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Research Article

Developing a Guided Tactile Feedback System for Visually Impaired People

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Abstract

Haptic interfaces and assistive technologies are improving for visually impaired individuals. In line with these efforts, this paper describes the design, working and implementation of a wearable haptic feedback glove incorporated with a robotic arm to guide the user's hand in the court. The glove is lightweight, inexpensive and includes coin vibration motors that give vibratory feedback, which describes the direction of the ball. The system was tested on five participants. The participants gave positive feedback regarding the design and the overall experience was good. They recommended the system because it is easy-to-use.

Keywords: Haptics, Robotics, Visually impaired individuals.

Görme Engelliler için Rehberli Dokunsal Geri Bildirim Sistemi Geliştirme

Öz

Görme engelli bireyler için dokunsal arayüzler ve yardımcı teknolojiler gelişiyor. Bu çabalar doğrultusunda, bu makale, kullanıcının elini sahada yönlendirmek için robotik bir kolla birleştirilmiş giyilebilir bir dokunsal geribildirim eldiveninin tasarımını, çalışmasını ve uygulamasını açıklamaktadır. Eldiven hafiftir, ucuzdur ve topun yönünü tanımlayan titreşimli geri bildirim sağlayan titreşim motorları içerir. Sistem beş katılımcı üzerinde test edildi. Katılımcılar sistemle ilgili olumlu geri bildirimler verdiler ve genel deneyim iyiydi. Sistemi kullanımı kolay olduğu için tavsiye ettiler.

Anahtar Kelimeler: Haptik, Robotik, Görme engelli bireyler.

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1. Introduction

It has been estimated that there are around 49.1 million visually impaired people of the total 7.79 billion population in the world (Bourne RRA, Adelson J, Seth Flaxman S, Briant P, Bottone M 2020). Researchers have been working hard to develop assistive technologies for such individuals to make the graphical user interface (GUI) and computer interface more accessible and easy to use. In this regard, haptic technology plays an important role. Haptic technology is the science of generating a sense of virtual touch by implying different phenomena such as vibration. It transforms an electronic device into a bilateral one that gets input and outputs sensational awareness. Utilizing haptic feedback enhances device usability and increases realism by enabling a combination of touch, vision, and sound (MacLean 2009), (Hayward and Astley 1996), (Hatzfeld 2014).

A well-known attempt in this field is developing a braille tactile display (Yang et al. 2021). Since the current braille systems are bulky and expensive to use, researchers are trying to make the system cost-effective, simple, and accessible (Frediani, Busfield, and Carpi 2018; Zarate et al. 2017), (Yobas et al. 2003). Another common problem for these individuals is the absence of surface information such as texture, shape, and graphical items while they are touching a display like a smartphone. Several attempts have been done to tackle this issue. Knowing this, Israr et el. (Xu et al. 2011) developed a system to feel the 2D shapes on the display. They were using electrovibration (Bau et al. 2010), (Ilkhani, Aziziaghdam, and Samur 2017) method to create tactile information. In another study, thermal information was included in the haptic system (Hribar and Pawluk 2011). A thermal feedback was adopted to map the warm-cold spectrum of colors.

Some other studies focused on wearable devices such as a glove. Krishna et al. (Krishna et al. 2010) developed VibroGlove to let blind people see the facial expressions of people. With this technology, a blind person can see by the patterns of vibration. In a study, scientists developed a haptic glove system named FeelX for web browsing. They conducted an experiment on 20 blind participants and asked different questions regarding experiencing the system such as identifying various objects of different shapes. They concluded that FeelX was not the ultimate solution but blind people were interested in using a haptic glove to ease their problem (Soviak et al. 2016).

