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A Prototype of Tactile and Transformable Support Device for Visually Impaired Tabletop Gamers

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Abstract: Accessibility in digital video games has been improved by introducing design guidelines and adaptive controllers for disabled players. However, accessibility in tabletop board games remains untouched. Playing and taking pleasure in such analog games is almost impossible, especially for blind players. This study focuses on a prototype tactile transformable support device specifically designed for visually impaired players. The support board enables visually impaired players to understand the current state of the game board and make strategic decisions independently in board game sessions. The board's transformable nature facilitates dynamic adjustments during gameplay. It can adapt to different game scenarios and ensure a smooth and enjoyable experience for visually impaired players.In this paper, we present the design process and technical specifications of the tactile transformable support device. Through this research, we aim to provide an inclusive gaming experience for visually impaired players.

Keywords: Accessibility, inclusive design, entertainment

1. Introduction

Board games have gained significant popularity in recent years, attracting a diverse community of gamers. Websites such as Board Game Geek[3], The Dice Tower[24], and Shut Up and Sit Down[23] have become valuable platforms for enthusiasts to discuss their hobbies, share reviews, and discover new board games. These board games, designed for two or more players, foster cooperation and teamwork, providing an ideal environment for social interaction and strengthening interpersonal relationships.

While board games offer numerous social benefits, they also serve as a creative outlet, particularly for children[14]. Through board games, individuals can express their imaginative and strategic abilities, enhancing cognitive skills and fostering a sense of enjoyment and accomplishment.

However, despite the growing interest in board games, the experiences of blind and low-vision gamers are often overlooked. Modified versions of popular games like Chess, Monopoly, and Uno have been around to enable visually impaired players to participate. These adaptations often incorporate tactile and braille prints to assist visually impaired players. Nevertheless, many modern board game designs, with their reliance on color-coded cards and small images, pose significant challenges for visually impaired players to fully engage in game sessions.

This research proposes a novel framework that combines real-time state tracking and tactile feedback to address the limitations faced by visually impaired players in modern board games. The framework aims to enhance the accessibility of board game sessions by leveraging camera-based technology and a transformable optional board. The real-time state tracking component utilizes computer vision algorithms to track the state of the board game session in real time. By analyzing the visual input from a camera, the framework can identify the positions of game elements such as pawns, cards, and resources. This tracking functionality enables the framework to generate a representation of the game state.

The second component of the framework focuses on transforming visual information into tactile feedback. The optional board, equipped with pins and motors, dynamically reconfigures its surface to provide tactile representations of the game state. Through this transformable board, visually impaired players can interact with the game elements, feeling the positions and movements of pawns, the layout of cards, and the availability of resources. The tactile feedback provides a tangible and accessible means for blind players to comprehend and engage with the game session in real time.

The implementation involves a combination of hardware and software components. A camera is mounted above the game board to capture the visual input, which is then processed using computer vision algorithms. The algorithms identify key elements and their positions on the board, extracting relevant information for the game state. The transformable optional board incorporates pins that can be raised or lowered to create tactile representations. These representations are synchronized with the real-time game state, allowing visually impaired players to perceive the spatial arrangement and changes in the game elements. The design of the optional board ensures that it is adjustable and adaptable to various board game sizes and configurations.

In the evaluation phase, visually impaired participants will have an involvement in testing the framework. Their feedback and experiences will be collected through interviews, surveys, and observation of their gameplay sessions. This feedback will help assess the effectiveness of real-time state tracking and tactile feedback in improving accessibility for blind players in board games.

By combining real-time state tracking and tactile feedback, this framework has the potential to revolutionize the board game experience for visually impaired players, fostering inclusivity and equal participation in the gaming community.

2. Related Works

Numerous studies that explored accessibility and inclusive

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design, including digital games and board games context, have been around in recent years. These works gave us robust and valuable insights into designing a framework that could enhance accessibility experiences for visually impaired players during board game sessions.

2.1 Game Adaptation

In the book Developing Inclusive Games: Design Frameworks for Accessibility and Diversity[4], the author gave us a comprehensive framework for designing inclusive games for players with various disabilities, including those with visual impairment. The book offers guidelines and strategies to ensure that our framework provides an enjoyable gaming experience for all players.

