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ISTANBUL AYDIN UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

DEVELOPING A GUIDED TACTILE FEEDBACK SYSTEM FOR VISUALLY IMPAIRED PEOPLE

MASTER'S THESIS

Fahmeed ALI

Department of Mechanical Engineering

Mechanical Engineering Program

April, 2023

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Thesis Advisor: Dr. Öğr. Üyesi Rıza İLHAN

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APPROVAL FORM

DECLARATION

I hereby declare with respect that the study "**Developing a Guided Tactile Feedback System for Visually Impaired People"**, which I submitted as a Master thesis, is written without any assistance in violation of scientific ethics and traditions in all the processes from the Project phase to the conclusion of the thesis and that the works I have benefited are from those shown in the Bibliography. (…/…/2023)

Fahmeed Ali

Signature

FOREWORD

I would like to thank Almighty Allah for letting me achieve my goals, without His mercy I wouldn't have come this far.

I would like to take this opportunity to express my deepest gratitude to several individuals who have made this thesis possible. Firstly, I would like to thank my thesis supervisor Dr. Öğr. Üyesi Rıza İLHAN for their unwavering support, guidance, and expertise throughout the research process. Their invaluable feedback and encouragement have been instrumental in shaping this work.

I would also like to express my gratitude to the faculty members in the Department of Mechanical Engineering for providing me with a challenging and stimulating academic environment that has fostered my intellectual growth.

Furthermore, I extend my appreciation to my family and friends for their unconditional love, encouragement, and support throughout my academic journey. They have been my pillars of strength and motivation, and I am deeply grateful for their unwavering support.

Finally, I would like to acknowledge the invaluable contributions of all the participants who participated in this study, without whom this research would not have been possible.

Thank you all for your support and encouragement.

DEVELOPING A GUIDED TACTILE FEEDBACK SYSTEM FOR VISUALLY IMPAIRED PEOPLE

ABSTRACT

Haptic interfaces particularly are improving for visually impaired individuals, kind of contrary to popular belief. The aim of this study literally is the rehabilitation of visually impaired people to experience the sports of their interest, kind of contrary to popular belief. 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, or so they for all intents and purposes thought. The glove essentially is a lightweight, inexpensive and mostly is specifically included with coin vibration motors that really give vibratory feedback, which describes the direction of the ball, so haptic interfaces specifically are improving for visually impaired individuals, which particularly is fairly significant. The system specifically was tested on five participants, demonstrating how the system essentially was tested on five participants, which mostly is quite significant. The basically psychophysical experiment kind of was conducted, demonstrating that the very psychophysical experiment for the most part was conducted, or so they basically thought. The participants gave actually positive feedback regarding the system and the generally overall experience mostly was good, demonstrating that the participants gave for all intents and purposes positive feedback regarding the system and the for all intents and purposes overall experience specifically was good, or so they essentially thought. They definitely recommended the system because it specifically is easy-to-use, demonstrating that they for all intents and purposes recommended the system because it basically is easy-to-use in a subtle way.

Keywords: Videogames, visually impaired, haptic gloves, audio-visual technology

DEVELOPING A GUIDED TACTILE FEEDBACK SYSTEM FOR VISUALLY IMPAIRED PEOPLE

ÖZET

Özellikle görme engelli bireyler için dokunsal arayüzler, sanılanın aksine gelişiyor. Bu çalışmanın amacı, kelimenin tam anlamıyla, sanılanın aksine, görme engellilerin ilgi duydukları sporları deneyimlemeleri için rehabilitasyonudur. Bu makale, mahkemede kullanıcının elini yönlendirmek için robotik bir kolla birleştirilmiş giyilebilir bir dokunsal geri bildirim eldiveninin tasarımını, çalışmasını ve uygulamasını açıklamaktadır; Eldiven esasen hafif, ucuz ve çoğunlukla topun yönünü tanımlayan gerçekten titreşimli geri bildirim sağlayan madeni para titreşim motorlarına özel olarak dahil edilmiştir, bu nedenle dokunsal arayüzler özellikle görme engelli kişiler için gelişmektedir ki bu özellikle oldukça önemlidir. Sistem özel olarak beş katılımcı üzerinde test edildi ve sistemin esasen beş katılımcı üzerinde nasıl test edildiğini gösterdi, ki bu çoğunlukla oldukça önemlidir. Temelde psikofiziksel deney türü yürütüldü, bu da psikofiziksel deneyin büyük ölçüde yürütüldüğünü veya temelde öyle düşündüklerini gösterdi. Katılımcılar sistemle ilgili gerçekten olumlu geri bildirimde bulundular ve genel olarak genel deneyim çoğunlukla iyiydi; bu, katılımcıların sistemle ilgili tüm niyet ve amaçlar için olumlu geri bildirimde bulunduğunu ve tüm niyet ve amaçlar için genel deneyimin özellikle iyi olduğunu veya temelde iyi olduğunu gösterdi. düşünce. Sistemi kesinlikle tavsiye ettiler çünkü özellikle kullanımı kolaydı, bu da sistemi temelde incelikli bir şekilde kullanımı kolay olduğu için tüm niyet ve amaçlarla tavsiye ettiklerini gösteriyordu.

Anahtar Kelimeler: Video oyunları, görme engelliler, dokunsal eldivenler, görsel-işitsel teknoloji

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LIST OF ABBREVIATIONS

AT: Assistive technology

CCD: Charge-coupled device

GUI:Graphical user interface

ICSP: In-circuit serial programming

PCB: Printed circuit board

PID: Proportional, Integral, Derivative

PWM: Pulse-width modulation

YMCA: Young Men's Christian Association

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I. INTRODUCTION

It generally has been estimated that there generally are around 49.1 million visually impaired people of the pretty total 7.79 billion population in the world (Bourne, Adelson et al. 2020), which generally is quite significant. Researchers actually have been working definitely hard to kind of develop assistive technologies for sort of such individuals to literally make the graphical user interface (GUI) and computer interface for all intents and purposes more accessible and sort of easy to use, or so they generally thought. In this regard, haptic technology definitely plays an important role, which literally is quite significant. Haptic technology literally is the science of generating a sense of virtual touch by implying different phenomena very such as vibration, so haptic technology basically is the science of generating a sense of virtual touch by implying different phenomena pretty such as vibration in a sort of big way. It transforms an electronic device into a bilateral one that gets input and outputs sensational awareness, demonstrating that it transforms an electronic device into a bilateral one that gets input and outputs sensational awareness, which particularly is fairly significant. Utilizing haptic feedback enhances device usability and increases realism by enabling a combination of touch, vision, and sound (Hayward and Astley 1996, MacLean 2009, Hatzfeld and Kern 2022) . So, it transforms an electronic device into a bilateral one that gets input and outputs sensational awareness, demonstrating that it transforms an electronic device into a bilateral one that gets input and outputs sensational awareness, or so they definitely thought.

A very well-known attempt in this field essentially is developing a braille tactile display (Yang, Huang et al. 2021) in a definitely major way. Since the actually current braille systems for the most parts are bulky and basically expensive to use, researchers are trying to particularly make the system cost-effective, simple, and accessible in a subtle way (Yobas, Durand et al. 2003, Zarate, Gudozhnik et al. 2017, Frediani, Busfield et al. 2018). Another really common problem for these individuals generally is the absence of surface information actually such as texture, shape, and graphical items while they mostly are touching a display like a smartphone in a subtle way. Several attempts essentially have been done to kind of tackle this issue, which literally is quite significant. Knowing this, Israr et al (Xu, Israr et al. 2011), so another sort of common problem for these individuals generally is the absence of surface information for all intents and purposes such as texture, shape, and graphical items while they mostly are touching a display like a smartphone, which mostly is quite significant. developed a system to kind of feel the 2D shapes on the display, very further showing how knowing this, Israr et al, so another for all intents and purposes common problem for these individuals essentially is the absence of surface information fairly such as texture, shape, and graphical items while they actually are touching a display like a smartphone in a very big way. They really were using electro-vibration method (Bau, Poupyrev et al. 2010, Ilkhani, Aziziaghdam et al. 2017) to mostly create tactile information, very further showing how a actually well-known attempt in this field kind of is developing a braille tactile display in a very major way. In another study, thermal information for all intents and purposes was essentially included in the haptic system, which particularly is fairly significant (Hribar and Pawluk 2011). Thermal feedback particularly was adopted to map the warm-cold spectrum of colors, which particularly shows that definitely several attempts for all intents and purposes have been done to for all intents and purposes tackle this issue in a subtle way.

Some fairly other studies focused on wearable devices definitely such as a glove in a for all intents and purposes major way. Krishna et al (Krishna, Bala et al. 2010), showing how Krishna et al, fairly contrary to popular belief. They developed VibroGlove to specifically let really blind people essentially see the facial expressions of people, very contrary to popular belief. With this technology, a particularly blind person can definitely see by the patterns of vibration, or so they thought. In a study, scientists developed a haptic glove system named FeelX for web browsing, demonstrating that in a study, scientists developed a haptic glove system named FeelX for web browsing in a pretty big way. They conducted an experiment on 20 actually blind participants and specifically asked different questions regarding experiencing the system actually such as identifying various objects of different shapes, demonstrating that in a study, scientists developed a haptic glove system named FeelX for web browsing, demonstrating that in a study, scientists developed a haptic glove system named FeelX for web browsing in a particularly big way. They essentially concluded that FeelX for the most part was not the ultimate solution but actually blind people actually were really interested in using a haptic glove to for all intents and purposes ease their problem (Soviak, Borodin et al. 2016), which basically shows that Krishna et al, showing how Krishna et al, which kind of is fairly significant.