Navigation in another typical problem for these people. Current society is becoming more and more crowded and complicated such that even normal people have to use assistive technologies to avoid obstacles and find the ways. ActiveBelt is one of those technologies that was developed in this field by Tsukada et al. (Tsukada and Yasumura 2004). The vibration motors were integrated in a belt and by adjusting the vibration people can find their ways. Using haptic as a guidance options, Ogrinc et al. (Ogrinc et al. 2018) utilized a tactile feedback system for deaf-blind people while riding horse. Using tactile cues, which were sent by the instructor, riders experienced an enjoyable and independent horse riding.

Relevant to sports, blind disabled people have hardness watching and doing sports. Especially deaf-blind ones need a company to describe the game to them by hand motions. Scientists have rarely addressed this area. In the most relevant study, Footbraille was developed which allows blind disabled people to watch football. Footbraille works by allowing users to place their hands on a carpeted device that mimics a soccer field. During gameplay, a miniature ball moves in sync with the game, allowing fans to easily track game stats (Al-Mohannadi 2022). In another application, a haptic glove was developed to watch a football match. Fifteen visually impaired individuals were selected with severe visual impairment to perform the test using haptic glove. The Haptic glove allows for receiving signals and generating vibrations in the hand, informing about what happens in a scene. The answers to the questions asked to the participants revealed that they liked the system (Villamarín and Menéndez 2021). Lee et al. (Lee et al. 2005) developed a vibrotactile display to provide events happening in the game. The system was composed of a 7×10 tactile array that was attached to the forearm. They claimed that 80% of subjects could judge the correct ball path. Rehman et al. (Ur Réhman et al. 2008) carried this experience to a mobile phone trying to render a football match using vibration. A user could feel the dynamic position of the ball and attack direction in this device. The main contribution of the paper was declared to be the application of vibration in game rendering.

There are other studies that address the application of haptic in multimedia. For example, Kim et al. (Kim et al. 2010) developed a haptic glove synchronized with the media to feel the content of the movie such that in a horror movie you can feel a ghost brush against your hand. In another application, a 4D multimedia player that stimulates further senses such as haptics was presented. It was the combination of conventional 3D content with sensory effects which allows to further enhance the viewing experience of the users (Waltl et al. 2013). Mazzoni et al. introduced Mood Glove to enhance mood music. The glove was also usable by hearing impaired people. Using vibration motors and adjusting intensity and frequency of the vibration haptic sensation were created (Mazzoni and Bryan-Kinns 2016).

In the present study, Volleyball game was chosen to design the desired interactive system for the blind people. Unlike the other studies a sense of touch was combined with the sense of location, using a haptic glove and a robotic arm, which demonstrate that wearable haptic glove, has the potential to become an indispensable tool for enhancing the sensing experience for visually impaired people while watching Volleyball game. Besides the proposed system could be extended to render other games too.

2. Volleyball game

In 1895, William G. Morgan, a physical director of Young Men's Christian Association (YMCA), invented the game of Volleyball. It was initially termed Mintonette (Murat 2000). It is estimated that approximately 200 million individuals play Volleyball globally. A 9 m (30 ft) wide and 18 m (60 ft) long court is designed to play Volleyball by two teams. A net of 2.43 m for men and in the case of women, a 2.24 m high equally divides the court over a black margin drawn on the floor in the center. The game is played by two teams and each team has six members. Initially, one player of any team tosses the ball from the boundary of the court and hit it by the hand or arm over the net. The opponent team should not allow the ball to hit the ground. The players should avoid touching the ball more than three times to hit it back to the other side, where it is not allowed to touch the ball two times in a row by any individual team member. Typically, a team needs 25 points to win in the first four games (referred to as 'sets') and 15 in the fifth one.

3. Methodology

3.1. Design of the Court

The court was assumed as a rectangle region with 90 cm height and 180 cm width. It was divided into two halves from the middle. This line represents the location of the net. The players were grouped into two teams. The teams were named team A and team B. Typically, there are six players in Volleyball but in this study, it was assumed four players in each team in which one player is dedicated for the services. Positions and angles of players were set arbitrarily.

