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3D Echolocating system for the visually impaired based on bat SONAR approach

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ABSTRACT

Video games are becoming widely used today for entertainment and socializing. However, with all the technology there are few games for the blind or the visually impaired people. In the literature, research attempts for wearable and/or assistive systems designed to support visually impaired people are limited in terms of accuracy and support only limited tasks; such as: learning activities, sending SMS, ... etc.. They use predefined tasks and train visually impaired individual to use the system. For navigation and detecting obstacles whilst moving in uncertain environment, visually impaired people would need fruitful research regarding training visually impaired people to understand and interpret the 3D sounds; commonly known as BATS based software. BATS software supports independent mobility for visual impairments individuals benefit as it provides means to navigate, detect objects, and react to uncertain issues in surrounding using sound navigation and ranging (SONAR). In this paper, we propose a game that allows visually impaired/blind individual to be trained to interpret sounds through the game by play against a sighted opponent (teacher/ relevant or mother for the child). The main idea of the game is to let the sighted player raise sounds; programmed in the game players attack each other's area. The sighted player mode will have both visuals and audio. According to the Bat system, the blind/visually impaired will have 3D audio, Ultrasonic sensors are used for detecting the obstacles whilst the Servo motors are used to give a precise position and the google glasses to make object type recognition. The sighted opponent will enforce objects occurrences inside the game and the blind/ visually impaired user would be trained use the system in order to be able determine types of the objects, distance to objects compensate the visuals.

KEY WORDS: ECHOLOCATION, EDUCATION, BLIND, VISUALLY IMPAIRMENT, BAT HEARING SYSTEMS, SPATIAL SOUND, AUDIO DESCRIPTIONS, PERCEPTIBLE FEEDBACK, GOOGLE MAPS, GOOGLE GLASSES, ULTRASOUND SENSORS

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INTRODUCTION

Video games industry has grown quickly since it emerged in 1970s. People play video games for entertainment and socializing. In 2016, the industry generated more than $30.4 billion in revenue from selling games. In 2018, frequent gamers play multiplayer and online games spend an average of 7 hours a week. The average gamer age is 34 years (2019). The attractive design of the user interface and the idea of the game keep people playing. Today, most of the games interface and audio are 3D that gives the game more reality. Also, the accessories that used to play the game with like virtual reality, controller, and headphone. However, with all this technology there are few games for the blind or the visually impaired people (Kolarik et al. 2014). According to the *world health organization*, the visually impaired population worldwide exceeds 1.3 billion and 36 million of this population are totally blind (2019). Accessibility refers to the design of products, devices, services, or environments for people who experience disabilities (Henry, Abou-Zahra & Brewer 2014). Game accessibility allows people with visual disabilities the chance to have access to multimedia games equivalent to sighted people. It is challenging since the main feedback channel in games is usually visual while it is difficult or even impossible for visually impaired players to receive feedback from games (Giannakopoulos et al. 2018).

In fact, game accessibility a more challenging and complex problem than computer accessibility and web accessibility (Archambault et al. 2007). To make games accessible to blind players, visual feedback needs to be replace with another form of feedback that is perceivable by a blind player, such as auditory or haptic. Option for visual replacement with audio include: screen readers, Audio cues: using real world sounds, or Sonication. In some cases it is difficult to replace visual with audio such as in music games, in such cases haptic feedback is preferred over audio. (Archambault et al. 2007) (Yuan, Folmer & Harris 2011):

Echolocation is an acoustical process for both object location and identification by means of sending sound pulses and receiving the reflected echoes (Kim 2015). Bats are known to be able of echolocation (Sumiya et al. 2019). They would give a short whistle and estimate the distance from the shoreline by the returning echo. If the echo came back from both sides at the same time they'd know that they were in the middle of the channel. They could recognize different shorelines by the different echoes - a rocky cliff, for example, would give a clear distinctive echo, whereas a sandy beach would give a more prolonged echo. They could even pick up an echo from logs. Echolocation is mostly used to discuss the responses of bats and dolphins, which are known for their echolocating abilities. It was first used by Griffin in 1944 (Griffin 1944) to describe the exceptional ability of bats to navigate in the darkness, experiments have shown that this ability was based on the principles of echolocation (Kolarik et al. 2014) (Koning 2014). Humans are not considered among the echolocating species. However, some blind human can develop echolocation skills and show remarkable spatial abilities and become an expert echolocator (Yu et al. 2018).