Adaptation guidelines proposed by Da Rocha et al. focus on the development of adapting board games to make them more inclusive and enjoyable for visually impaired players[6]. The guidelines suggested in the paper cover various aspects, including tactile elements, braille, or other alternative text formats, audio cues or narration, and other assistive technologies. The authors also discuss the importance of clear and intuitive game components, tactile markers, and accessible rulebooks to ensure that visually impaired players can participate fully and understand the game mechanics. The paper provides us with practical guidelines that can assist us in adapting board games for players with visual impairment

2.2 Device for Visually Impaired Players

Focuses on the development of an interactive augmented reality map specifically designed for individuals with visual impairment has been done in recent years. Albouys-Perrois et al. points out the limitations of current low-tech Orientation and Mobility (O&M) tools, such as tactile maps, which are commonly used by visually impaired individuals[1]. They also created a prototype that combines various sensory modalities, including projection, audio output, and tactile tokens. This combination allows individuals with low vision or blindness to explore existing maps and actively construct or modify them according to their needs. Their results also indicated a high level of user satisfaction with the prototype's functionality and usability. By involving the end-users in the design process, the study highlights the importance of participatory design in creating inclusive technology solutions that cater to the specific need of the target user group.

The visual nature of board games can create barriers for blind and visually impaired players who may struggle to read cards or locate game pieces. Game Changer[15] addresses the accessibility challenges faced by blind and visually impaired individuals when engaging in board and card games, which rely heavily on visual information. In the paper, Game Changer[15] incorporates two main features to enhance accessibility. First, it provides an audio description that verbally conveys the visual information present in the game, allowing visually impaired players to understand the game state and make informed decisions. Second, it includes tactile addition that provides physical cues modifications to game components, enabling visually impaired players to interact with game pieces more effectively.

3. Transformable Device

A novel interactive system called "inFORM" introduces a new way of interacting with digital content in the physical world[12]. The system consists of a large-table like surface composed of a grid of individually actuated pins. These pins can move up and down to form three-dimensional shapes and objects on the surface. By manipulating the pins, the system can render physical representations of digital content, such as 3D models, data visualizations, or interactive elements. "inFORM" showed that the system can effectively enhance the interaction experience by providing haptic feedback. However, "inFORM' has a rather large system that is stationary and not dynamic. Based heavily on the "inFORM' system and architecture, we aim to provide a dynamic and easy-to-move tactile transformable board for visually impaired players.

3.1 System Requirement

Our study's objective is to evaluate the effectiveness of a prototype tactile transformable board in improving accessibility for visually impaired players in modern board games. It is carefully designed to address the specific requirements of visually impaired players. These requirements include:

- Tactile Feedback: Visually impaired players rely on tactile feedback to understand the game state. The transformable support board is equipped with pins and motors that create tactile representations of the game state, allowing players to feel and interpret game elements through touch.
- Real-Time Audio Feedback: In addition to tactile feedback, the system includes real-time audio feedback. This audio feedback provides spoken descriptions of the game state and events, helping visually impaired players stay informed during the game.
- Game State Updates: The real-time state tracking component continuously updates the game state and provides audio cues to indicate changes in the game. This ensures that visually impaired players remain informed about the ongoing gameplay.
- Dynamic and Adaptable: The transformable board should be comfortably used during board game sessions and has the ability to adapt to other board games.

By addressing these specific hardware and software requirements, our system is tailored to enhance accessibility and inclusivity for visually impaired players in board games. Through tactile feedback, audio descriptions, and customizable settings, we aim to create an enjoyable and immersive gaming experience that allows visually impaired players to participate on an equal footing with their sighted peers.

3.2 Hardware Component

The hardware component of our system consists of a camera and a transformable support board. A camera mounted above the board game will capture the ongoing game session in real-time. This camera will serve as a primary visual input for our system. The transformable support board, equipped with pins and motors inside, are essential elements for providing tactile feedback to visually impaired players. The board can dynamically reconfigure its surface to create tactile representations of the game state.