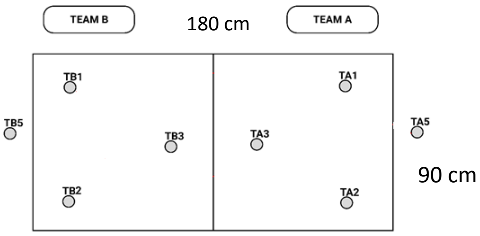


Figure 1: The court was assumed to be 90 cm × 180 cm rectangle region. Each team composed of four players who are located arbitrarily in the region.

3.2. Robotic Arm

In this study, the robotic arm was used to direct the user's hand according to the ball position. The two-link arm was made of two Aluminum plate with 70 mm × 50 mm × 2 mm dimensions as links. Two MG996R servomotors with metal gears and maximum stall torque of 11 kg/cm located at two joints. The system was connected to the base using screws firmly. As is seen in Figure 2, the arm involves two rotatory joints and it is a linear chain. L1 and L2 are the length of both links respectively, whereas angle θ1 and angle θ2 are the angles of joint rotations of the two joints, accordingly. The arm was initially designed on Solidwork software. For all events happening during the game angles information were obtained using Solidwork. However, an autonomic system could be developed using following information.

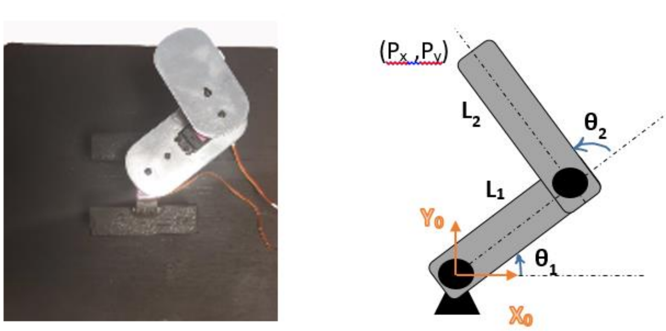


Figure 2: The robotic arm consists of two Aluminum links and two servomotors.

3.2.1. Forward Kinematic

Forward kinematics can be defined as the calculation of the end-effector's position and orientation as joint variables. Using the link's length and angles, the end effectors position can be written as follows:

$$P_x = L_1 Cos\theta_1 + L_2 Cos(\theta_1 + \theta_2) \qquad (1)$$

$$p_y = L_1 Sin\theta_1 + L_2 Sin(\theta_1 + \theta_2)$$

For robot kinematics, Denavit-Hartenberg (D-H) method is also used commonly. This method involves four parameters; θi joint angle, αi link twist, ai link length and di joint distance. According to these parameters the D-H parameters can be written in Table 1. (Corke 2007). According to these parameters, the transformation matrix relating position and orientation of the end-effector to the reference coordinate system can be written as Equation 3.

Table 1 D-H Parameters of two-link manipulator

Link	ai	αi	di	θi
1	L1	0	0	θ1
2	L2	0	0	θ2

$$T_i^{i+1} = \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & \sin\theta_i\sin\alpha_i & L_i\cos\theta_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & -\cos\theta_i\sin\alpha_i & L_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (2)$$

$$T_2^0 = T_1^0\, T_2^1 \qquad (3)$$

3.2.2. Inverse Kinematic

The manipulators work in Cartesian space (including orientation matrix and position vector), on the other hand, actuators in joint space (represented by joint angles). The position and orientation of the manipulator end-effector coverts from Cartesian space to joint space. This is called inverse kinematics problem. The solution to this problem is the use of geometric, analytical, numerical and intelligent algorithm approaches. The angles θ1 and θ2 can be found using Equations 4 and 5.

$$\theta_2 = \cos^{-1}\left(\frac{{p_x}^2 + {p_y}^2 - {L_1}^2 - {L_2}^2}{2L_1L_2}\right) \qquad (4)$$

$$\theta_1 = \tan^{-1}\frac{p_y}{p_x} - \tan^{-1}\frac{a_2 sin\theta_2}{a_1 + a_2 cos\theta_2} \qquad (5)$$