Human echolocation is the ability to locate objects in the environment through interpreting acoustic echoes (Thaler & Goodale 2016). A human trained in echolocation can obtain information about the environment around him such as objects, he can also accurately identify distance and size. Most of us have encountered a blind person walking alone and able to avoid obstacles while navigating (Sohl-Dickstein et al. 2015) (Milne 2014) (Thaler & Goodale 2016). There are two different types of echolocation: passive and active (Flanagin et al. 2017). Passive echolocation is interpreting the echoes of the natural sounds produced around you. On the other hand, in active echolocation, you will actively produce sounds and then receive and interpret the reflected echoes to extract localization information (Koning 2014). Studies have revealed that blind and visually impaired people are more sensitive to acoustic reverberations echoes than sighted people (Thaler 2015). They use the natural surrounding echoes or the reflected sound waves to sense details about their environment and build a mental image of it. Therefore, they have the potential to use echolocation system like Bats to detect where objects are. To actively echolocate, blind people have to learn how to visualize their surroundings by making clicking sounds with their tongue and using their echoes to gauge information about their environment and move about. Blind people who become experts in click-based human echolocation are able to determine an object's distance, size, texture and density. Echolocation can be seen as an effective mobility, location and orientation aid for blind and visually impaired people, with which they can improve their independencies and quality of life (Milne 2014) (Thaler & Goodale 2016).

Each Audio technology made it possible to present audio with a 3D effect. 3D audio effects are sounds that play through a stereo output, surround sound speakers, speaker arrays, and through smart phones and handheld gaming systems, headphones. 3D audio is very important in gaming and is more important in designing games for the blind (Russo, Sacks & Vandal 2012). It gives people the ability to hear voices from different positions and allow them to have a realistic feeling of the environment of a particular app or a game. Adding a 3D audio to the game will provide users with a more real experience allowing them to know what their surroundings

are, what is close to them and what is far from them. With the help of 3D audio, game developers can create different games for blind or visually impaired players by using it to help the player imagine the games environment and providing a 3D audio to their surroundings or enemies and their movement to help the blind/visually impaired players to locate them. There are different ways to stimulate the 3D sound, but the most practical way is to use a game engine with the ability to take a sound and create spatial perspective by placing it in the scene of the action such as Unity (Technologies no date) and Unreal (Epic Games no date) game development kit.

In the last few years, the world became aware of the need for technologies and software that is designed specifically for the blind and visually impaired people. The growth of these technologies and software is slow in game industry. A number of games currently employ mechanisms to assist players who are blind. Here, we will survey some e-games that are developed for the blind. A Blind Legend (Dowino no date) is an audio-based game that offers a 3D audio experience to the player. The user play as a blind knight whose wife has been kidnapped and must rescue her with the help of his daughter who give the blind knight the directions to where to go next. The daughters sound is 3D, while wearing your head phones the user can hear where she is and follow her voice. At the beginning the player is given instructions on how to play using a human audio that introduce him the basic controls to play the game, for example, to move you need to drag your finger on the screen to the direction you want to go next, forward, backward, left or right, and to move faster you need to drag your finger farther and hold it on the screen. Lifting your finger from the screen will stop the knight from moving. Papa Sangre II (Webster no date) is an audio game for sighted and blind people for only iOS users. Papa Sangre II doesn't have a graphical user interface which makes players use their fiction to imagine. In this game, player navigate a dark world using sound only, guided by a narrator voiced by Sean Bean who is Lord of the Rings and Game of Thrones star. Even without graphics, the game is one of the biggest selling points for games. The first thing that player told in Papa Sangre II is that "you are dead" and they must find the way to the land of living. There are set of instructions that let gamer navigate the game like to move forward tap the two lower corners of your iPhone or iPad. Entombed (Driftwood Games no date) is a game for blind and visually impaired designed by driftwood audio entertainment company. This game has been in development since 2008. In Entombed, you battle to escape a deep and brutal dungeon and having been thrown into the infamous pit then you have to find a passage that returns you to the surface. Along the way, you will face ogres, menacing goblins and living statues. Depending on the sound, you keeping away from hurt and try again to reach the safety surface. Blindfold Racer(Kid Friendly Software, Inc no date) is a driving game where you drive with ears instead of eyes. It is a free game for blind and sighted people. Game depends on the audio instead of graphical user interface but if player sighted can see road after level over. It fit kids and adults.