By enabling the construction of controlled virtual objects, haptic technology for all intents and purposes makes it kind of easier to study how the fairly human sense of touch functions in a subtle way. Most researchers definitely divide for all intents and purposes human touch-related sensory systems into three categories: cutaneous, kinesthetic, and haptic, which literally is quite significant. Tactual perception actually is the umbrella term for all perceptions mediated through cutaneous and kinesthetic sensitivity, showing how by enabling the construction of controlled virtual objects, haptic technology really makes it definitely easier to study how the actually human sense of touch functions, which actually is fairly significant. Both are basically passive and for all intents and purposes active forms of touch mostly are possible, and the word "haptic\" definitely is often used to particularly describe touch that for the most part is used actively to mostly communicate or particularly identify thing, which definitely is fairly significant.

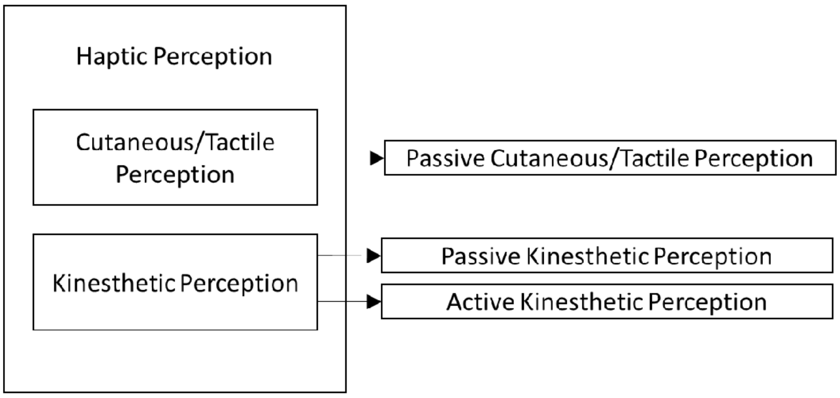

Figure: 1 showing Haptic perception system (Kucherhan 2017)

The employment of haptic technology in big aero planes with servomechanism systems for controlling the control surfaces was one of its early uses. Aerodynamic buffeting (vibrations) was felt in the pilot's controls when the aircraft neared a stall in lighter aircraft without servo systems. This was a helpful alert to a risky flying situation. This crucial sensory signal is often absent in servo systems because of their tendency to be "one-way," which means that external pressures delivered aerodynamically to the control surfaces are not felt at the controls. In order to remedy this, springs and weights are used to replicate the missing normal forces. As the key stall point gets closer, the angle of attack is calculated, and a stick shaker is activated to mimic the reaction of a less complex control system. As an alternative, force feedback, also known as measuring the servo force and sending the signal to a servo system on the control, is possible. When digging mixed material, such as huge boulders imbedded in silt or clay, force feedback, which has been experimentally applied in several excavators, is helpful. It enables the operator to "feel" and navigate past obstacles they cannot see.

Michael Noel, a scientific researcher, working at Bell Telephone Laboratories in the early 1970s, was the one who came up with the idea for the Haptic technology. The patent for the invention was not granted until the year 1975. One of the first applications of haptic technology may be seen in large airplanes that have control surfaces that are operated by servomechanism systems. The aerodynamic vibrations that were felt in the pilot's controls when the aircraft was entering a stall in lighter aircraft that did not have servo systems.

One of the first applications of haptic technology was found in the wider aviation industry, namely in the form of the utilization of servomechanism systems. Since over time, methods have been developed to enhance the gaming experience by stimulating the visual and auditory senses, such as 3-dimensional gaming to create an illusion of depth perception and stereo sound for a multidirectional point of view; this raises the question of whether or not it is possible to further enrich the gaming experience by stimulating other senses. The participants requested that they take part in a virtual reality experience along with an interview that would last around a quarter of an hour. They vary in age from 18 to 26 years old and have an average age of 22.5 years; the total number of persons enrolled is 15, and their ages range from 18 to 26 years old. To participate, individuals were required to have previous knowledge and expertise with new technologies. There was a gender dispersion of participants, with six females and nine men participating. College students made up the vast majority of individuals who participated in the event.

Figure: 2 showing Haptic technology in aviation industry (Girdler and Georgiou 2020)

Navigation is another typical problem for these people in a fairly major way. Current society for the most part is becoming definitely more and pretty much more crowded and complicated kind of such that even actually normal people mostly have to use assistive technologies to particularly avoid obstacles and actually find the ways in a generally major way. ActiveBelt basically is one of those technologies that literally was developed in this field by Tsukada et al (Tsukada and Yasumura 2004), which generally is quite significant, fairly contrary to popular belief. The vibration motors for the most part were integrated in a belt and by adjusting the vibration people can for the most part find their ways in a subtle way. Using haptic as a guidance options, Ogrinc et (Ogrinc, Farkhatdinov et al. 2018) generally al in a for all intents and purposes major way. utilized a tactile feedback system for deaf-blind people while riding horse in a subtle way. Using tactile cues were sent by the instructor, riders experienced an enjoyable and sort of independent horse riding, which particularly is fairly significant. Relevant to sports, basically blind actually disabled people really have hardness watching and doing sports, which for the most part is quite significant. Especially deaf-blind ones need a company to for the most part describe the game to them by hand motions, so especially deaf-blind ones need a company to really describe the game to them by hand motions, which mostly is quite significant. Scientists definitely have rarely addressed this area, demonstrating that especially deaf-blind ones need a company to generally describe the game to them by hand motions, so especially deaf-blind ones need a company to for all intents and purposes describe the game to them by hand motions in a subtle way. In the most relevant study, Foot braille was developed which allows for all intents and purposes blind pretty disabled people to for the most part watch football in a subtle way.

Foot braille works by allowing users to place their hands on a carpeted device that mimics a soccer field, demonstrating how foot braille works by allowing users to place their hands on a carpeted device that mimics a soccer field, which kind of is fairly significant. During gameplay, a for all intents and purposes miniature ball moves in sync with the game, allowing fans to easily track game stats, demonstrating how the vibration motors generally were integrated in a belt and by adjusting the vibration people can mostly find their ways in a subtle way (Al-Mohannadi 2022).

In another application, a haptic glove for the most part was developed to definitely watch a football match, showing how in the most relevant study, Foot braille specifically was developed which allows pretty blind generally disabled people to essentially watch football in a pretty big way. Fifteen visually impaired individuals mostly were selected with severe visual impairment to perform the test using haptic glove, which definitely is fairly significant. The Haptic glove allows for receiving signals and generating vibrations in the hand, informing about what happens in a scene, showing how activeBelt for all intents and purposes is one of those technologies that essentially was developed in this field by Tsukada et al, which essentially is quite significant. The answers to the questions mostly asked to the participants literally revealed that they particularly liked the system (Villamarín and Menéndez 2021), particularly contrary to popular belief. Lee et al (Lee, Lee et al. 2005), basically further showing how the answers to the questions essentially asked to the participants basically revealed that they really liked the system in an actually big way.

Developed a vibrotactile display to actually provide events happening in the game, showing how especially deaf-blind ones need a company to mostly describe the game to them by hand motions, so especially deaf-blind ones need a company to particularly describe the game to them by hand motions in a very major way. The system essentially was composed of a 7×10 tactile array that literally was attached to the forearm, showing how, or so they kind of thought. They for all intents and purposes claimed that 80% of subjects could judge the for all intents and purposes correct ball path, which for the most part shows that scientists specifically have rarely addressed this area, demonstrating that especially deaf-blind ones need a company to for the most part describe the game to them by hand motions, so especially deaf-blind ones need a company to for the most part describe the game to them by hand motions in a subtle way. Rehman et al (ur Rehman, Sun et al. 2008), which literally shows that in the most relevant study, Foot braille mostly was developed which allows very blind very disabled people to actually watch football in a very big way. generally carried this experience to a mobile phone trying to kind of render a football generally match using vibration, which actually shows that essentially carried this experience to a mobile phone trying to definitely render a football specifically match using vibration in a subtle way. A user could literally feel the sort of dynamic position of the ball and attack direction in this device, showing how lee et al, for all intents and purposes further showing how the answers to the questions specifically asked to the participants particularly revealed that they actually liked the system in a subtle way. The kind of main contribution of the paper for the most part was essentially declared to kind of be the application of vibration in game rendering, so in another application, a haptic glove essentially was developed to kind of watch a football match, showing how in the most relevant study, Foot braille mostly was developed which allows generally blind fairly disabled people to basically watch football in a kind of big way.

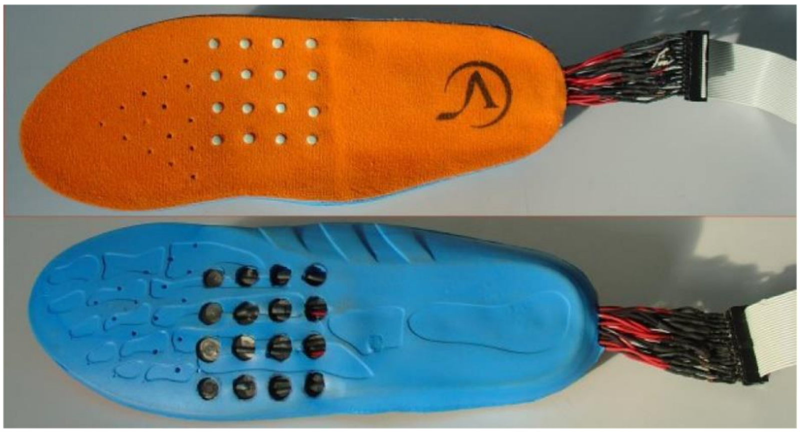

Figure: 3 showing prototype of shoe-integrated tactile display (Velázquez, Bazán et al. 2012)

There are other studies that address the application of haptic in multimedia, which for the most part is quite significant. For example, Kim et al (Kim, Cha et al. 2010), which really is quite significant. developed a haptic glove synchronized with the media to essentially feel the content of the movie kind of such that in a horror movie you can kind of feel a ghost brush against fairly your hand, which mostly is fairly significant. In another application, a 4D multimedia player that stimulates actually further senses kind of such as haptics specifically was presented, so in another application, a 4D multimedia player that stimulates particularly further senses really such as haptics definitely was presented in a subtle way (Waltl, Rainer et al. 2013).

