Designing Accessible Video Games for Visually Impaired Players: An HCI-Based Interaction Model and Multi-Level Strategies

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Abstract

Electronic games have become the main form of digital entertainment, but they rely too much on picture feedback, which makes it difficult for visually impaired players to join in. In order to solve this problem, our research puts forward a general interaction model from the perspective of human-computer interaction (HCI), which includes three stages: perception, decision-making and input operation. We find that if we lack visual perception, it will trigger a chain reaction, which will affect the subsequent decision-making and operation, and ultimately make people unable to enjoy the game. Electronic games have become the main form of digital entertainment, but they rely too much on picture feedback, which makes it difficult for visually impaired players to join in. In order to solve this problem, our research puts forward a general interaction model from the perspective of human-computer interaction (HCI), which includes three stages: perception, decision-making and input operation. We find that if we lack visual perception, it will trigger a chain reaction, which will affect the subsequent decision-making and operation, and ultimately make people unable to enjoy the game.

Keywords: Visual impairment; Video games; Human-Computer Interaction (HCI); Game accessibility; Multimodal interaction

1. Introduction

In recent decades, video games has become one of the most influential forms of mass entertainment in the world. The income of the game industry has surpassed that of movies and music, and video games are increasingly regarded as an important medium for cultural exchange and social interaction. Different from the traditional media, the game emphasizes interactivity, so that players can not only be spectators, but also become participants in the story.

Despite the rapid development, there are still many people who are blocked out because of inconvenient use. According to the World Health Organization, about 1.3 billion people in the world have different forms of disability, accounting for almost 16% of the global population [1]. Players with poor eyesight will encounter great difficulties when playing digital games, because most games mainly rely on pictures to interact, which makes it difficult for users with poor eyesight to fully participate in and experience the games. This not only limits their entertainment choices but also makes the digital divide worse.

Compared with the relatively slow progress of the game, the accessibility design of software and network has made significant progress. Operating systems increasingly combine built-in screen readers, keyboard shortcuts, and other auxiliary functions, while the Web Content Accessibility Guide (WCAG) proposed by W3C has played an important role in promoting Internet inclusiveness [2]. Instead, the game accessibility guide is still in its early stages. The International Association of Game Developers (IGDA) released 19 guidelines in 2004 [3], and then the Norwegian media organization expanded the guidelines to 34. However, these are still general, lacking specific operational details of different types of disabilities, which limit their practical impact.

Under this background, our research established a general game interaction model from the perspective of human-computer interaction (HCI) and analyzed the challenges that visually impaired players encountered in this framework. According to these findings, we put forward some design methods, including a multi-mode feedback mechanism, a "virtual probe+sonar" system, and a semantic recognition plug-in based on conceptual artificial intelligence. These methods hope to provide some theoretical references and practical ideas for designing games that are friendly to more people.

2. Literature Review

The research on game accessibility can be traced back to early efforts aimed at providing alternative information channels for disabled players. Early studies mainly focused on auditory and tactile feedback. These techniques transformed visual information into auditory or tactile signals, enabling basic interaction in virtual environments. For example, Westin proved through the case study Terraforms that players with visual impairment can use spatialized audio and auxiliary feedback to navigate the 3D environment, laying the foundation for the development of "audio games" [4].

In the game industry, the International Game Developers Association (IGDA) issued the first set of relatively systematic barrier-free guides in 2004. It contains 19 principles, such as voice prompt, simplifying operation and providing other feedback methods. However, most of these frameworks are general and do not provide detailed operational instructions for specific disabled groups. Therefore, their practical application is quite limited. In contrast, the accessibility standards in the field of web pages are more mature. Web Content Accessibility Guidelines (WCAG) proposed by W3C have been widely used in software and web page development, which have brought many useful inspirations to the research of game accessibility [5].

In recent years, scholars have conducted a systematic study on the interaction needs of visually impaired players. These requirements can generally be divided into three aspects: spatial information acquisition, simplified control, and immersive experience. Qiu said that multimodal auditory cues based on sound parameters can significantly improve spatial orientation and interaction in multiplayer games [6]. Loebel has developed an accessible chess application that integrates screen readers, tactile feedback and high contrast visual mode, improving the usability of visually impaired users [7]. Monika and Johry emphasized the importance of voice user interface to enable visually impaired children to play with their peers with normal vision, thus enhancing social interaction and enjoyment [8]. These findings emphasize that accessibility design should not only ensure that games are "playable” but also ensure that they are truly "enjoyable", balancing function and entertainment.

