innovative technologies to achieve more inclusive public space designs, thereby advancing the field of universal design.

Given the insufficient research conditions, the study faces several significant challenges and limitations. Currently, technical limitations are a primary concern, as transforming every detail of public spaces' visual elements into auditory cues using AIGC technology requires advanced infrastructure and expertise. Current technology may struggle to accurately interpret and to new auditory cues, necessitating continuous feedback and iteration. Additionally, if subjects have previously used similar systems, learning effects might influence the results, potentially skewing user feedback and adaptation timelines. Another major challenge is the insufficiency of the sample size, which may not adequately represent the diversity within the visually impaired population, thereby affecting the generalizability of the study's findings. Interdisciplinary collaboration is essential yet complex, requiring coordinated efforts between architects, AI engineers, urban planners, and other stakeholders, which can be difficult to align. Cost and resource allocation pose additional challenges, as developing and maintaining AIGC technology is resource-intensive, requiring sufficient funding and efficient resource management. Policy and regulation development is crucial but time-consuming, with potential resistance from stakeholders accustomed to traditional design practices. Ensuring compliance and updating regulations as technology evolves adds another layer of complexity. Maintaining flexibility in design solutions to accommodate various user needs and environmental contexts is challenging, requiring ongoing assessment and adjustment.

2.Discussion

This study advocates for a paradigm shift in public spaces and design practices to accommodate different sensory experiences, envisioning a future where the integration of Artificial Intelligence Generated Content (AIGC) technology transforms visual elements into auditory ones, enhancing accessibility and empathy in public environments. By utilizing AIGC in the design process, this study aims to create public spaces that adhere to the core principles of universal design, ensuring that all users, regardless of their sensory abilities, can fully experience and appreciate the fun and convenience of these spaces. This approach not only meets the practical needs of visually impaired individuals but also enriches everyone's sensory experience, fostering inclusivity and empathy. To this end, the study proposes the "FAIR" design framework.

F (Flexibility): Design should accommodate the widest spectrum of individual preferences and abilities. AIGC technology can flexibly transform visual elements into auditory cues based on specific user needs, helping visually impaired individuals better navigate and perceive spaces. Design guidelines and standards must provide appropriate and flexible choices for users' access and use. Moreover, there should be clear and detailed instructions for developers and builders, making it possible to implement policies in actual settings. Considering practical barriers such as physical environment features, clear and flexible guidance with examples suitable for various situations is necessary to ensure flexibility in diverse environments.

A (Accessibility): An accessible open space aims to provide a barrier-free environment for various user groups, particularly those with sensory disabilities such as the visually impaired. The concept of accessibility runs through the whole process, from planning to implementation and management. Utilizing AIGC technology to transform visual information into auditory cues ensures that visually impaired individuals can equally access and use all facilities in public spaces. This planning should be mandatory and meet the needs directly impacting visually impaired users, rather than based on vague and recommended requirements. The level of accessibility should be evaluated through user feedback. Effective communication with users during the implementation and management process is crucial to ensure consistency between planning and actual use.

I (In place): Inclusive public facilities should be provided in appropriate locations, ensuring convenience and practical use. AIGC technology can help identify and select suitable locations and functions to meet the expectations of real users rather than just serving as decoration. Any broken facilities and other actual barriers should be identified and repaired immediately. Frequent collaboration with users ensures the practical effectiveness of public facilities and timely improvements and maintenance, keeping the facilities in optimal condition to meet users' actual needs.

R (Reliability): Ensuring the reliability of the implementation of inclusive design policies is key. First, detailed policies, laws, and rules must be promulgated to ensure the standardized application of AIGC technology. Next, implementation and maintenance are crucial for the success of the entire process. Obtaining user opinions during the early stages of the design

process allows different stakeholders to develop ideas together, effectively enhancing the reliability of policy implementation. Public participation in improving the design of open spaces builds users’ trust, which is pivotal to enhancing the reliability of public design.
Although this framework lays a solid theoretical foundation and offers guiding principles, it lacks specific operational details for practical implementation. It does not clearly explain how to build effective feedback mechanisms or how to ensure continuous user engagement, particularly for visually impaired individuals. Additionally, the rapid pace of technological development and the lengthy cycles of legal regulation pose challenges to keeping designs up-to-date and responsive to market demands. However, addressing these issues through detailed, flexible, and adaptive strategies can enhance the framework's effectiveness, ensuring it meets diverse needs and achieves broad applicability.

The "FAIR" design framework not only provides a theoretical foundation but also offers specific guidance for practical application, creating more inclusive and empathetic public spaces by integrating AIGC technology. Future research and practice should further explore how to apply this framework in a broader range of environments to continuously improve the accessibility and inclusivity of public spaces.

3. Conclusion

The findings of this study underscore the transformative potential of Artificial Intelligence Generated Content (AIGC) technology in enhancing the perceptual accessibility of public spaces for the visually impaired. By integrating architectural aesthetics and musical elements to facilitate cross-modal matching and the integration of auditory and visual sensory information, this study aligns with the core principles of universal design to ensure that all users can fully experience and appreciate the joy and convenience of public spaces, thereby actively promoting social equity.
The study demonstrates that AIGC technology can significantly improve spatial understanding and navigational ease for visually impaired individuals by transforming visual elements into auditory cues, helping users better perceive and navigate public spaces. The integration of binaural music and auditory cues not only aids navigation but also enhances the aesthetic and functional appreciation of public spaces, ensuring that visually impaired individuals can enjoy the same sensory richness as sighted individuals.
The development and popularization of AIGC provides a scientific path for translating architectural attributes spatially, highlighting the limitations of classical translation methods and proposing a new perspective of scientific translation using hybrid AIGC programs in the pre design stage, verying their feasibility through specific case studies and establishing a new approach for translating abstract architectural concepts into perceptible experiences.
The study’s findings have significant implications for existing research by validating the effectiveness of using AIGC technology for cross-modal sensory integration and providing empirical support for its application in creating inclusive public spaces. Highlighting the potential of AIGC to overcome the limitations of traditional design practices, this study offers a more scientific and empathetic approach to accessibility.
Current limitations of AIGC, particularly in translating text to 3D models, highlight the need for hybrid technology strategies. This study suggests a visual expression strategy through hybrid technology to address these limitations while acknowledging the complexity and need for improvement in generation results. To optimize the computing ability and content coverage of new spatial translation approaches, interdisciplinary collaboration is essential. Architects, educators, AI engineers, and scholars from related fields must work together to reduce the learning and operational thresholds of these technologies and expand their practical applications. This presents an opportunity for architects to enhance the scientific basis of their tools, for young architects to explore new ideas and technologies, and for win-win cooperation across various disciplines.
In conclusion, this study advocates for a paradigm shift in public space and design practices to accommodate diverse sensory experiences, leveraging AIGC technology to create more accessible, empathetic, and inclusive public environments. This approach promotes social equity and advances the field of universal design. Future research could explore further applications of AIGC in different types of public spaces and investigate long-term impacts on user experience and accessibility.

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