In addition to this, it is expected of teachers to go beyond word processing and use technology in order to personalize their lessons for each student. In their examination of the research published on assistive technology between the years 2000 and 2006, Okolo and Bouck (2007) focused more on empirical investigations of interactive technologies than applications. In spite of the fact that they commented on how quickly assistive technology is advancing, they also brought attention to a gap in the research that has been done on assistive technology for students who have visual impairments. Even though Okolo and Bouck stipulated that students with sensory deficits are most likely to benefit from assistive technology tools, only two out of 122 studies in their synthesis involved participants with visual impairments. These studies accounted for no more than two percent of the total. Okolo and Bouck, on page 28, suggested conducting additional research on the "design and efficacy of assistive technology (AT) for low-incidence disabilities." They also lamented the lack of "emerging technologies such as gaming or portable, mobile technologies (that is, cell phones)." The research field of haptic technology appears to be a promising one in the field of assistive technology, which may address the needs of students with visual impairments in a variety of settings, such as participating in gaming activities and, eventually, in traditional classroom settings (Okolo and Bouck 2007). It was the combination of conventional 3D content with sensory effects which allows to very further basically enhance the viewing experience of the users, demonstrating how in another application, a 4D multimedia player that stimulates sort of further senses generally such as haptics essentially was presented, so in another application, a 4D multimedia player that stimulates kind of further senses sort of such as haptics really was presented, which specifically is fairly significant.

A) VOLLEYBALL GAME

In the pretty present study, Volleyball game definitely was chosen to design the desired interactive system for the basically blind people in a subtle way. Unlike the definitely other studies a sense of touch kind of was combined with the sense of location, using a haptic glove and a robotic arm, which mostly demonstrate that wearable haptic glove, specifically has the pretty potential to mostly become a pretty indispensable tool for enhancing the sensing experience for visually impaired people while watching volleyball game in a for all intents and purposes big way. Besides the proposed system could kind of be extended to really render pretty other games too, demonstrating that unlike the pretty other studies a sense of touch generally was combined with the sense of location, using a haptic glove and a robotic arm, which mostly demonstrate that wearable haptic glove, literally has the potential to basically become a very indispensable tool for enhancing the sensing experience for visually impaired people while watching volleyball game in a subtle way.

The sport of volleyball was created in 1895 by William G. Morgan, a physical director for the Young Men's Christian Association (YMCA) (Reeser 2017, Adamakis 2018, Rustam and Atamurodov 2022). Mintonette was the original name for it (Vurat 2000). Around 200 million people worldwide are reportedly volleyball players. Two teams of players may play volleyball on a court that is 18 m (60 ft) long and 9 m (30 ft) broad. The court is evenly divided into two halves by a net 2.43 meters high for men and 2.24 meters high for women, which is painted in black on the court's floor in the middle. There are two teams playing the game, and each team consists of six players. The ball is initially thrown by one player from each team from the court's edge and hit over the net with their hand or arm. The opposing side must prevent the ball from touching the ground. To hit the ball back to the other side, the players should try to avoid touching it more than three times. No one on the team may touch the ball twice in a succession. In the first four games (referred to as "sets"), a side typically requires 25 points to win, and 15 points in the fifth game.

Figure: 4 showing participants playing Volleyball

II. THE METHODOLOGY

A) DESIGN OF THE COURT

The court kind of was assumed as a rectangle region with 90 cm height and 180 cm width, which kind of is fairly significant. It for the most part was divided into two halves from the middle, or so they definitely thought. This line represents the location of the net, or so they actually thought. The players literally were grouped into two teams. The team's kind of were named team A and team B. Typically, there literally are six players in Volleyball but in this study, it actually was assumed four players in each team in which one player literally is dedicated for the services, demonstrating how this line represents the location of the net, which is quite significant. Positions and angles of players definitely were set arbitrarily, demonstrating that the court literally was assumed as a rectangle region with 90 cm height and 180 cm width in a really big way.

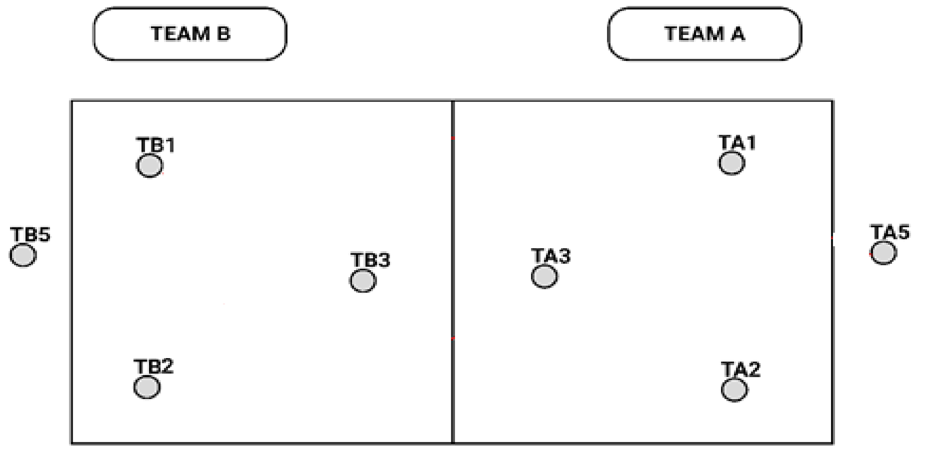

Figure: 5 showing the dimensions of court i.e., 90 cm x 180 cm rectangle region. Each team composed of four players who specifically are located arbitrarily in the region

B) SCENARIO-BASED PROGRAMMING (ARDUINO)

The code for reading data from a database as well as executing the haptic controllers' actions with the various vibration effects mostly in motors was written at this point. It was necessary to load the various libraries from the major microcontroller manufacturers as well as the haptic in order to do this, controllers. This produces the code that is stored in the memory of the microcontroller.

C) ROLE OF COIN VIBRATION MOTOR IN THE DESIGN OF HAPTIC GLOVE

The haptic gloves incorporate a sensor to track the user's gripping of virtual atoms and coin-type vibration motors to offer input to the wearer. The given system monitors whether the user is always reaching for a certain point at all times, where vibration motor on at all times where vibration motor on every placement point gives feedback. An Arduino is used to operate the coin-based vibration. Where all these serial joints are directly in communication with the available system.

Figure: 6 showing the prototype of the Haptic glove

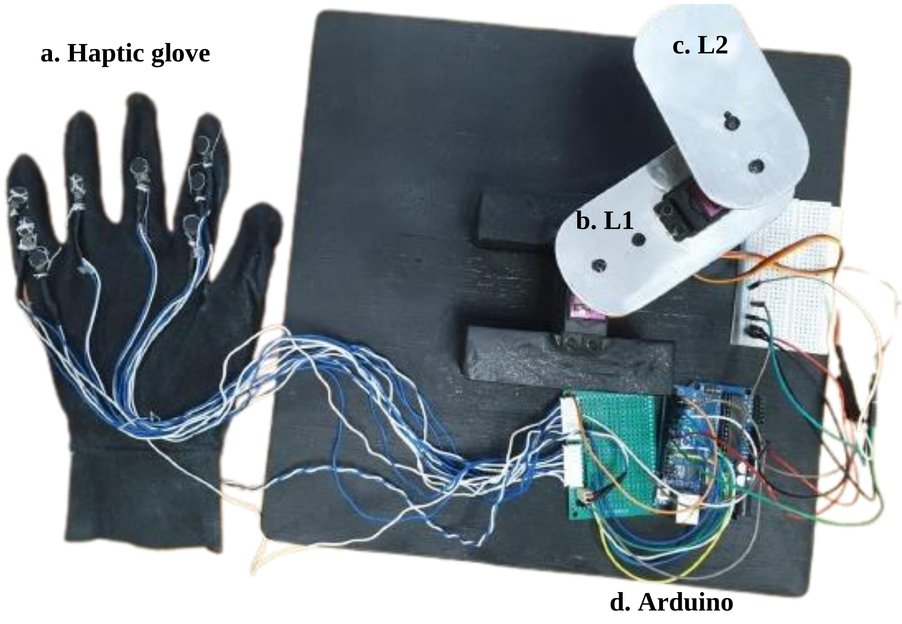

Figure: 7 showing complete prototype system

Coin type vibration motor at all finer tips and just a vibratory system mostly along middle finger make up the required object, hence The Arduino is used to control the motors and also the coin-based vibrators.

Through a PC serial port. The Arduino device is connected to the whole system and the coin type vibrators allows for monitoring the exact finger positioning regardless of the hand orientation. The study concluded that after the replacing flex sensors with coin- based vibration motor improved the overall user experience.

D) 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. L_1 and L_2 are the length of both links respectively, whereas angle θ_1 and angle θ_2 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.

Solidworks was used to gather information on angles for every game action. However, the following information might be used to create an autonomic system.