The idea of the game is the player avoids hitting animals while driving. The player drives his/her car by listing to what on the road. It is a multi-level game and require headphones to have fully enjoy them. SixthSense (Hyun Soo KIM no date) is a game for both blind and sighted people. It is free application on app store. The SixthSense is an action-horror game. The game idea is to fight the zombies with various of weapons. The player can control the game by sliding and tapping the screen. The player required to wear headphone to play the game because it is provided with 3D surround sound to make the player feels like he is really attacked by the zombies. Also, it has voice over function for blind player. In an attempt to enhance racing games accessibility and allowing players who are blind to play the same racing games as do sighted players, RAD was developed as a racing auditory display (Smith & Nayar 2018). It is an audio-based user interface. It works with a standard pair of headphones and comprises two novel sonication techniques: the sound slider for understanding a cars speed and trajectory on a racetrack and the turn indicator system for alerting players of upcoming turns.

In this paper, we present an e-game application that allows the blind/visually impaired player to play with sighted opponent. The main idea of the game is to let the players attack each other's area. The game will have two different modes. The first one is the blind mode; it will have 3D audio for the blind/visually impaired player to compensate the visuals. The second mode is the sighted player mode where it will have both visuals and audio. To create the 3D model for sighted people in the game, Unity 3D is chosen so that it can attract sighted people to the game and let them share fun with blind people.

MATERIAL & METHODS

Our game interfaces are 3D interfaces. First interface's aim is to define if the user is blind or sighted and it is an audio interface. Second interface contains registration form. Third interface is the main menu which contains two buttons: Play (to start new game) and Tutorial (to play the tutorial). Fourth interface is level of difficulty to let the player choose which level she/he wants to play. Fifth interface is choosing opponent to let the player choose which available opponents to play against. Last interface is result interface, to inform both players about