3.3 Software Component

The framework's software component also plays a vital role in the real-time state tracking. To process any visual information, computer vision algorithms are employed to analyze the visual input. These algorithms help identify key elements on the board, such as pawns, cards, and resources. Lastly, it will extract relevant information to generate a representation of the current game state.

The real-time state tracking component will ensure that the framework keeps up with the dynamic nature of board game sessions. As the camera captures the ongoing gameplay, the computer vision algorithms process the visual data, continually updating the game state representation. This process allows visually impaired players to stay informed about the position and movements of game elements throughout the game session. Then, the board's pins and motors can be raised or lowered. These pins and motors will create tactile representations that correspond to changes in-game elements. This tactile feedback enables visually impaired players to interact with the game elements effectively.

To ensure the framework's versatility, the support board is designed to be adjustable and adaptable to various board games and configurations. The ability to accommodate different board layouts makes our solution suitable for a wider range of board games, enhancing its practicality and usability for the target user group.

During the evaluation phase, we will engage visually impaired participants in testing our framework. Furthermore, we will collect valuable feedback and insights regarding the effectiveness of real-time state tracking and tactile feedback in improving accessibility for visually impaired players in board games. We anticipate that our framework will significantly enhance the board game experience for visually impaired players. By providing real-time state tracking and tactile feedback, we aim to foster inclusivity, empower visually impaired players to participate fully, and strengthen their social interactions within the gaming community.

4. Experimental System Design

This section outlines the experimental specifications for a transformable support device to assist visually impaired players in participating effectively in board game sessions. The device employs pins and motors to provide tactile feedback, acting as a secondary game board where players can interact with and track game components.

4.1 Device Overview

The primary purpose of this device is to enhance the gaming experience for visually impaired individuals by providing tactile feedback. Those tactiles represent the position and movement of player pawns and other game components during board game sessions.

4.2 Tactile Feedback Generation

The device made from balsa wood (Figure 2) features an array of tactile pins (Figure 1) strategically positioned to correspond with the game board's layout. These pins can be raised or lowered to represent the current position of player pawns, game pieces, and other essential elements. The pins have a 25 mm height and are embedded in the motor below (Figure 3).

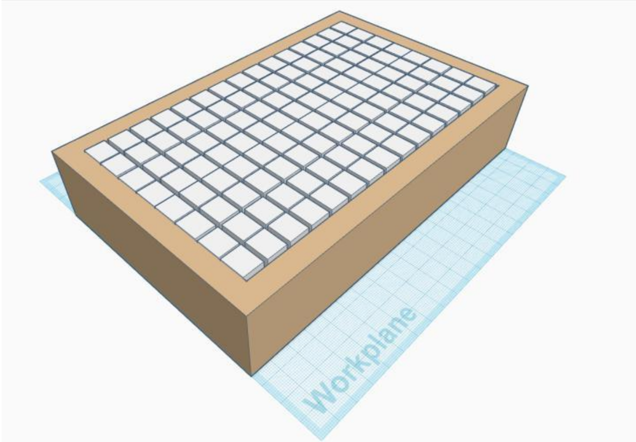

Figure 1 3D representation of the Transformable Support Device

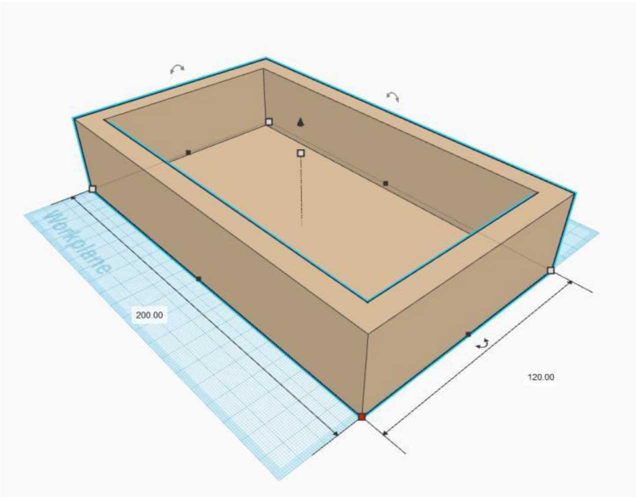

Figure 2 The inside of the device before motors is inserted

The motors will control the movement of the pins and are designed to raise or lower the pins with precision, providing accurate tactile feedback to the user. The pins will be designed to withstand continuous use and provide a comfortable tactile experience for users.