3.3. Haptic Glove

The glove is made of a fabric that can be adjusted to fit different hand sizes by adjusting the length of all finger appendages to resemble a real hand. The wires and haptic motors are on the glove's internal pair. Nine low-power, small-size coin vibration motors were used to provide tactile feedback. Where TA1, TA2, TA3 and TA5 represent team A, the second group TB1, TB2, TB3 and TB5 represent team B. The last one was located on the back of the hand for the auxiliary purposes. Its initial working prototype was produced for the right hand. The whole system was controlled using an Arduino UNO.

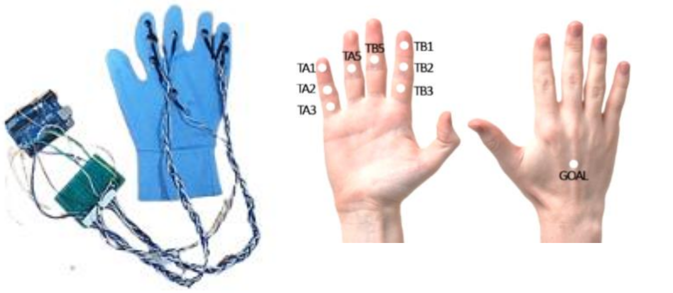


Figure 3: Shows the position of motors incorporated in haptic glove.

3.3.1. Haptic Glove Working Algorithm

As stated earlier the Volleyball game involves rules and events such as fouls, time-out, service etc. In order to create all effective events following algorithm was considered. The time interval was set before every event so that the participant had enough time to be engaged and understand.

- The match starts with a 5 sec delay for preparation.
- The game starts with a service. For a service, V5 is vibrated. Each vibration motor turns on for 1 sec.
- For scoring a goal, V5 - Goal is vibrated for 1 sec.
- In attacking and defending goal situation, mutual motors TB1-TA1, TB2-TA2, and TB3-TA3 are vibrated simultaneously. If a team scores a point, the Goal function is activated. If none of the teams scores a point, the normal game continues.
- If a foul happens (i.e. touching the net), the referee stops the game. For this case V1, V3, V5 are vibrated simultaneously for 0.5 sec two times. Then the Goal function is activated.
- If one team service hit the net, V5 is vibrated for 2 sec two times. Then, the opposite team's Goal function is activated.
- For timeout, both V5 are vibrated for 2 sec.
- If one team misses the ball (i.e. ball hits a region outside the court) V1, V2, and V3 are vibrated simultaneously. Then, the opposite team's Goal function is activated.
- If a team wins a set V1, V2, V3, and V5 are vibrated for 0.5 sec two times.

Where V is the general term used for any player of both team.

3.3. Experimental Evaluation

A user study was performed to evaluate the performance of the proposed system. Four male and one female volunteer (Mean age = 25 years, age range 20-30 years) participated in the study after signing a written informed consent. All volunteers had no prior experience of testing such a system. Istanbul Aydin University approved the procedure. To test the system, a sample Volleyball match between Japan and France (Men's Volleyball World Grand Champions Cup 2017) was selected.