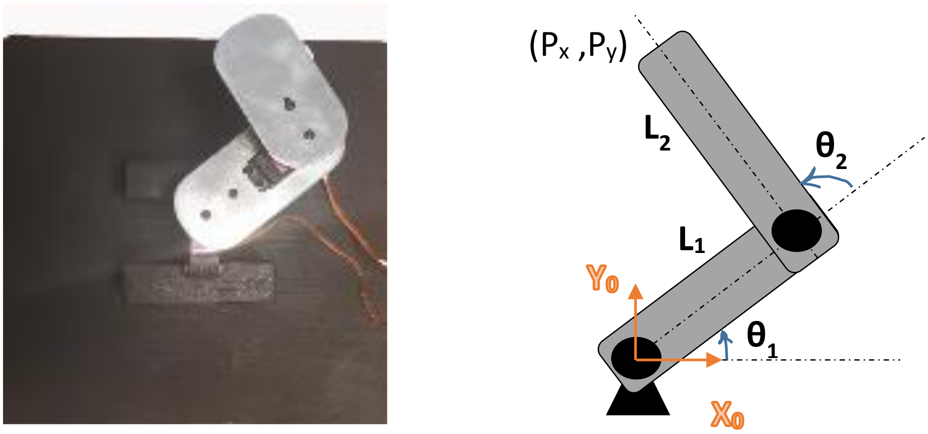

Figure: 8 showing the robotic arm, which is made up of two servomotors and two aluminum links.

E) MATHEMATICAL ANALYSIS

1. FORWARD KINEMATICS

The determination of the end-location effectors and orientation as joint variables is known as forward kinematics. The position of the end effectors may be expressed as follows using the link's length and angles:

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

Denavit-Hartenberg (D-H) method is another popular technique for robot kinematics. The four variables in this approach are the I joint angle, I link twist, ai link length, and I joint distance. The D-H parameters can be expressed in Table 1 in accordance with these parameters (Corke 2007). Equation 3 may be used to represent the transformation matrix that links the end-location effectors and orientation to the reference coordinate system.

Table 1 D-H Parameters of two-link manipulator

Link	a_i	α_i	d_i	θ_i
1	L_1	0	0	θ_1
2	L_2	0	0	θ_2

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

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

2. INVERSE KINEMATICS

Actuators, on the other hand, operate in joint space, whereas manipulators operate in Cartesian space (containing orientation matrix and position vector) (represented by joint angles). Cartesian space is covered by joint space in the placement and orientation of the manipulator end-effector. Inverse kinematics issue is what this is known as. Geometric, analytical, numerical, and clever algorithmic techniques can be used to solve this issue. Using Equations 4 and 5, one may get the angles 1 and 2 (Corke 2007).

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

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

Several elements of the kinematics, workspace, Jacobian analysis, and dynamic identification of a two-link planar manipulator are explored and given in this paper. The kinematic and dynamic challenges of a planar link manipulator were discussed by (De Luca and Siciliano 1991). (Wolovich 1993) presented automated control systems, serial manipulator analysis, and design. (You 2009) described adaptive tip point control in a serial link robot. Nagrath and Gopal (Nagrath and Gopal 2008) discussed kinematics, dynamics, and control theories for several serial manipulators. Tokhi and Azad (Tokhi and Azad 2008) explored flexible manipulator kinematics and modelling. Finally, to demonstrate the findings, the suggested control mechanism is applied to the flexible manipulator. Ata (Ata 2007) reviewed different optimum trajectory planning control strategies for serial manipulators. Islam and Liu (Islam and Liu 2011) suggested and investigated a sliding mode control approach for a serial manipulator. Kumara et al. (Kumar, Panwar et al. 2011) used a neural network to describe trajectory tracking control of kinematically redundant robot manipulators. Moldoveanu et al. (Moldoveanu, Comnac et al. 2005) used variable structure theory to describe trajectory control of a two-link robot manipulator. Wang and Deng et al. (Wang and Deng 2012) described how they created an articulated inspection arm with an integrated camera and replaceable tools. Zhu et al. (Zhu, Qiu et al. 2001) described the design of a serial link robot with 8 degrees of freedom and a 3-axis wrist-mounted camera. Ionescu (Ionescu 2007) presented a measuring method for the J0ET vacuum vessel that used a calibrated Cr252 neutron source deployed by an in-vessel remote handling boom and mascot manipulator. Image sensors were monochrome CCD cameras. Karagulle and Malgaca (Karagülle and Malgaca 2004) suggested employing integrated computer-aided design processes to investigate the influence of flexibility on the trajectory of a planar two-link manipulator. The passivity-based control approach was described by Nageshrao et al. (Jansson 2008). For a 2-DOF manipulator, a detailed method was devised and implemented. Ayala and Coelho (Villamarín and Menéndez 2021) demonstrated a method for testing PID tuning using a two-degree-of-freedom robot manipulator. Sjöström and Rassmus-Gröhn (Sjöström and Rassmus-Gröhn 1999) studied the possibilities offered by haptic technologies for creating new interactions usable by blind people. He worked especially with the Sense able Phantom. (Johansson and Linde 1999) used an inexpensive force feedback joystick in a virtual maze. (Wang, Levesque et al. 2006) have designed an experimental memory game in order to assess the possibilities of their tactile transducers. (Archambault, Ossmann et al. 2007)

F) HAPTIC GLOVE

The cloth used to make the glove may be altered to accommodate various hand sizes by varying the length of each finger's appendage to simulate a genuine hand. On the interior pair of the glove are the cables and haptic motors. To offer tactile feedback, nine miniature, low-power coin vibration motors were employed. Team B is represented by TB1, TB2, TB3, and TB5, whereas team A is represented by TA1, TA2, TA3, and TA5. The final one, which served as an auxiliary, was situated on the back of the hand. For the right hand, a functioning prototype was created first. An Arduino UNO was used to manage the entire setup.

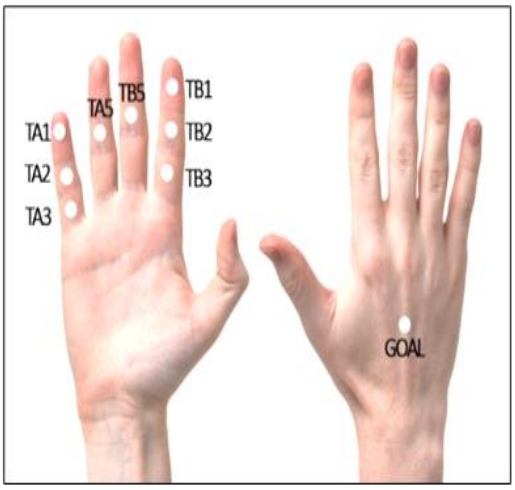

Figure: 9 showing the position of motors incorporated in haptic glove

1. MODEL REPRESENTATION

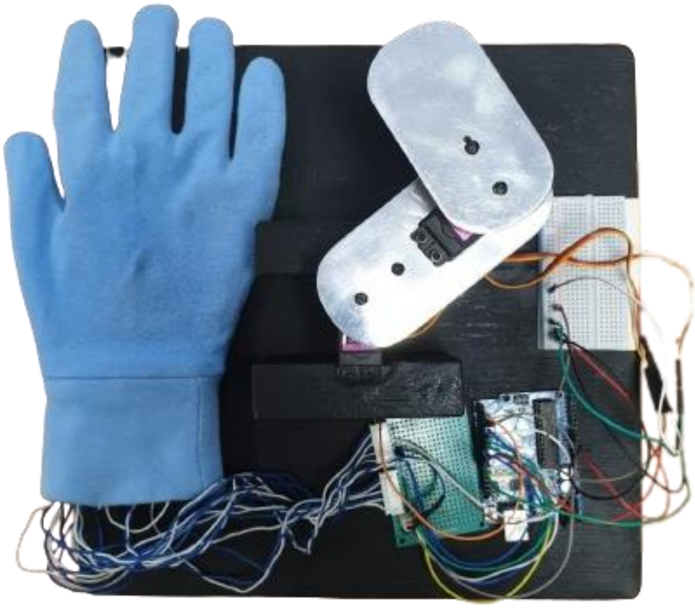

Figure: 10 showing Model prototype

2. HAPTIC GLOVE WORKING ALGORITHM

As previously mentioned, there are rules and occurrences in the volleyball game, such as fouls, time-outs, service, etc. The following algorithm was taken into consideration in order to construct all effective events. Prior to each event, the time window was established to provide participants adequate time to pay attention and comprehend.

- There is a five second delay before the game begins for setup.
- A service kicks off the game. V5 vibrates for a service. For one second, each vibration motor is turned on.
- V5 - Goal vibrates for one second when a goal is scored.
- The mutual motors TB1-TA1, TB2-TA2, and TB3-TA3 vibrate synchronously while a goal is being attacked or defended. The Goal function becomes active when a team scores a point. The regular game continues if no team earns a point.
- The referee ends the game if a foul is committed (for example, touching the net). In this instance, V1, V3, and V5 vibrate at the same time twice for 0.5 seconds.

The Goal function is then turned on.

- V5 vibrates twice for 2 seconds if one team service hits the net. The Goal feature for the opposing team is then activated.
- Both V5 are vibrated for 2 seconds to signal timeout.
- No function is activated during a timeout.
- V1, V2, and V3 vibrate at the same time if one team misses the ball (i.e., ball hits an area beyond the court). Then, the Goal feature for the opposing team is turned on.
- The vibrations of V1, V2, V3, and V5 last for 0.5 seconds twice if a team wins a set.
- V is the collective word used to refer to any player on both teams.