However, several limitations remain. Most studies focus on educational or puzzle games, while relatively few accessibility adaptations exist in mainstream commercial genres such as action or shooting games [9]. In addition, many existing methods lack a unified theoretical framework. On the contrary, they rely on temporary solutions that are difficult to generalize or reuse [5]. From an industry perspective, developers' understanding of accessibility is still limited. The relevant content of education and training is still insufficient, which limits its wider adoption [10]. Finally, although artificial intelligence and multimodal technologies have been proposed as potential solutions, most of the work is still in the conceptual stage. There are few systematic applications or empirical evaluations [11].

Generally speaking, although previous studies have provided many theories and methods for interactive strategies based on hearing, touch and voice, there are still some shortcomings in the adaptation of mainstream games, the construction of theoretical framework and cross-platform expansion. In order to solve these problems, we need a more comprehensive game interaction model and a design scheme with low cost, easy expansion and no obstacles.

3. Game Interaction Model and the Impact of Visual Impairment

In order to better understand the interactive mechanism of game theory, we put forward a general three-stage model in this study. This model includes three stages: perception, decision-making and input execution.

In the perception stage, players receive stimuli through senses such as sight, hearing and touch. According to the game type, these stimuli can be divided into two categories: primary and secondary. Major stimuli are essential, without which the game cannot be played. For example, the most important thing in first person shooter games is visual stimulation. Other sensory stimuli are used to supplement information, and the lack of them may reduce the sense of immersion, but it may not necessarily affect playing games, such as background sounds and vibration cues.

In the decision-making stage, players will process the obtained information and then make appropriate actions according to the situation. This may include things like target recognition, observing the surrounding environment, and making strategies.

At the input execution stage, players turn decisions into concrete operations through keyboards, handles or other devices. These operations will change the state in the game and start the next interactive cycle.

These three stages are interdependent. Any interruption of any stage may screw up the whole process.

In this framework, the biggest challenge for visually impaired players appears in the perception stage. Most games rely heavily on visual input. Invisibility will prevent players from getting the main game information. For example, in shooting games, information about enemy positions and environmental obstacles is mainly seen with eyes. It is usually difficult to judge the position accurately only by listening to sound or tactile cues [1]. Similarly, in rhythm games, if the player can't see the visual cue, it may be difficult to recognize the next beat, so it is easy to make a series of mistakes later.

The consequences of this perceptual limitation have had a series of chain reactions in subsequent stages. It makes the decisions made less accurate and less timely. Although input execution is technically possible, the lack of immediate feedback can increase cognitive load. It also reduces fluency and enjoyment. In multiplayer games, these inefficiencies further hinder collaboration and reduce the overall experience.

In short, perceptual limitations are the main problem faced by visually impaired players. They directly hinder information acquisition, indirectly constrain decision-making and input execution. This chain effect suggests that fragmented solutions may not be enough [12]. On the contrary, accessibility strategies must cover the entire interactive process. They should provide alternative information channels in the perception process, while also incorporating auxiliary mechanisms for decision-making and input execution. Therefore, the proposed model is not only an explanatory framework, but also the foundation for designing targeted accessibility strategies.

4. Accessibility Design Strategies

Based on the interaction model and the analysis of the challenges faced by visually impaired players, this study proposes a set of multi-level barrier free strategies. The overall approach is built around three complementary directions: multimodal awareness compensation, active exploration through virtual detection mechanisms, and cross platform adaptation through AI based semantic recognition plug-ins.

4.1 Multimodal Perception Compensation

Since most games mainly rely on vision, visually impaired players face the most serious obstacles in the perception phase. In order to alleviate this limitation, auditory and tactile channels can be used as alternative ways of information transmission. Hearing compensation includes several methods. Voice prompt provides an oral description of the target and game status, usually through the voice generated by the screen reader or the system. Ambient sound cues (such as footsteps, wind, or collisions) convey location and context information. Sound production technology maps abstract variables such as distance or speed to sound parameters such as pitch, volume or rhythm [13]. Audible icons use different voices to further distinguish objects or events, so that players can quickly identify interactive categories. In addition, tactile feedback transmitted by vibration or pressure signals can provide redundant confirmation of collision, warning, or target capture events. In summary, these multimodal strategies create an alternative sensory environment that allows players to build situational awareness without visual input.