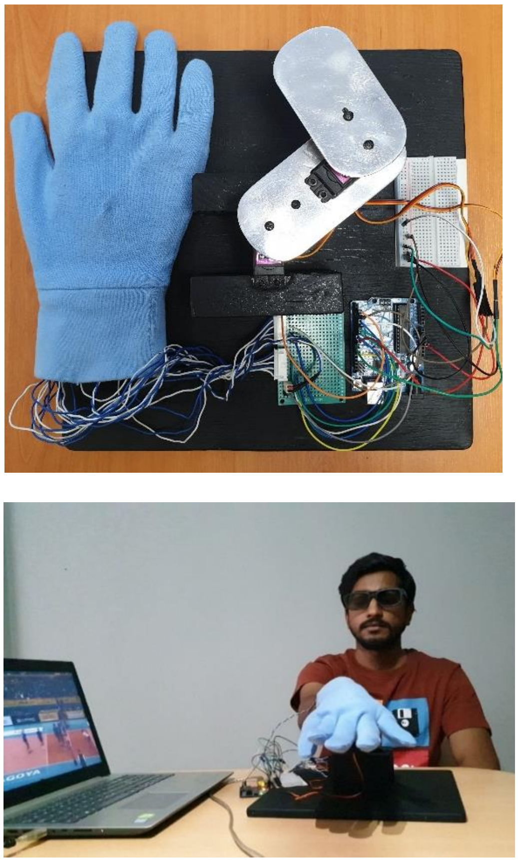
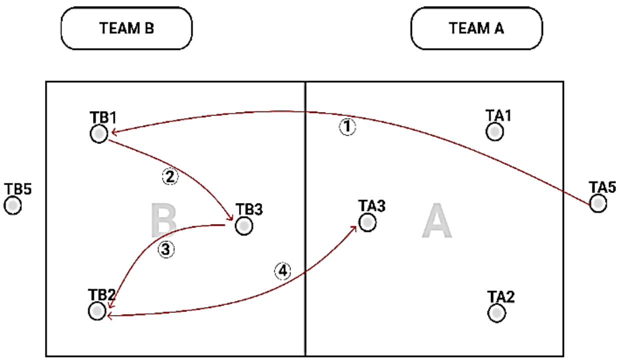
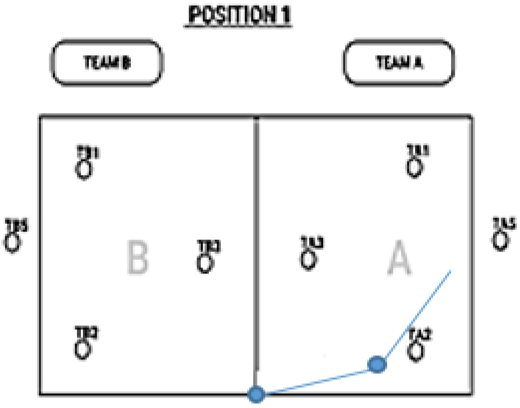
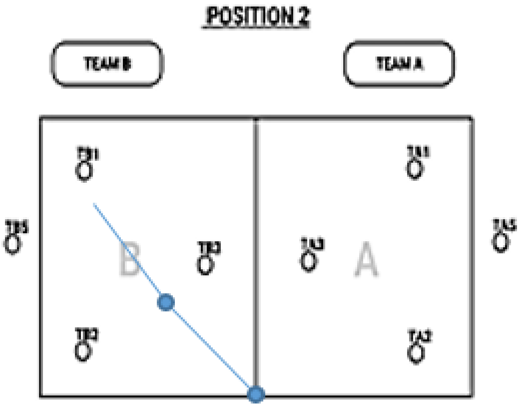


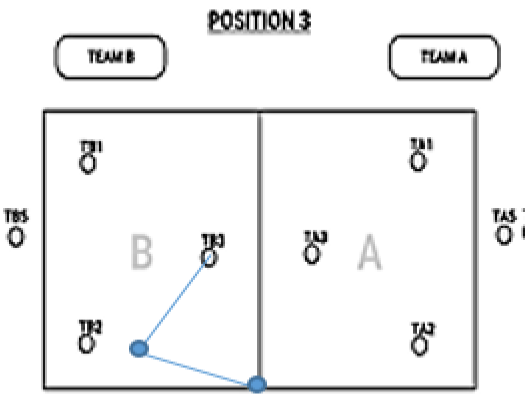
Figure 4: The developed system is seen on the right. The subject puts his hand on the robotic arm. It guides the user's hand to the desired position.