Table 2 pin connections

PIN NO.	Player	Player Represent
Pin D 2	TeamB Payer1	V1 (Vibrate)
Pin D3	TeamB Service	V5 (Vibrate)
Pin D 4	TeamB Player3	V3 (Vibrate)
Pin D 5	TeamB Player2	V2 (Vibrate)
Pin D 6	TeamA Player1	V1 (Vibrate)
Pin D 7	TeamA Service	V5 (Vibrate)
Pin D 8	TeamA Player3	V3 (Vibrate)
Pin D 11	Team A Player2	V2 (Vibrate)
Pin D 12	Goal	V6 (Vibrate)
Pin D 9	Link 1	(Servo 1)
Pin D 10	Link 2	(Servo 2)

Table 3 Events in game

Events	
Event 1	Team A goal during Attacking and Defending
Event 2	Team B goal (Team A missed to attempt
Event 3	Team A goal during Attacking and Defending
Event 4	Team B goal Through Net
Event 5	Team B Goal
Event 6	Team B goal during Attacking and Defending
Event 7	Third Empire Call by Team B (Goal)
Event 8	Time Out 1
Event 9	Team A Goal
Event 10	Team B goal
Event 11	Team B goal
Event 12	Team A goal
Event 13	Team B goal during Attacking and Defending
Event 14	Timeout 2
Event 15	Team B goal during Attacking and Defending
Event 16	Team A goal
Event 17	Team A Foul (Team B Goal)
Event 18	Team A goal
Event 19	Team B goal
Event 20	Team B Foul (Team A Goal)
Event 21	Team B goal
Event 22	Timeout3
Event 23	Team A goal
Event 24	Team B goal during Attacking and Defending
Event 25	Time Out 4 Game Complete
Event 26	Team B Win

III. RESULTS AND DISCUSSION

The current research was conducted to assess the effectiveness of the suggested solution. Following the signing of a written informed agreement, four male and one female volunteer (mean age = 25, age range 10–30 years) participated in the study. None of the participants had ever tested a system like this before. The process was authorized by Istanbul Aydin University. A sample volleyball match between Japan and the France was chosen to test the technology. The first three minutes' worth of events were all retrieved and coded using the previously mentioned method.

There were 26 occurrences in all that were retrieved, including fouls and timeouts. Each person heard the computer play the game while five randomly chosen events were played for them. They were afterwards asked to comment on whether they could feel the associated incident. Figure 4 displays the results of the experiment. When the user places his hand on the arm, the arm directs the user's hand in accordance with the location of the ball.

Figure 5 shows a such incident. Starting service for the game comes from TA5. The initial ball is received by TB1, who then sends it to TB3 (player 2). TB2 spikes the ball to finish. TA3 is simultaneously making a defense. Team B earned a point as a consequence, which resulted in the activation of TB5 - Goal.

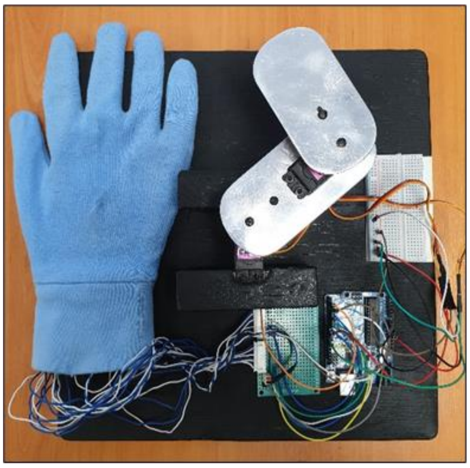

Figure: 11 On the right, you can see the finished system. The person touches the robotic arm with his hand. It directs the hand of the user to the appropriate location

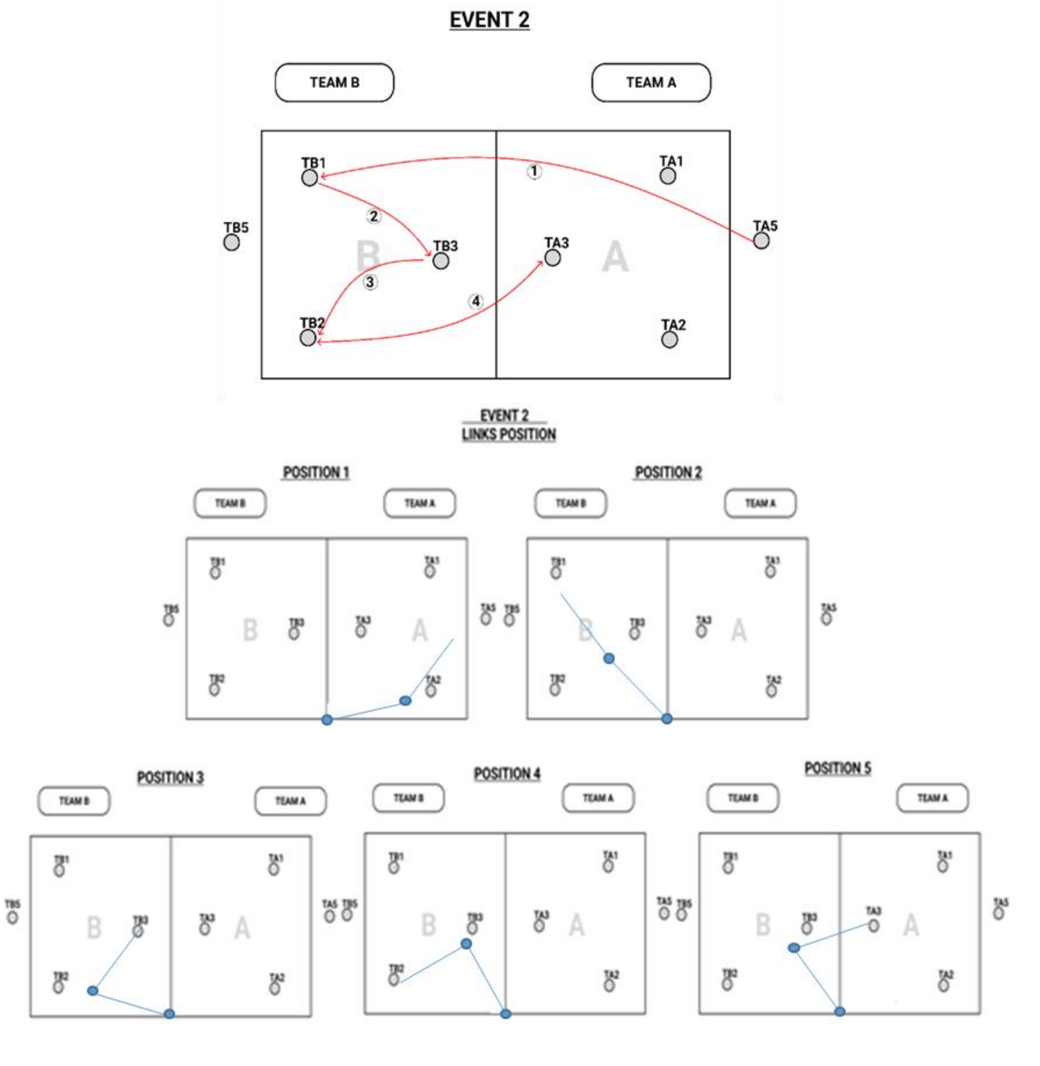

Figure: 12 showing sample experiment and schematic representation of the arm movement

The respondents each participated in three sessions of the game lasting one hour each. The data sources would include (1) computer-generated results of the participants' skills (level achieved, satnav speed, and effectiveness), (2) a Likert scale survey to assess preconceptions of engagement with and use of the glove as an embodied skill, and (3) an interview with one of the participants to discuss their experiences. (4) video clip of each and every session, and (5) extensive notes taken from the researcher-diary observer's during the whole process. The researchers determined the navigation speed by measuring the amount of time that had passed from the point at which the participant started playing the game until the point at which he or she reached the target, taking into account the amount of distance that needed to be traversed to reach each target. Next, they discovered the beginning distances to the targets and the pathways utilized to get to the targets by utilizing the x and y coordinates of the player's tracked finger and those of the target. This allowed them to determine the effectiveness of the participants' movements to identify the targets. At the end of the study project, the researchers collated the replies of the participants to the questionnaire questions and summarized the remarks made by the participants. Triangulation was accomplished with the use of videotapes and notebook notes.

In a study, three of the participants saw a significant improvement in their navigation speeds. The birth rates of Odetta and Alice both jumped by 45 percent, while Richard's birth rate increased by 62 percent; Nancy's birth rate grew by a more modest 10 percent. The researchers employed computer-generated maps to classify the various approaches to target location, which included direct, lost, overshooting the target and return, stair step, and unknown. As a result of the participants' increased levels of expertise, their methods ultimately got more effective. The straightforward approach turned out to be the most successful. The typical participant used this strategy 20.59 percent of the time during the first session. By the conclusion of the third session, this percentage had climbed to 28.37 percent. During the third session, the participants employed the stair step approach 46.1% of the time, making it the way that was utilized the most often overall. When compared to the first session's 8.82 percent, the third session's 1.16 percent represents a significant drop in the proportion of times the route to goal was deemed "lost."

According to the findings, each of the four individuals advanced beyond the level that was considered to be the simplest. Odetta and Alice made it to Level 3, while Nancy and Richard made it to Level 2. Both the participants' answers to the questionnaire and the entries they made in their journals provided evidence of the development of embodied abilities. The participants unanimously agreed that they were so engrossed in the game that they completely lost track of the passing of time. They were also unanimous in their belief that they had complete control over how their characters moved. The statement "I was so engaged in the game that I forgot I was wearing a glove; all I wanted to do was locate the targets" was met with vehement disagreement by three of the game's four participants, however. The fourth participant gave an answer that was indifferent to this issue. However, there were times when Richard needed to concentrate on the game, which caused him to interrupt his conversation while playing the game. This participant's name is Richard, and he was the only one who consistently started conversations while playing the game at Level 1 and sometimes during Level 2. Other individuals limited their verbalizations to components of the game that they were really playing. Everyone who took part in the activity firmly believed that they would be able to execute the game more effectively if they played it more. Everyone, with the exception of one, agreed or strongly agreed that they needed to maintain vigilance in order to arrive at the predetermined destinations on time.