4.2 Virtual Probe Mechanism

Although passive compensation can provide necessary information, it usually makes players rely on system driven prompts. In order to enhance the agent's ability, this study introduces a "virtual probe" mechanism, which is inspired by the use of a white cane in real world navigation. Players can actively control the probe to scan its surrounding environment by adjusting the direction and detection radius of the probe. When the probe encounters a virtual object, the system will trigger auditory or tactile feedback, with different signals corresponding to the categories of enemies, objects, or obstacles. This mechanism enables players to actively explore the environment instead of waiting for system prompts, thus fostering greater autonomy. The probe design also emphasizes flexibility, because its parameters can adapt to different contexts, as well as usability, because its operation reflects the familiar real-world strategy.

4.3 Probe + Sonar System

In order to enhance environmental feedback, the virtual probe can be integrated with the sonar excitation mechanism to form a "probe+sonar" combination system. The system provides multi-level information support through the following core functions:

1） Sonar Scanning - By continuously emitting sensing signals, this system, similar to a sonar system, allows players to continuously obtain three-dimensional spatial information, dynamically constructing spatial understanding in their minds without constantly receiving discrete information, which reduces the gaming experience.

2） Object-Specific Sound Tags - Each interactive object in the game has a unique sound. When they are detected, the system will respond by referencing the tag's sound, allowing players to quickly identify the object in front of them and understand its approximate function based on the different elements, such as the sound quality and pitch of the interactive object.

3） Real-Time Positional Reporting - The system will report on the player's location, facing direction, and sensed direction while minimizing the decrease in player immersion, thereby helping the player maintain a sense of direction and achieve a smoother gaming experience.

4） Haptic Integration - The system uses vibrations of different intensities and frequencies to help players make appropriate prompts when needed, such as when deviating from a predetermined route, so that players can filter more useful information and make corresponding decisions.

By combining these features, the probe + sonar system provides a more comprehensive and dynamic method of environmental perception. Due to its relative simplicity and low cost of small-scale implementation, this design is mainly suitable for low-cost games such as single-player games and educational games.

4.4 AI-Based Universal Accessibility Plugin

Although the probe+sonar system can provide visually impaired people with better gaming experience, its implementation is based on further development of specific games, which brings higher development costs and limited reusability. To address these challenges, this study outlines the conceptual design of a universal accessibility plugin based on artificial intelligence semantic recognition. This plugin uses a multimodal model to automate the recognition and feedback process, and has the following characteristics:

1） Underlying Principle and Architecture - This plugin uses multimodal AI models to analyze images, textures, and 3D models in games, and automatically generates semantic labels for objects, mapping them to predefined auditory or tactile feedback templates to create recognition mapping feedback channels.

2） Developer Integration - This plugin aims to minimize the workload of developers. By providing object lists, semantic tags, or basic assets, developers can make plugins run without large-scale code modifications. This lightweight integration reduces the burden of repetitive work.

3） Feedback and Adaptation - The AI template library contains typical examples of various types of feedback, allowing developers to select suitable templates in advance according to their needs and then make adjustments that match the game's tone. For example, detecting enemy systems may trigger sharp audio and strong vibrations. In this case, developers can modify the tone and pitch properties based on the type of game being developed and the historical background.

4） Potential Advantages - Compared to customized solutions, AI plugins provide higher scalability and convenience. Because the number of semantic tag classifications is basically fixed, by configuring and training AI in multiple games, it will continuously collect data and optimize solutions, thereby automatically providing more suitable feedback. Meanwhile, if it can be integrated with large-scale language models (LLM), it will have a broader application space.

5） Data and computing requirements - Implementing such plugins requires a significant amount of data and computing resources. It must handle multimodal inputs, including visual frames, audio streams, and object metadata. Training requires access to large-scale datasets to fine tune recognition accuracy. Real time semantic analysis also requires GPU or TPU acceleration to maintain low latency. For consumer devices, lightweight deployment strategies (such as edge computing, model compression, or local coaching) are essential. These measures balance accuracy, efficiency, and cost, making the plugin easy to widely adopt.

Although the plugin framework is still in the conceptual stage, it outlines a feasible path for the integration of artificial intelligence and human-computer interaction, providing a potential solution for utilizing AI to promote inclusive game design.

4.5 Summary

In summary, this chapter proposes solutions to improve the gaming experience of visually impaired individuals from different dimensions: compensating for lost sensory input through multimodal design, actively exploring mechanisms for game coherence and predictability, and providing cross game adaptation through artificial intelligence. Although each strategy has its limitations, they provide possibilities for academic research and practical design of future accessible games at various levels.