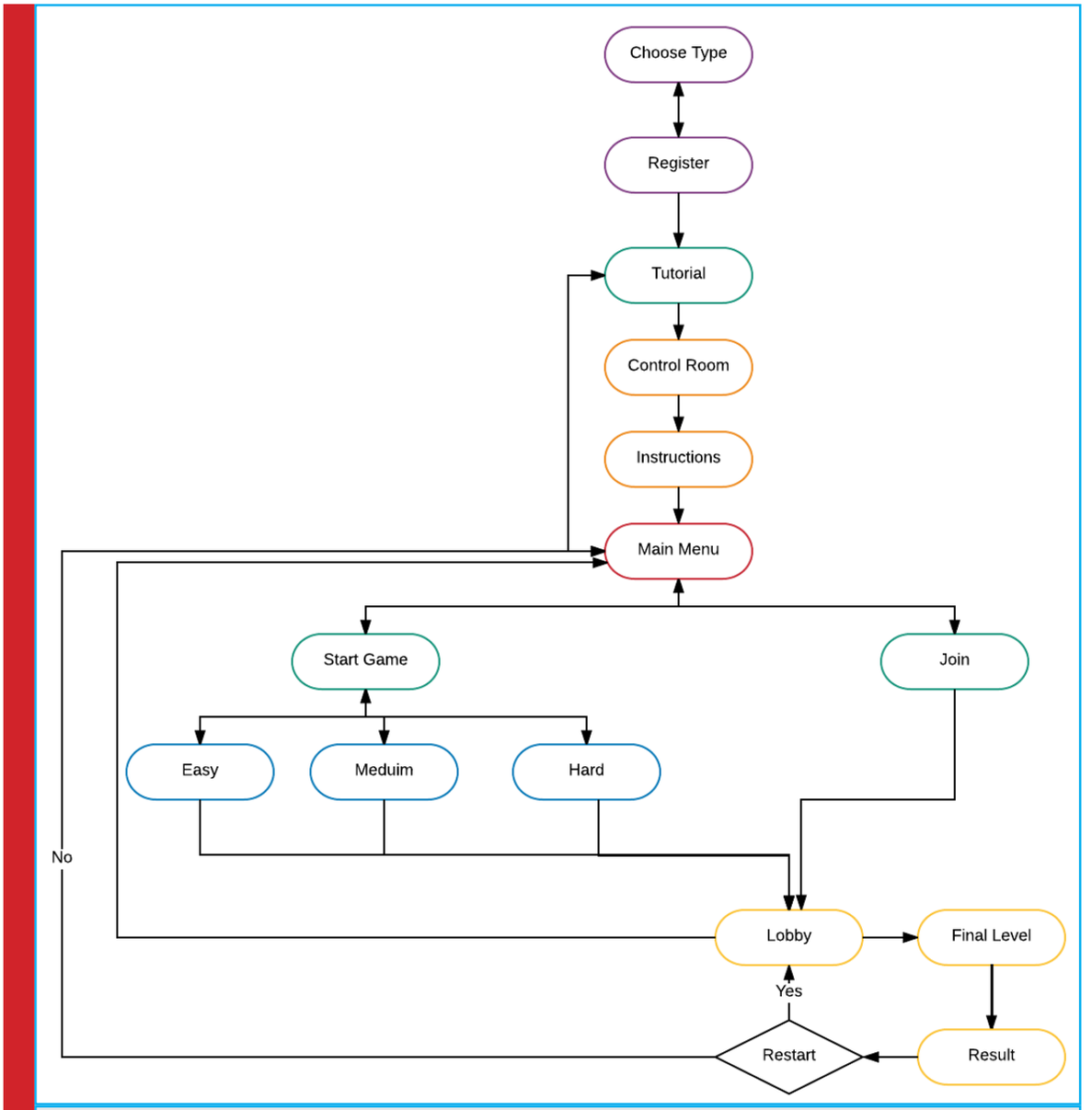

FIGURE 1. System Interfaces hierarchy

game's result and to let the players play again if they want to. Also, there are three different levels on the game.

The proposed game as an assistive system is based on using echo processing techniques for interpreting the echo from the surrounding objects, people in order to be able to decide direction, changing position, and or performing an action.For this purpose, Ultrasonic sensors are used for detecting the obstacles whilst the Servo motors are modeled and used inside the game used to give a precise position and the google glasses to make object type recognition. Accordingly, the system assists the user's avatar to sense the environment through the ultrasound and servo motors and hence the sensory data will be used for input to a simple fuzzy controller in order to calculate and make real time accurate decisions based on the information in order to enable the user to navigate safely in uncertain environment.

The algorithm is used for indoors and outdoors for the purpose of wider coverage over also day time as at night time

The game provides a range of distance between the user foot radius circle. The system would allow the user to