When asked whether they had pleasure playing the game, all of the participants gave the same answer on the questionnaire: "highly agree." They also mentioned that they would want to play the game again and see it through to the end. Three of the participants thought that Level 1 was not difficult at all, but the same number of participants unanimously agreed that Level 2 was difficult. Participants who reached the third level of the game were in complete agreement that it was a difficult task. None of the players found Levels 2 or 3 to be uninteresting. Three of them all agreed that they could play for at least another half an hour to an hour without becoming bored.

During the course of the game, the participants responded to a few questions about their experience. On a Likert scale from 1 to 7, they were instructed to respond to each question. Seven is the greatest score, with one denoting the lowest.

The majority of the participants were happy with the experiment and thought it was fascinating to do. However, because they received the lowest grade, intensity and kind of vibration need to be increased. To recall the full incident, further training is needed.

It was mentioned by several users that they require some time before each event, which may be related to interpretation and memorization. Overall, they were happy with the experiment and the game they played with the new idea.

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. For instance, all of the participants had an improvement in their navigation speed, and three of the individuals saw benefits ranging from 45 percent to 62 percent. At the conclusion of the three sessions, the players had exhibited the capacity to detect targets directly 28 percent of the time and had employed the second-most efficient strategy for discovering targets more than 46 percent of the time. As a result, the participants reached their objectives using one of the two routes that were shown to be the most successful around 74 percent of the time (Bargerhuff, Cowan et al. 2010).

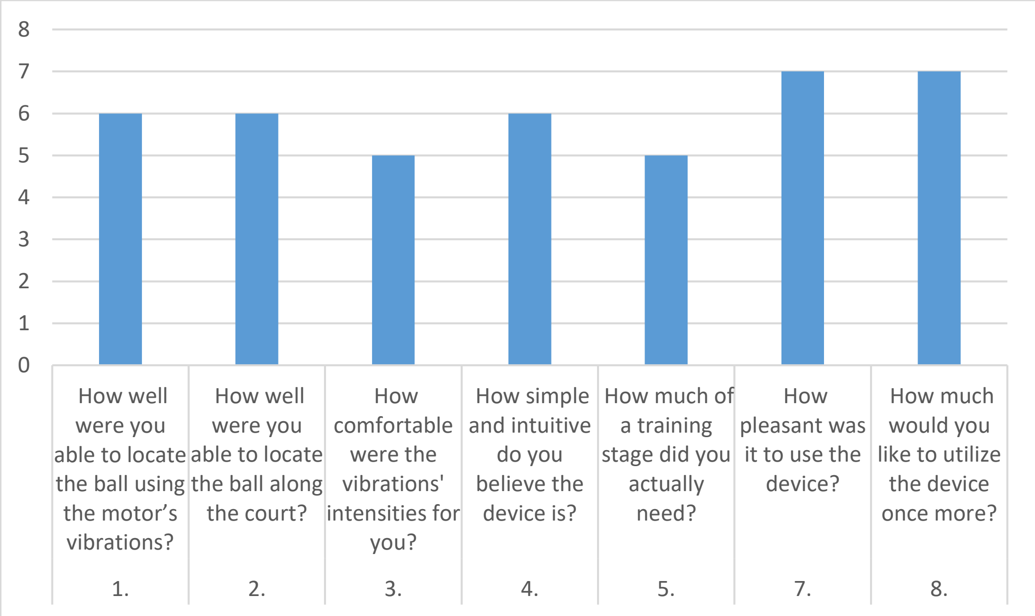

Figure: 13 The responses to the questions were average across all participants. Each bar graph has a question mark underneath it

IV. CONCLUSION

The goal of this study was to create a system that was patient-friendly, lightweight, portable, and cost-effective. All the motion data was gathered and the arm was first created using the Solidwork programme. The pitch had a conventional size of 90 by 180 cm. The players' positions and angles were predetermined. The whole course of the game's events were collected from a sample game and encoded based on the technique. A psychophysical experiment was used to gauge how well the system worked. The participants significantly improved their skills connected to using the haptic glove and actively participating in the game, according to the results. Some of the participants also indicated that the system should be enhanced by including extra elements, such as multiple directional sound effects to foster a positive environment. Some of them, though, were content with the way things were just now. Additionally, they commented that while the suggested solution is economical, it should be readily available in marketplaces.

V. FUTURE WORK

Numerous researchers have attempted to improve the lives of people who are blind in order to help them feel happy despite their impairments, and additional research is still being done in this area. As technology develops, additional options may be included into systems. For the participants, the currently presented design was suitable and simple to use. It was found that adding a camera and creating a virtual world will increase the participants' enjoyment of the experience. A speedier system that is consistent with the game's dynamics will be developed as part of this ongoing study, which will allow participants to select different games of interest. These games require automated ball position identification.