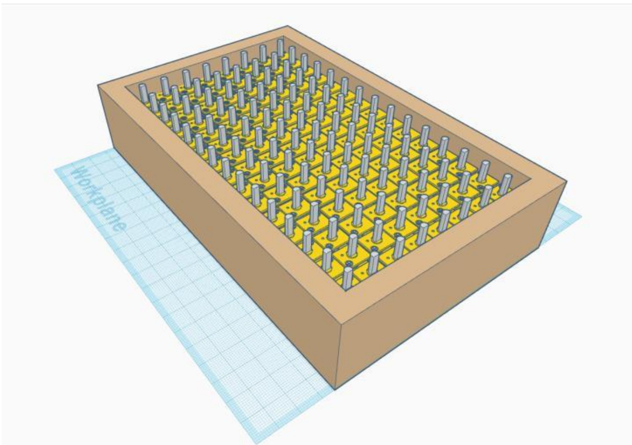

Figure 3 The motors uses to control the pin's heights

In this prototype device, we will use 120 motors to control the pin's movement as shown in Figure 3. These 120 motors will be arranged into 15 rows of horizontal panels, 8 rows of vertical panels. We are using a 6V DC geared motor, as it can manipulate the height of the pins. Another reason we use this motor is it can operate quietly to minimize disruption during gameplay.

For each pin, we can update the height position to provide haptic feedback to visually impaired players. For example, we can tell the motor to slightly raise the pins to indicate a path the player can take in the game. Also, the motor can fully raise the pins to indicate the location of each player's pawns, cards, or other resources (Figure 4).

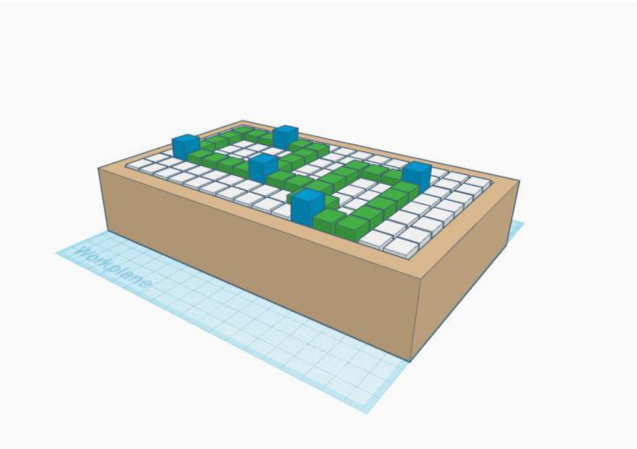

Figure 4 The motor can control the pins to be slightly (green) or fully raised (blue), and can be lowered (white)

4.3 Object Tracking

Object tracking is our system's essential component, allowing us to provide real-time game state updates and tactile feedback. This technology involves advanced computer vision techniques and hardware components to monitor and interpret the positions and movements of game elements, including game pieces, cards, and resources. Central to our object-tracking technology are computer vision algorithms. These algorithms analyze visual input from a camera mounted above the game board. The primary role of these algorithms is to identify key game elements and track their movements.

The algorithms will recognize various game pieces, such as pawns, tokens, and cards, by their unique shapes and characteristics. This recognition enables the system to understand the initial setup of the game board and track the positions of these elements during gameplay. As the game progresses, the algorithms continually track the movements of game pieces. By comparing successive frames, the system can determine when a pawn is moved and placed and how it interacts with other elements on the board.

By integrating advanced computer vision algorithms and tactile feedback generation, our object-tracking technology is the backbone of our system. Allowing visually impaired players to enjoy board games with a high degree of independence and engagement. This technology paves the way for a more inclusive gaming experience, ensuring that board games can be accessible to all, regardless of visual impairments.