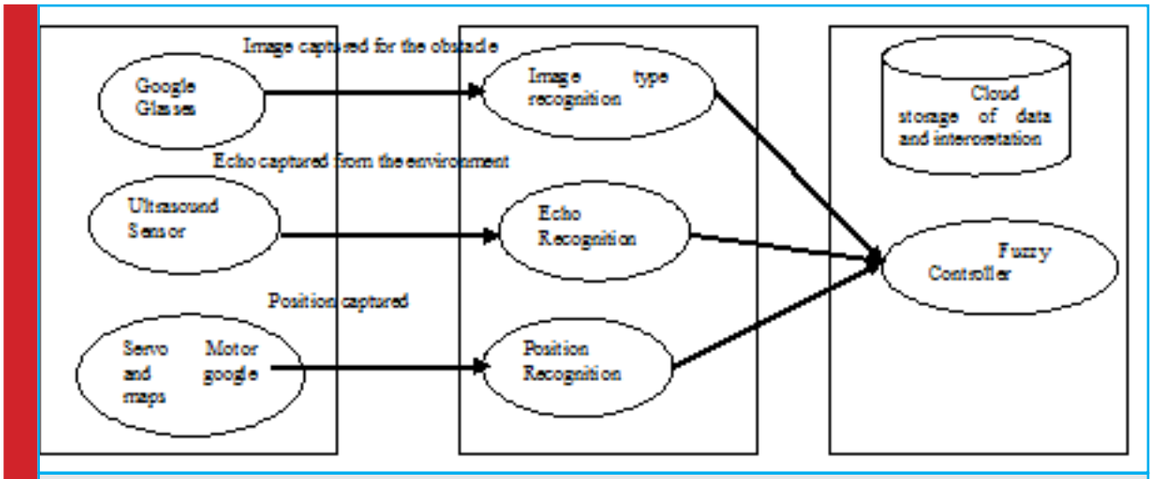

FIGURE 2. Process Flow

detect dynamic and static objects of different sizes(ranging from 8 cubic cms to 2 cubic meters). In addition, the object to be detected by the system from 20 cm to 6 m.

The algorithm would first detect one of the following user's modes:

- Orientation mode (routes instructions, tracing the user's location by tracing the bath, improving learnability of user's brain cognition of the environment and mapping the instructions to the experiences objects)
- Position Locator Mode (this mode enables tracking algorithm to map the user's path to original position in order to precisely determine the current position of user using GPS technology.
- Travel Mode: in this mode the system detects the user's steps and switched to the travel mode. The ultrasound and servomotor starts to gather information about the surrounding environment and interprets the information according to the position, size of the obstacles around the user body from the ground to the head; detecting the surrounding the obstacles; calculating the distance between the user and the obstacle; Prepare a rout or path plan and translates the path into a set of instructions.

RESULTS AND DISCUSSION

The experiment was designed to get 10 participants involved. Ages of the participants ranged from 5 years to 20 years. The participants were asked to attend an orientation session to learn about the game. There were more than one scenario to run the game with the teacher opponent (teacher avatar inside the game) navigates and creates obstacles and other avatars in the game. Hence, the visually impaired player would start with unknown environment to him and then will start with receiving few instructions then he will start build and recognize his instructions under the mentor of the teacher or relatives opponents. Real time response and recognition of the system was under evaluation within parts of the

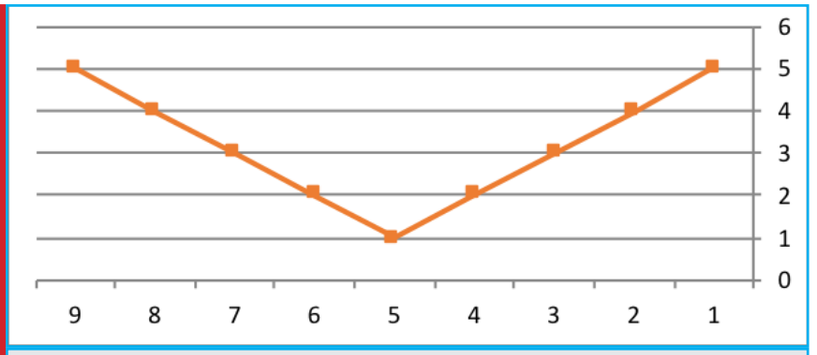

FIGURE 3. Sound Reflection in db over .9 seconds

second. Figure 3 below presents the system allowed the visually impaired avatar to recognize the object within 0.9 second.

CONCLUSION

The research in this paper focuses on the use of Bats hearing system together with the google glasses in order to make an assistive technology to aid the visually impaired people moving in uncertain environment. The proposed game allows the blind/visually impaired player to play with sighted opponent in order to recognize objects created by the sighted opponent. The system uses ultrasound sensors,

In future work, a new level could be added with more enemies for more excitement. Furthermore, we aim to provide an online voice chat between the players so they can communicate with each others during the game if they want. In addition, we will create a friend list to allow the player to add his friends and family.

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