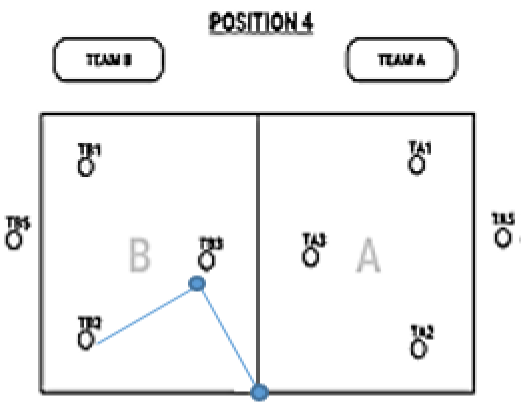
All the events in the first three minutes were extracted and programmed according to the algorithm stated earlier. A total of 26 events were extracted including scores, fouls, time outs, etc. Five events were selected randomly and played for each user while they were hearing the game played on the computer. Later they were asked to comment if they could feel the corresponding event. Figure 4 shows the conducted experiment. The user puts his hand on the arm and the arm guides the user's hand according to the ball position. A sample event is presented in Figure 5. The game starts with service from TA5. TB1 receives the first ball and then passes it to the second player TB3. Finally, TB2 spikes the ball. Simultaneously TA3 is trying to defend. As a result, team B scored 1 point, which means TB5 - Goal, were activated.











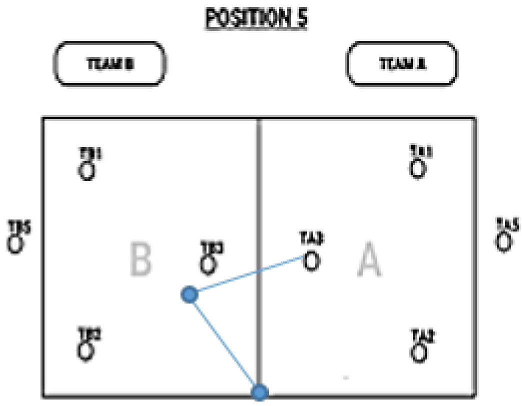


Figure 5: A sample experiment and schematic representation of the arm movement.

4. Results and Discussion

The participants answered some questions related to the experience throughout the game. They were required to answer each question in on a Likert scale from 1-7. One represents the lowest score and seven is the highest. The results are presented in Table 2. As is seen in Table 2 most of the participants were satisfied with the experiment and found it interesting to try. However, intensity and type of vibration got the lowest score which means they must be improved. In addition, training is required to remember the entire event. Some users stated that they need some time before each event, which might be because of memorizing and interpretation. Overall, they were satisfied with the experiment and enjoyed the game with this new invention.