5. System Use Case

Our research presents a use case wherein the system facilitates the active participation of visually impaired players. We explore the application of a tactile transformable board system with a focus on the widely popular game "Pandemic."[26]

Figure 5 Pandemic board game

Cooperative board games, exemplified by "Pandemic," offer dynamic and engaging experiences (Figure 5). However, engaging in these games can be challenging for visually impaired players. Our study presents a use case that illustrates how our transformable support device system addresses the unique needs of visually impaired players. Enabling them to actively participate in the board game sessions.

The system's computer vision algorithms and tactile feedback can describe the evolving game state as shown in Figure 7. That will allow visually impaired players to keep up with teammates' moves (Figure 6) and the evolving status of disease outbreaks. The tactile feedback mechanism translates these changes into touch, allowing the player to adapt their strategies effectively.

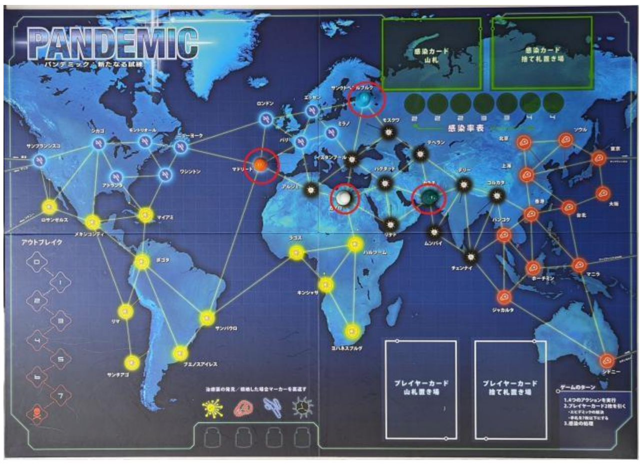

Figure 6 The board game "Pandemic", showing the location of each player's pawns (shown in red circle)

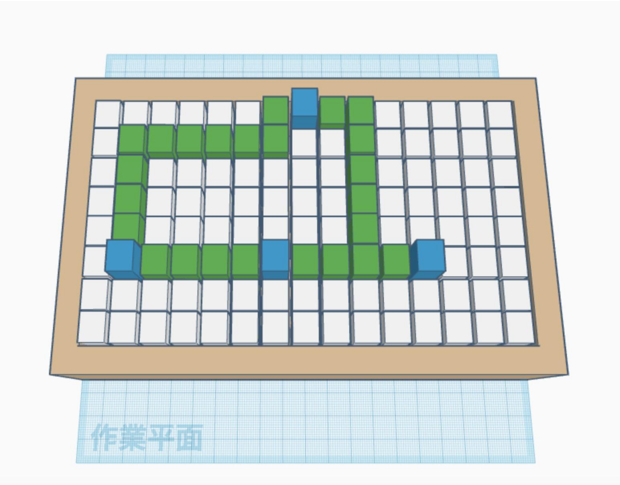

Figure 7 The transformable board showing the player pawns location using tactile feedback

By leveraging computer vision technology and tactile feedback, our system promotes inclusivity. Empower visually impaired players to engage fully and strengthen social interactions within the gaming community. Our study highlights the transformative potential of such systems, making cooperative board games accessible and enjoyable for all, regardless of visual impairments.

6. Conclusion

While adaptations of classic board games have been around to facilitate blind participation, modern board games often present formidable barriers due to their reliance on intricate visual elements, color-coded cards, and tiny images. We introduce a groundbreaking framework that amalgamates real-time state tracking and tactile feedback. Aimed at enhancing the accessibility of board games for blind and low-vision players.

We used a different approach by leveraging camera-based technology and a transformable optional board. The real-time state tracking component employs computer vision algorithms to monitor the board game's state. By processing visual input from a mounted camera, the framework interprets the positions of various game elements, such as pawns, cards, and resources, creating a comprehensive representation of the game state.

The tactile feedback element embedded in the transformable support board equipped with pins and motors. It serves as a bridge between visual information and tangible engagement for blind players. This dynamic board provides tactile representations that align with real-time game state changes.

As we move on, visually impaired participants will be actively involved in testing our framework. Their invaluable feedback shapes the future of accessible board gaming. Through their experiences and insights, we will assess the efficacy of real-time state tracking and tactile feedback in improving the inclusivity of modern board games.

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