Towards a Generalized Acoustic Minimap for Visually Impaired Gamers

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ABSTRACT

Video games created for visually impaired players (VIPs) remain inequivalent to those created for sighted players. Sighted players use minimaps within games to learn how their surrounding environment is laid out, but there is no effective analogue to the minimap for visually impaired players. A major accessibility challenge is to create a generalized, acoustic (non-visual) version of the minimap for VIPs. To address this challenge, we develop and investigate four acoustic minimap techniques which represent a breadth of ideas for how an acoustic minimap might work: a companion smartphone app, echolocation, a directional scanner, and a simple menu. Each technique is designed to communicate information about the area around the player within a game world, providing functionality analogous to a visual minimap but in acoustic form. We close by describing a user study that we are performing with these techniques to investigate the factors that are important in the design of acoustic minimap tools.

CCS CONCEPTS

• **Human-centered computing → Auditory feedback**; *Accessibility technologies*; Accessibility systems and tools.

KEYWORDS

Audio navigation tools; acoustic minimaps; blind-accessible games; visual impairments

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1 INTRODUCTION

Mainstream 3D video games are largely inaccessible to visually-impaired players (VIPs) because they often lack crucial accessibility tools [4, 17]. Although some recent mainstream games [6] have made strides in making certain in-game abilities accessible to VIPs, many crucial abilities still remain inaccessible. Among these is the ability for the player to perceive and understand the layout and shape of their surroundings, which prior work has established is crucial to granting VIPs with an enhanced sense of space, presence, and fun within the game world [1, 3, 23].

Video games often use *minimaps* to communicate information about the player's surrounding environment. A minimap is a small map that is visible in a corner of the game screen [25]. Minimaps help sighted players determine their local position and orientation within the game environment, as well as the contents and layout of the area. Specifically, as various authors have described [5, 12, 20, 25], minimaps offer players the following affordances:

(1) The surrounding area's shape.
(2) The surrounding area's size (scale).
(3) The presence and spatial arrangement of items in the area.
(4) The player's position and orientation within an area.
(5) Nearly real-time access to all of the information above (1–4).
(6) A sense of immersion within the game world.

A major accessibility challenge is to create a generalized, acoustic analogue to the minimap for VIPs. It should grant the same affordances that a visual minimap grants but using sound instead of visuals or haptics (the latter often requiring special hardware).

In this work, we develop and investigate four different methods of providing an acoustic minimap: a companion smartphone app, echolocation, a directional scanner, and a simple menu of points-of-interest. These techniques represent a wide range of possibilities for providing VIPs with a better sense of the space around them. Creating a generalized, acoustic minimap can help make the experience within games more fun and fulfilling for VIPs. We close by giving an overview of our planned user study.

2 RELATED WORK

Our work builds from a history of tools and techniques for communicating spatial layouts to VIPs, which were designed for both virtual (video game) environments and the real world.

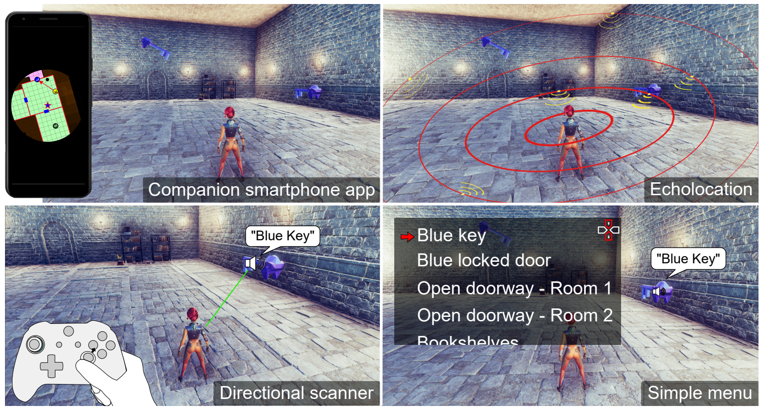

Figure 1: Depictions of our four acoustic minimap techniques: a companion smartphone app, echolocation, a directional scanner, and a simple menu of points-of-interest.

Regarding tools made for virtual environments, many audio-based games created for VIPs — games such as *Terraformers* [16, 22], *A Hero's Call* [15], and *Shadowrine* [10] — present the world and/or its contents in the form of lists and grids. However, mainstream games for sighted players do not confine users to such structures — they allow for free, unrestricted movement within a 3D game world. As a result, list- and grid-based presentations cannot be generalized to *any* type of environment or play style.

Regarding tools made for the real world, many mainstream blind navigation systems such as NavCog3 [18] and Microsoft Soundscape [11] give users a very limited sense of awareness of their surrounding environment. Although these systems provide users with a near-real-time sense (#5) of their position and orientation within an area (#4), they do not provide information about the area's shape and size (#1 and #2) and may provide only limited information about the arrangement of items within the area (#3).