5. Conclusion and Future Work

This study investigates the accessibility challenges faced by visually impaired players in video games from the perspective of human-computer interaction (HCI). By constructing a universal interaction model consisting of perception, decision-making, and input execution, it is clear that the lack of visual input among visually impaired individuals can cause a chain reaction that hinders the entire interaction process. On this basis, different strategies were proposed from three levels: multimodal perception compensation, virtual probes combined with sonar feedback, and general plugins based on conceptual artificial intelligence. These methods consider and attempt to address these issues from the perspectives of information substitution, user agency, and cross platform adaptability, collectively providing a reference framework for theoretical exploration and practical design.

At the same time, there are still some restrictions. The proposed models and strategies have not yet undergone large-scale empirical verification, and the design of AI plug-ins is still in the conceptual stage. Further research is needed to evaluate the effectiveness of these strategies through user research and explore their applicability in multi-person and immersive environments. In addition, with the continuous progress of artificial intelligence and multimodal technology, the development of low-cost, universal accessible design toolkits may become a key factor to support industry adoption.

In a word, this study combines theoretical modeling with multi-level strategies to provide a new perspective for barrier-free game design. Although preliminary in nature, the research results aim to promote the ongoing discussions in academia and practice, and support efforts to make visually impaired players participate in digital entertainment more equitably.

REFERENCES

[1] World Health Organization. (2024). Health equity for persons with disabilities: guide for action. World Health Organization.
[2] World Wide Web Consortium. (2018). Web Content Accessibility Guidelines (WCAG) 2.1. https://www.w3.org/TR/WCAG21/
[3] International Game Developers Association. (2004). IGDA accessibility in games: Motivations and approaches [White paper]. IGDA Game Access Special Interest Group. https://igda-gasig.org/wp-content/uploads/2011/10/igda_accessibility_whitepaper.pdf
[4] Westin, T., Bierre, K., Gramenos, D., & Hinn, M. (2006). Game accessibility case study: Terraformers—a real-time 3D graphic game. In Proceedings of the 5th International Conference on Disability, Virtual Reality and Associated Technologies (pp. 95–100).
[5] Yuan, B., Folmer, E., & Harris, F. C. (2011). Game accessibility: A survey. Universal Access in the Information Society, 10(1), 81–100. https://doi.org/10.1007/s10209-010-0189-5
[6] Qiu, S., Xieraili, O., Wang, L., Guo, Z., & Liu, Z. (2025, June). Together in Play: Encouraging social interaction between blind and sighted players with a hide-and-seek game. In International Conference on Human-Computer Interaction (pp. 239–254). Springer Nature Switzerland.
[7] Loebel, J. M., Haase, M., Kümmel, F., & Rafayevych, V. (2025, June). Extending and designing an inclusive chess app for users with cognitive and visual impairments: A participatory design approach. In International Conference on Human-Computer Interaction (pp. 153–167). Springer Nature Switzerland.
[8] Monika, & Johry, A. (2024, November). Voice user interface for designing inclusive games for children with visual impairment and sighted pupils. In Indian Conference on Human-Computer Interaction Design and Research (pp. 89–98). Springer Nature Switzerland.
[9] Andrade, R., Rogerson, M. J., Waycott, J., Baker, S., & Vetere, F. (2019, May). Playing blind: Revealing the world of gamers with visual impairment. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1–14). ACM.
[10] Bierre, K., Chetwynd, J., Ellis, B., Hinn, D. M., Ludi, S., & Westin, T. (2005, July). Game not over: Accessibility issues in video games. In Proceedings of the 3rd International Conference on Universal Access in Human-Computer Interaction (pp. 22–27).
[11] Rodis, N., Sardianos, C., Radoglou-Grammatikis, P., Sarigiannidis, P., Varlamis, I., & Papadopoulos, G. T. (2024).

Multimodal explainable artificial intelligence: A comprehensive review of methodological advances and future research directions. IEEE Access.

[12] Robins, J. (2019). Barrier determination framework for video game analysis regarding users with visual impairments (Doctoral dissertation, University of Huddersfield).

[13] Sekhavat, Y. A., Azadehfar, M. R., Zarei, H., & Roohi, S. (2022). Sonification and interaction design in computer games for visually impaired individuals. Multimedia Tools and Applications, 81(6), 7847–7871.