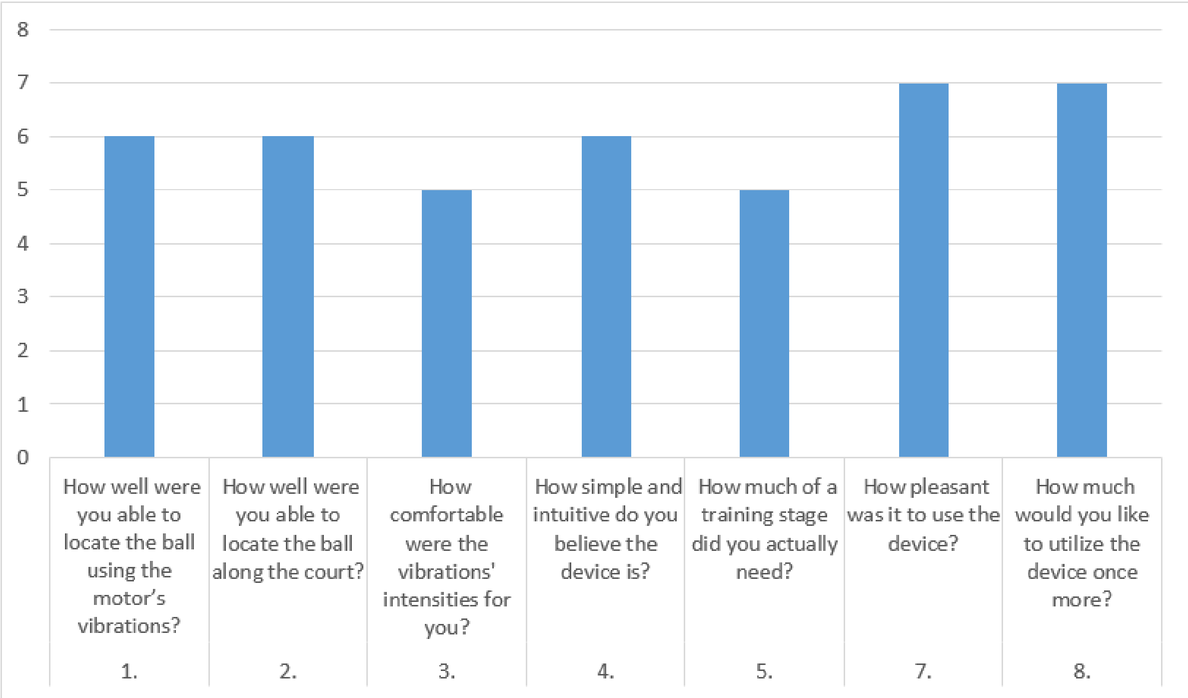
5. Conclusion

The idea of this study was to build a cost-effective, light-weighted, portable, and patient-friendly system. The arm was initially designed on Solidwork software and all the motion information was obtained. The standard dimensions of the pitch were 90 cm by 180 cm. Positions and angles of players were set. A sample game was chosen and the entire events in the game were extracted and coded according to the algorithm. The performance of the system was evaluated using a psychophysical experiment. According to the findings, the participants significantly improved their abilities related to the usage of the haptic glove and their active participation in the game. Some of the participants also suggested that the system could be improved by adding more features such as multiple directional sound effects to create an enthusiastic environment. Whereas some of them were satisfied with the current system. They also gave feedback that the proposed system is cost-effective but it needs to be easily available in markets.

5. Future Work

Many scientists have worked on assistive technologies for visually impaired individuals in order to make them feel joyful in spite of their disabilities, yet more studies are ongoing. The technology is getting advanced and more options can be integrated into the systems. The present proposed design was satisfactory and easy-to-use for the participants. It was observed that the integration of camera and providing virtual environment in the system would make the participants feel more enjoyable.

Table 2 Showing scores of Questionnaire-based survey



This study is an on-going project and will build a system in which a participant can choose other games of their interest, which requires automatic ball position recognition, and faster system compatible with the game's dynamics.

References

Al-Mohannadi, Al-Dana. 2022. "Innovative ICT Accessibility Solutions in Stadiums and Fan Zones for Persons with Visual Impairment and Blindness." Nafath 7(19): 28–33.

Bau, O., I. Poupyrev, A. Israr, and C. Harrison. 2010. "TeslaTouch." In Proceedings of the 23nd Annual ACM Symposium on User Interface Software and Technology - UIST '10, New York, New York, USA: ACM Press, 283.

Bourne RRA, Adelson J, Seth Flaxman S, Briant P, Bottone M, Vos T et al. 2020. "Global Prevalence of Blindness and Distance and Near Vision Impairment in 2020: Progress towards the Vision 2020 Targets and What the Future Holds." Investigative Ophthalmology & Visual Science 61(7): 2317.

Corke, Peter I. 2007. "A Simple and Systematic Approach to Assigning Denavit-Hartenberg Parameters." IEEE Transactions on Robotics 23(3): 590–94.