Another technique is echolocation, which has been explored for both real [9, 14, 19] and virtual [1, 2] environments. Echolocation can allow individuals to learn about the structure of the area they are in, including the locations and physical properties of nearby objects [19]. As it satisfies the six minimap affordances from the Introduction. As such, we are currently exploring echolocation in the context of these six affordances.

3 ACOUSTIC MINIMAP TECHNIQUES

We created four techniques for facilitating an acoustic minimap that are inspired by existing tools and techniques for communicating spatial information via sound. Each technique is designed to communicate information about the area around the player within a game, satisfying the affordances of a visual minimap to varying degrees but in acoustic form. It is important to note that none of these techniques are intended to act as a perfect acoustic minimap tool. Rather, we are using the tools that we develop to discover which factors are important when designing an acoustic minimap.

The four techniques (shown in Figure 1) are as follows:

(1) *Companion smartphone app:* A smartphone-based tool that allows VIPs to survey a minimap of their surrounding area by dragging their finger along their phone's touchscreen. This technique is inspired by previous work exploring touchscreen-based maps for VIPs [7, 8, 24].
(2) *Echolocation:* A tool that allows players to emit a mouth click-like sound in all directions and uses the physical properties of the game environment to simulate reverb.
(3) *Directional scanner:* A tool that allows players to point the game controller's right thumbstick in any direction to hear what lies directly in that direction relative to the player. This technique is inspired by NavStick [13].
(4) *Simple menu:* A status-quo tool that presents a list of points-of-interest in the player's surrounding area. Players can "select" a menu item to place a looping audio beacon at the corresponding item's location.

4 USER STUDY

Our user study has three goals: (1) to determine what factors are important to designing acoustic minimaps within games, (2) to see how well each of the four techniques satisfies the affordances that minimaps should provide (#1–6 mentioned previously), and (3) to establish which technique(s) VIPs prefer and why.

We are developing a representative 3D adventure game in the Unity game engine [21] as a testbed for the four techniques. In our game, players must escape a multi-room dungeon by collecting keys and other objects to solve puzzles. We will ask participants to play the game using all four techniques: one per game level. We will then ask them to provide their general impressions of each technique and to evaluate each with respect to the six affordances.

We hypothesize that each of the four techniques will have its own advantages and disadvantages over the others, depending on the player's current goal and the type of environment they are in. Although much of the research community's focus has been on exploring simple menus (Technique 4) and echolocation (Technique 2), the research community can benefit from comparing them with each other and comparing them against other options (Techniques 1 & 3). Ultimately, we plan to use the insights from our study to develop a new set of principles for developing acoustic minimaps, which can make mainstream 3D games more blind-accessible and make gaming a more fun and fulfilling experience for VIPs.

REFERENCES

[1] Ronny Andrade, Steven Baker, Jenny Waycott, and Frank Vetere. 2018. Echohouse: exploring a virtual environment by using echolocation. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction (OzCHI '18)*. Association for Computing Machinery, 278–289. https://doi.org/10.1145/3292147.3292163

[2] Ronny Andrade, Melissa J. Rogerson, Jenny Waycott, Steven Baker, and Frank Vetere. 2020. Introducing the Gamer Information-Control Framework: Enabling Access to Digital Games for People with Visual Impairment. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Association for Computing Machinery, 1–14. https://doi.org/10.1145/3313831.3376211

[3] Ronny Andrade, Jenny Waycott, Steven Baker, and Frank Vetere. 2021. Echolocation as a Means for People with Visual Impairment (PVI) to Acquire Spatial Knowledge of Virtual Space. *ACM Transactions on Accessible Computing* 14, 1 (Mar 2021), 4:1–4:25. https://doi.org/10.1145/3448273

[4] Dominique Archambault, Thomas Gaudy, Klaus Miesenberger, Stéphane Natkin, and Rolland Ossmann. 2008. *Towards Generalised Accessibility of Computer Games.* Lecture Notes in Computer Science, Vol. 5093. Springer Berlin Heidelberg, 518–527. https://doi.org/10.1007/978-3-540-69736-7_55

[5] Felix Bork, Ulrich Eck, and Nassir Navab. 2019. Birds vs. Fish: Visualizing Out-of-View Objects in Augmented Reality using 3D Minimaps. In *2019 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. 285–286. https://doi.org/10.1109/ISMAR-Adjunct.2019.00-28

[6] Naughty Dog. 2020. *The Last of Us Part II.* Sony Interactive Entertainment.