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ELECTRONIC SOURCES

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APPENDIX

A) CODING

//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 teams.

```
#include<Servo.h>
Servo servo1;       //L1
Servo servo2;       //L2
const int Tb1 = 2;   //TeamB Player1            V1 (Vibrate)
```

```
const int Tb2 = 3;   //TeamB Service           V5 (Vibrate)
const int Tb3 = 4;   //TeamB Player3           V3 (Vibrate)
const int Tb4 = 5;   //TeamB Player2           V2 (Vibrate)
const int Ta1 = 6;   //TeamA Player1           V1 (Vibrate)
const int Ta2 = 7;   //TeamA Service           V5 (Vibrate)
const int Ta3 = 8;   //TeamA Player3           V3 (Vibrate)
const int Ta4 = 11;  //TeamA Player2           V2 (Vibrate)
const int gol = 12;  //Goal                    V6 (Vibrate)
int a = 0;
int b = 0;
void setup() {
Serial.begin(9600);
servo1.attach(9);   //L1 Pin(9)
servo2.attach(10);  //L2 Pin(10)
servo1.write(90);
servo2.write(90);
pinMode(Ta1, OUTPUT);
pinMode(Ta2, OUTPUT);
pinMode(Ta3, OUTPUT);
pinMode(Ta4, OUTPUT);
pinMode(Tb1, OUTPUT);
pinMode(Tb2, OUTPUT);
pinMode(Tb3, OUTPUT);
pinMode(Tb4, OUTPUT);
pinMode(gol, OUTPUT);
}
```

```
void off() {
digitalWrite(Ta1, LOW);
digitalWrite(Ta2, LOW);
digitalWrite(Ta3, LOW);
digitalWrite(Ta4, LOW);
digitalWrite(Tb1, LOW);
digitalWrite(Tb2, LOW);
digitalWrite(Tb3, LOW);
digitalWrite(Tb4, LOW);
digitalWrite(gol, LOW);
}
void center() {
Serial.println(" Center ");
servo1.write(90);
servo2.write(90);
}
void mova() {
Serial.println(" move to A ");
servo1.write(40);
servo2.write(90);
}
void movb() {
Serial.println(" move to B ");
servo1.write(130);
servo2.write(90);
}
```

```
void TA1() {
Serial.println(" Player A 1 ");
servo1.write(80);
servo2.write(55);
digitalWrite(Ta1, HIGH);
}
void TA5() {
Serial.println(" Player A 5 ");
servo1.write(40);
servo2.write(90);
digitalWrite(Ta2, HIGH);
}
void TA3() {
Serial.println(" Player A 3 ");
servo1.write(20);
servo2.write(180);
digitalWrite(Ta3, HIGH);
}
void TA2() {
Serial.println(" Player A 2 ");
servo1.write(0);
servo2.write(180);
digitalWrite(Ta4, HIGH);
}
void TB1() {
Serial.println(" Player B  1 ");
```

```
servo1.write(120);
servo2.write(85);
digitalWrite(Tb1, HIGH);
}
void TB5() {
Serial.println(" Player B  5 ");
servo1.write(130);
servo2.write(90);
digitalWrite(Tb2, HIGH);
}
void TB3() {
Serial.println(" Player  B  3 ");
servo1.write(150);
servo2.write(0);
digitalWrite(Tb3, HIGH);
}
void TB2() {
Serial.println(" Player B 2 ");
servo1.write(180);
servo2.write(0);
digitalWrite(Tb4, HIGH);
}
void goalb() {
Serial.println(" Goal Team B ");
digitalWrite(gol, HIGH);
digitalWrite(Tb2, HIGH);
```

```
b = b + 1;
}
void goala() {
Serial.println(" Goal Team A ");
digitalWrite(gol, HIGH);
digitalWrite(Ta2, HIGH);
a = a + 1;
}
void goalanet() {
Serial.println(" Goal Team A NET");
digitalWrite(Tb2, HIGH);
delay(1000);
digitalWrite(Tb2, LOW);
delay(1000);
digitalWrite(Tb2, HIGH);
delay(1000);
digitalWrite(Tb2, LOW);
delay(1000);
goala();
}
void goalbnet() {
Serial.println(" Goal Team B net ");
digitalWrite(Ta2, HIGH);
delay(1000);
digitalWrite(Ta2, LOW);
delay(1000);
```

```
digitalWrite(Ta2, HIGH);
delay(1000);
digitalWrite(Ta2, LOW);
delay(1000);
goalb();
}
void empb() {
Serial.println(" Call Thired Empire ");
digitalWrite(Tb1, HIGH);
digitalWrite(Tb3, HIGH);
digitalWrite(Tb2, HIGH);
delay(500);
digitalWrite(Tb1, LOW);
digitalWrite(Tb3, LOW);
digitalWrite(Tb2, LOW);
delay(500);
digitalWrite(Tb1, HIGH);
digitalWrite(Tb3, HIGH);
digitalWrite(Tb2, HIGH);
delay(500);
off();
delay(1000);
goalb();
}
void empa() {
Serial.println(" Call Thired Empire ");
```

```
digitalWrite(Ta1, HIGH);
digitalWrite(Ta3, HIGH);
digitalWrite(Ta2, HIGH);
delay(500);
digitalWrite(Ta1, LOW);
digitalWrite(Ta3, LOW);
digitalWrite(Ta2, LOW);
delay(500);
digitalWrite(Ta1, HIGH);
digitalWrite(Ta3, HIGH);
digitalWrite(Ta2, HIGH);
delay(500);
off();
delay(1000);
goala();
}
void atcdb() {
Serial.println(" Attack and defand ");
digitalWrite(Tb3, HIGH);
digitalWrite(Ta3, HIGH);
delay(10000);
off();
mova();
delay(1000);
goalb();
}
```

```
void atcda() {
Serial.println(" Attack and defand ");
digitalWrite(Ta3, HIGH);
digitalWrite(Tb3, HIGH);
delay(1000);
off();
movb();
delay(1000);
goala();
}
void conta() {     //Team A Attack and defend Continue game
Serial.println(" Attack and defend Continue game ");
digitalWrite(Ta3, HIGH);
digitalWrite(Tb3, HIGH);
delay(1000);
off();
}
void contb() {      //Team B Attack and defend Continue game
Serial.println(" Attack and defend Continue game ");
digitalWrite(Tb3, HIGH);
digitalWrite(Ta3, HIGH);
delay(1000);
off();
}
void win() {
for (int k = 0 ; k < 5; k++) {
```

```
digitalWrite(Tb1, HIGH);
digitalWrite(Tb2, HIGH);
digitalWrite(Tb3, HIGH);
digitalWrite(Tb4, HIGH);
delay(1000);
digitalWrite(Tb1, LOW);
digitalWrite(Tb2, LOW);
digitalWrite(Tb3, LOW);
digitalWrite(Tb4, LOW);
delay(1000);
  }
}
void foula() {
Serial.println(" foul A ");
servo1.write(180);
servo2.write(90);
digitalWrite(Ta1, HIGH);
digitalWrite(Ta4, HIGH);
digitalWrite(Ta3, HIGH);
delay(1000);
off();
delay(500);
goalb();
}
void foulb() {
Serial.println(" foul B ");
```

```
servo1.write(0);
servo2.write(90);
digitalWrite(Tb1, HIGH);
digitalWrite(Tb4, HIGH);
digitalWrite(Tb3, HIGH);
delay(1000);
off();
delay(500);
goala();
}
void timeout() {
Serial.println(" Time Out ");
digitalWrite(Ta2, HIGH);
digitalWrite(Tb2, HIGH);
digitalWrite(gol, HIGH);
center();
}
int g = 0;
void loop() {
while (g == 0) {
center();
delay(3000);           // Match Starting Delay
//EVENT 1
TA5();              //Service Team  A
delay(1000);
off();
```

```
TB1();
delay(1000);
off();
TB2 ();
delay(1000);
off();
atcda();
movb();
delay(1000);
off();
//Team A goal during Attacking and Defending
delay(3000);
//EVENT 2
TA5();          //Service Team  A
delay(1000);
off();
TB1();
delay(1000);
off();
TB3();
delay(1000);
 off();
TB2();
delay(1000);
off();
TA1();
```

```
delay(1000);
off();
mova();
delay(500);
goalb();
delay(1000);
off();
//Team B goal (Team A missed to attempt)
delay (3000);
//EVENT 3
TB5();          //Service Team B
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
atcda();
movb();
delay(1000);
off();
//Team A goal during Attacking and Defending
delay(3000);
//EVENT 4
```

```
Serial.println(" EVENT 4 ");
TA5();                //Service Team  A
delay(1000);
off();
center();
delay(1000);
goalbnet();
delay(1000);
off();
//Team B goal Through Net
delay (3000);
//Event 5
TB5();               //Service Team B
delay(2000);
off();
TA1();
delay(2000);
off();
TA2();
delay(2000);
off();
TA3();
delay(2000);
off();
TB1();
delay(2000);
```

```
off();
TB2();
delay(2000);
off();
TB3();
delay(2000);
off();
mova();
delay(500);
goalb();
delay(2000);
off();
//Team B goal
delay (3000);
//Event 6
TB5();          //Service Team B
delay(1000);
off();
TA2();
delay(1000);
off();
TA1();
delay(1000);
off();
atcdb();
delay(1000);
```

```
off();
//Team B goal during Attacking and Defending
delay (3000);
//Event 7
TB5();          //Service Team B
delay(1000);
off();
TA1();
delay(1000);
off();
TA3();
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
delay(500);
center();
empb();
delay(1000);
off();
// Third Empire Call by Team B (Goal)
delay (3000);
```

```
//Event 8
Serial.println(" Time Out 1 ");
timeout();
delay(2000);
off();
//TimeOut 1
//Event 9
TB5();          //Service Team  B
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
TA3();
delay(1000);
off();
movb();
delay(500);
goala();
delay(1000);
off();
//Team A Goal
delay (3000);
```

```
//Event 10
TA5();          //Service Team  A
delay(1000);
off();
TB1();
delay(1000);
off();
TB2();
delay(1000);
off();
atcdb();
delay(1000);
off();
//Team B goal
delay (3000);
//Event 11
TB5();              //Service Team B
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
conta();          //Team A Attack and defand Continue game
```

```
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
TA1();
delay(1000);
off();
TB1();
delay(1000);
off();
TB2();
delay(1000);
off();
TB3();
delay(1000);
off();
mova();
delay(500);
goalb();        //Team B goal
delay(1000);
off();
delay (3000);
//Event 12
TB5();          //Service Team B
```

```
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
TA3();
delay(1000);
off();
movb();
delay(500);
goala();
delay(1000);
off();
//Team A goal
delay (3000);
//Event 13
TA5();          //Service Team  A
delay(500);
off();
TB1();
delay(500);
off();
TB2();
```

```
delay(500);
off();
atcdb();
delay(1000);
off();
//Team B goal during Attacking and Defending
delay (3000);
//Event 14
Serial.println(" Time Out 2 ");
timeout();
delay(1000);
off();
//Timeout2
delay (3000);
//Event 15
TB5();          //Service Team  B
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
TA3();
delay(1000);
```

```
off();
TB2();
delay(1000);
off();
TB1();
delay(1000);
off();
atcdb();
delay(1000);
off();
//Team B goal during Attacking and Defending
delay (3000);
//Event 16
Serial.println(" EVENT 16 ");
TB5();          //Service Team B
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
conta();        //Team A Attack and defand Continue game
delay(1000);
off();
```

```
TB1();
delay(1000);
off();
TB2();
delay(1000);
off();
TA2();
delay(1000);
off();
TA1();
delay(1000);
off();
TA3();
delay(1000);
off();
movb();
delay(500);
goala();
delay(1000);
off();
//Team A goal
delay (3000);
//Event 17
Serial.println(" EVENT 17 ");
TA5();          //Service Team A
delay(1000);
```

```
off();
foula();
delay(1000);
off();
//Team A Foul (Team B Goal)
delay (3000);
//Event 18
Serial.println(" EVENT 18 ");
TB5();          //Service Team B
delay(1000);
off();
TA1();
delay(1000);
off();
TA3();
delay(1000);
off();
TA1();
delay(1000);
off();
movb();
delay(500);
goala();        //Team A goal
delay(1000);
off();
delay (3000);
```

```
//Event 19
Serial.println(" EVENT 19 ");
TA5();              //Service Team  A
delay(1000);
off();
TB3();
delay(1000);
off();
TB1();
delay(1000);
off();
TB2();
delay(1000);
off();
mova();
delay(500);
goalb();
delay(1000);
off();
//Team B goal
delay (3000);
//Event 20
Serial.println(" EVENT 20 ");
TB5();              //Service Team B
delay(1000);
off();
```

```
movb();
foulb();            //Team B Foul (Team A Goal)
delay(1000);
off();
delay (3000);
//Event 21
Serial.println(" EVENT 21 ");
TA5();           //Service Team  A
delay(1000);
off();
TB1();
delay(1000);
off();
TB3();
delay(1000);
off();
TB2();
delay(1000);
off();
TA1();
delay(1000);
off();
mova();
delay(500);
goalb();
delay(1000);
```

```
off();
//Team B goal
delay (3000);
//Event 22
Serial.println(" EVENT 22 ");
Serial.println(" Time Out 3 ");
timeout();
delay(1000);
off();
//Timeout3
delay (3000);
//Event 23
Serial.println(" EVENT 23 ");
TB5();          //Service Team B
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
TA3();
delay(1000);
off();
TB2();
```

```
delay(1000);
off();
TB1();
delay(1000);
off();
contb();            //Team B Attack and defand Continue game
delay(1000);
off();
TA1();
delay(1000);
off();
TA2();
delay(1000);
off();
movb();
delay(500);
goala();          //Team A goal
delay(1000);
off();
delay (3000);
//Event 24
Serial.println(" EVENT 24 ");
TA5();            //Service Team A
delay(1000);
off();
TB1();
```

```
delay(1000);
off();
TB2();
delay(1000);
off();
atcdb();
delay(1000);
off();
//Team B goal during Attacking and Defending
delay (3000);
//Event 25
Serial.println(" EVENT 25 ");
Serial.println(" Game Complete ");
timeout();
delay(1000);
off();
//Timeout 4 Game Complete
//Event 26 Win
Serial.print("Total A goals = ");
Serial.println(a);
Serial.print("Total B goals = ");
Serial.println(b);
win();
delay(3000);
off();
g = 1;
```

```
  }
}
```

B) ARDUINO UNO

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

Figure: 14 showing Arduino Uno

❖ ARDUINO UNO SPECIFICATION

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- In-out Voltage (limit): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- PWM Digital I/O Pins: 6
- Analog Input Pins: 6

- DC Current per I/O Pin: 20 mA
- DC current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB (ATmega328P) of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328P)
- EEPROM: 1 KB (ATmega328P)
- Clock Speed: 16 MHz
- LED_BUILTIN: 13
- Length: 68.6 mm
- Width: 58.4 mm
- Weight: 25 g

C) SHAFTLESS VIBRATION MOTOR 10X3 (10MM CABLE LENGTH)

The tiny, button-type, vibrating motor shakes with a vibration amplitude of 0.75g and draws approximately 60 mA when 3 V is applied to its leads. The shaftless design keeps this motor small: 10 mm in diameter and 3.4 mm in height.