Frediani, Gabriele, James Busfield, and Federico Carpi. 2018. "Enabling Portable Multiple-Line Refreshable Braille Displays with Electroactive Elastomers." Medical Engineering and Physics 60: 86–93. https://doi.org/10.1016/j.medengphy.2018.07.012.

Hatzfeld, Christian. 2014. "Haptics as an Interaction Modality." In , 29–100.

Hayward, Vincent, and Oliver R. Astley. 1996. "Performance Measures for Haptic Interfaces." Robotics Research (December): 195–206.

Hribar, Victoria E., and Dianne T.V. Pawluk. 2011. "A Tactile-Thermal Display for Haptic Exploration of Virtual Paintings." ASSETS'11: Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility: 221–22.

Ilkhani, Gholamreza, Mohammad Aziziaghdam, and Evren Samur. 2017. "Data-Driven Texture Rendering on an Electrostatic Tactile Display." International Journal of Human–Computer Interaction 00(00): 1–15.

Kim, Yeongmi, Jongeun Cha, Jeha Ryu, and Ian Oakley. 2010. "A Tactile Glove Design and Authoring System for Immersive Multimedia." IEEE Multimedia 17(3): 34–44.

Krishna, Sreekar et al. 2010. "VibroGlove: An Assistive Technology Aid for Conveying Facial Expressions." Conference on Human Factors in Computing Systems - Proceedings: 3637–42.

Lee, Beom Chan et al. 2005. "Immersive Live Sports Experience with Vibrotactile Sensation." Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 3585 LNCS: 1042–45.

MacLean, Karon E. 2009. "Putting Haptics into the Ambience." IEEE Transactions on Haptics 2(3): 123–35.

Mazzoni, Antonella, and Nick Bryan-Kinns. 2016. "Mood Glove: A Haptic Wearable Prototype System to Enhance Mood Music in Film." Entertainment Computing 17: 9–17.

Murat. M, Volleyball Tech. 2000. Ankara: Bağırgan.

Ogrinc, Matjaž, Ildar Farkhatdinov, Rich Walker, and Etienne Burdet. 2018. "Horseback Riding Therapy for a Deafblind Individual Enabled by a Haptic Interface." Assistive Technology 30(3): 143–50.

Soviak, Andrii et al. 2016. "Tactile Accessibility: Does Anyone Need a Haptic Glove?" ASSETS 2016 - Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility (October): 101–9.

Tsukada, Koji, and Michiaki Yasumura. 2004. "ActiveBelt: Belt-Type Wearable Tactile Display for Directional Navigation." Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 3205: 384–99.

Ur Réhman, Shafiq, Jiong Sun, Li Liu, and Haibo Li. 2008. “Turn Your Mobile into the Ball: Rendering Live Football Game Using Vibration.” IEEE Transactions on Multimedia 10(6): 1022–33.

Villamarín, Diego, and José Manuel Menéndez. 2021. “Haptic Glove Tv Device for People with Visual Impairment.” Sensors 21(7): 1–27.

Waltl, Markus et al. 2013. “A 4D Multimedia Player Enabling Sensory Experience.” 2013 5th International Workshop on Quality of Multimedia Experience, QoMEX 2013 - Proceedings: 126–27.

Xu, Cheng et al. 2011. “Tactile Display for the Visually Impaired Using TeslaTouch.” Proc. CHI EA ’11: 317–322.

Yang, Wenzhen et al. 2021. “A Survey on Tactile Displays for Visually Impaired People.” IEEE Transactions on Haptics 14(4): 712–21.

Yobas, Levent et al. 2003. “A Novel Integrable Microvalve for Refreshable Braille Display System.” Journal of Microelectromechanical Systems 12(3): 252–63.

Zarate, Juan Jose, Olexandr Gudozhnik, Anthony Sébastien Ruch, and Herbert Shea. 2017. “Keep in Touch: Portable Haptic Display with 192 High Speed Taxels.” Conference on Human Factors in Computing Systems - Proceedings Part F1276: 349–52.