[7] Timo Götzelmann. 2016. LucentMaps: 3D Printed Audiovisual Tactile Maps for Blind and Visually Impaired People. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '16)*. Association for Computing Machinery, 81–90. https://doi.org/10.1145/2982142.2982163

[8] Timo Götzelmann and Klaus Winkler. 2015. SmartTactMaps: a smartphone-based approach to support blind persons in exploring tactile maps. In *Proceedings of the 8th ACM International Conference on PErvasive Technologies Related to Assistive Environments (PETRA '15)*. Association for Computing Machinery, 1–8. https://doi.org/10.1145/2769493.2769497

[9] Daniel Kish. 2009. Human echolocation: How to "see" like a bat. *New Scientist* 202, 2703 (Apr 2009), 31–33. https://doi.org/10.1016/S0262-4079(09)60997-0

[10] Masaki Matsuo, Takahiro Miura, Masatsugu Sakajiri, Junji Onishi, and Tsukasa Ono. 2016. Audible Mapper & ShadowRine: Development of Map Editor Using only Sound in Accessible Game for Blind Users, and Accessible Action RPG for Visually Impaired Gamers. In *Computers Helping People with Special Needs (Lecture Notes in Computer Science)*, Klaus Miesenberger, Christian Bühler, and Petr Penaz (Eds.). Springer International Publishing, 537–544. https://doi.org/10.1007/978-3-319-41264-1_73

[11] Microsoft Research. 2018. Microsoft Soundscape - Microsoft Research. https://www.microsoft.com/en-us/research/product/soundscape/.

[12] Daniel R. Montello, David Waller, Mary Hegarty, and Anthony E. Richardson. 2003. *Spatial Memory of Real Environments, Virtual Environments, and Maps.* Psychology Press.

[13] Vishnu Nair and Brian A. Smith. 2020. Toward Self-Directed Navigation for People with Visual Impairments. In *Adjunct Publication of the 33rd Annual ACM Symposium on User Interface Software and Technology (UIST '20 Adjunct)*. Association for Computing Machinery, 139–141. https://doi.org/10.1145/3379350.3416156

[14] Liam J. Norman, Caitlin Dodsworth, Denise Foresteire, and Lore Thaler. 2021. Human click-based echolocation: Effects of blindness and age, and real-life implications in a 10-week training program. *PLOS ONE* 16, 6 (Jun 2021), e0252330. https://doi.org/10.1371/journal.pone.0252330

[15] Out of Sight Games. 2017. *A Hero's Call.*

[16] Pin Interactive. 2003. *Terraformers.*

[17] John R. Porter and Julie A. Kientz. 2013. An empirical study of issues and barriers to mainstream video game accessibility. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '13)*. Association for Computing Machinery, 1–8. https://doi.org/10.1145/2513383.2513444

[18] Daisuke Sato, Uran Oh, Kakuya Naito, Hironobu Takagi, Kris Kitani, and Chieko Asakawa. 2017. NavCog3: An Evaluation of a Smartphone-Based Blind Indoor Navigation Assistant with Semantic Features in a Large-Scale Environment. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility - ASSETS '17*. ACM Press, Baltimore, Maryland, USA, 270–279. https://doi.org/10.1145/3132525.3132535

[19] Lore Thaler and Melvyn A. Goodale. 2016. Echolocation in humans: an overview. *WIREs Cognitive Science* 7, 6 (2016), 382–393. https://doi.org/10.1002/wcs.1408

[20] Ross Thorn. 2018. *How to Play With Maps.* Ph.D. Dissertation. https://minds.wisconsin.edu/handle/1793/78913 Accepted: 2019-01-17T20:40:13Z.

[21] Unity Technologies. 2020. Unity. Unity Technologies.

[22] T. Westin. 2004. Game Accessibility Case Study: Terraformers – a Real-Time 3d Graphic Game. In *In Proc. of the The Fifth International Conference on Disability, Virtual Reality and Associated Technologies.* 95–100.

[23] Matt Wilkerson, Amanda Koenig, and James Daniel. 2010. Does a sonar system make a blind maze navigation computer game more "fun"?. In *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility (ASSETS '10)*. Association for Computing Machinery, 309–310. https://doi.org/10.1145/1878803.1878886

[24] Koji Yatani, Nikola Banovic, and Khai Truong. 2012. SpaceSense: representing geographical information to visually impaired people using spatial tactile feedback. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* Association for Computing Machinery, 415–424. https://doi.org/10.1145/2207676.2207734

[25] Krzysztof Zagata, Jacek Gulij, Łukasz Halik, and Beata Medyńska-Gulij. 2021. Mini-Map for Gamers Who Walk and Teleport in a Virtual Stronghold. *ISPRS International Journal of Geo-Information* 10, 22 (Feb 2021), 96. https://doi.org/10.3390/ijgi10020096