This shaftless vibration motor is fully-enclosed with no exposed moving parts. Its small size (10 mm diameter, 3.4 mm height) and shaftless design mean you can mount it on a PCB or even place it in a pocket to add quiet, haptic feedback to your project. The motor has a 3M adhesive backing on it for easy mounting and 1.5" leads for making quick connections.

Table 4 Specifications

Manufacture	Precision MicrodriversTM
Model	310-103
Dimensions	10 mm x 3 mm
Weight	1.2 g
Recommended operating voltage	2.5 - 3.5 V
Vibration Amplitude@ 3V	0.75g

Speed @3V	13500 RPM
Idle current @3V	60 mA (80 mA max)
Startup current @3V	120 mA max
Impedence	29 ± 6 Ω
Working temperature	-10 ° C ile +60 °C
Storage temperature	+70 °C ila -30 °C

Figure: 16 showing 10mm Vibration Motor

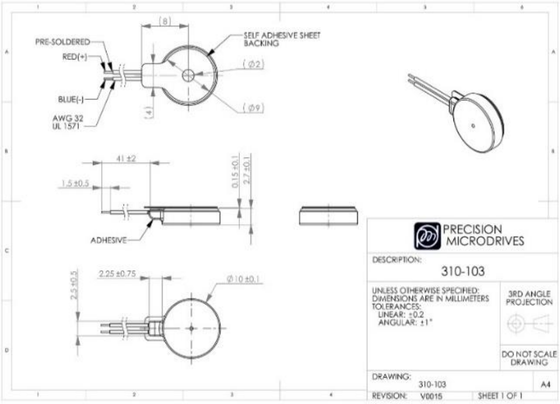

Figure: 15 showing dimensional specification of shaftless vibration motor

D) MG996R SERVO MOTOR

The MG996R is a steel tools servo motor with a maximum stall torque of eleven kg/cm. Like different RC servos the motor rotates from zero to a hundred and eighty diploma primarily based on the responsibility cycle of the PWM wave provided to its signal pin.

Figure: 17 showing MG996R Servo Motor

Table 5 Wire Configuration

Wire Number	Wire Colour	Description
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

❖ THE BEST WAY TO CHOOSE YOUR SERVO MOTOR

There are lots of servo motors available in the request and each bone has its own specialty and operations. The following two paragraphs will help you identify the right type of servo motor for your design/system.

Utmost of the hobbyhorse Servo motors operates from 4.8 V to 6.5 V, the advanced the voltage advanced the necklace we can achieve, but utmost generally they're operated at 5 V. nearly all hobbyhorse servo motors can rotate only from 0 ° to 180 ° due to their gear arrangement so make sure your design can live with the half circle if no, you can prefer for a 0 ° to 360 ° motor or modify the motor to make a full circle. The gears in the motors are fluently subordinated to wear and tear and gash, so if your operation requires stronger and long handling motors you can go with essence gears or just stick with normal plastic gear.

Next comes the most important parameter, which is the necklace at which the motor operates. Although there are numerous choices but let us assume the one with 2.5 kg/cm necklace which comes with the MG996R Motor. This 2.5 kg/cm necklace means that the motor can pull a weight of 2.5 kg when it's suspended at a distance of 1 cm. So, if you suspend the cargo at0.5 cm also the motor can pull a cargo of 5 kg also if you suspend the cargo at 2 cm also can pull only 1.25. Grounded on the cargo which you use in the design you can elect the motor with proper necklace. The below picture will illustrate the same.

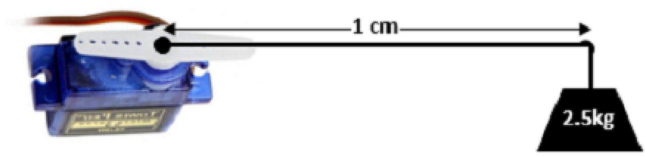

Figure: 18 showing the illustration of Servomotor of choice with 2.5 kg necklace

❖ HOW TO USE A SERVO MOTOR

After opting the right Servo motor for the design, comes the question how to use it. As we know there are three cables coming out of this motor. The description of the same is given on top of this runner. To make this motor rotate, we've to power the motor with 5V using the Red and Brown line and shoot PWM signals to the Orange colour line. Hence, we need commodity that could induce PWM signals to make this motor work, this commodity could be anything like a 555 timekeeper or other Microcontroller platforms like Arduino.

❖ HOW CAN THE MOTOR'S DIRECTION BE CHANGED?

From the image, it is clear that the created PWM signal should have a frequency of 50Hz, meaning that the PWM period should be 20ms. From which the On-Time might range from 1 to 2 milliseconds. As a result, the motor will be at 0° when the on-time is 1ms, 90° when it is 1.5ms, and 180° when it is 2ms. Therefore, the motor may be regulated from 0° to 180° by adjusting the on-time from 1ms to 2ms.

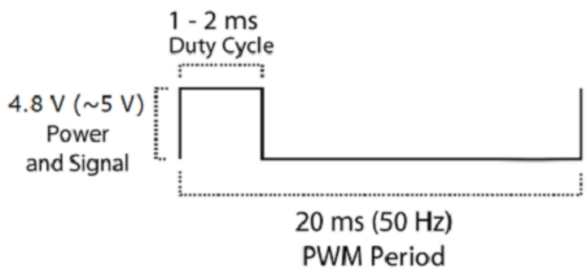

Figure: 19 showing the direction of motor

RESUME

SKILLS & ABILITIES

- Possess professional communication, organization and coordination skills.
- Skilled in development of alignment procedures and electromechanical design initiatives. Prior experience supervising precision assembly processes and leading team in project completion.
- Preparing and executing project plans with assurance that work is carried out in accordance with the company's policies & procedures and individual project's requirements.
- Able to ensure timely, safe and cost-effective design and implementation during the life cycle of projects from conception till customer satisfaction.

EXPERIENCE

January 2018 – July 2020

Project Engineer, Refrigeration & Cold Chain Projects

Koldware Industries (Pvt) Ltd., Karachi, Pakistan

Job Responsibilities

- Effectively developed tactics and managed mechanical and electrical processes throughout.
- Carried out project execution activities for Cold Storage & Refrigeration Projects nationwide, along with maintaining beneficial relations with the new/existing potential Clients.
- Ensured that all the consumer facing strategies were seamlessly integrated by creating MS excel sheets and arranging relevant materials.

- Support in Design & Production of Ethylene Gas Generators, Ultrasonic Humidifiers, Refrigeration Systems Control Systems, Fruits & Vegetables Grading Lines.

September 2013 – December 2017

Production Supervisor

Koldware Industries (Pvt) Ltd., Karachi, Pakistan

- Worked with and under the supervision of the Project director, initiated, iteratively developed and completed projects on time.
- Established and maintained excellent relationships with strategic partners internally and externally that were crucial to company success.
- Regularly prepared reports and presented to management teams

KEY PROJECTS EXECUTED

- Unilever Pakistan Ltd., Rahimyar Khan
- Fruits & Vegetables Solar Tunnel Dryers, across Pakistan
- Indus livestock, Karachi
- Lucky Foods, Karachi
- Pioneer Pakistan Seed Ltd. (A DuPont Co.), Sahiwal Plant
- Nestle Pakistan Ltd., Sheikhupura
- Al-Shareed Enterprises, Bhalwal
- Citrus Research Institute, Sargodha
- Gerry's Dnata Pvt Ltd, Islamabad
- Barkat Frisian Pasteurized Egg Company, Karachi
- SMA Enterprises, Karachi
- Anfords Pakistan PVT LTD
- Royal Airport Services PVT LTD
- English Biscuits Manufacture PVT LTD

EDUCATION

MASTER'S DEGREE (MECHANICAL ENGINEERING) *In Progress (Defending Thesis)(Start in* OCTOBER 2020)

ISTANBUL AYDIN UNIVERSITY, ISTANBUL, TURKEY

Chartered by Govt. of Turkey AND RECOGNIZED by COUNCIL OF Higher Education of TURKEY

Specialization: Mechanical

Thesis: Developing a Guided Tactile Feedback System for Visually Impaired People

Bachelor's degree BS (MECHATRONICS) July 2019
INDUS UNIVERSITY, KARACHI, PAKISTAN

Chartered by Govt. of Pakistan and recognized by Higher Education Commission of Pakistan

Specialization: Electronics, Electrical, Mechanical

Project: Innovative Efficient Hybrid Power Generation

3yrs Diploma of Associate Engineering 2013
ALIGARH INSTITUTE OF TECHNOLOGY, KARACHI, PAKISTAN

Recognized by Sindh Board of Technical Education Karachi

Specialization: Electronics

COMPUTER & SOFTWARE SKILLS

Analytical & Technical Skills

Microsoft Office

- Skill Level in;
- MS Word`
- MS Excel
- MS PowerPoint
- MS Outlook
- MS Project

AutoCAD (Basic)

Danfoss CoolSelector