UPPER EXTREMITIES INTERACTIVE REHABILITATION DEVICE FOR CHILDREN WITH CEREBRAL PALSY

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Mechatronics Engineering

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"UPPER EXTREMITIES INTERACTIVE REHABILITATION DEVICE FOR CHILDREN WITH CEREBRAL PALSY"** was prepared by **TAN PEH SERN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Mechatronics Engineering at Universiti Tunku Abdul Rahman.

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ABSTRACT

Many children are suffering from the effects of cerebral palsy (CP) and are not able to live their lives normally. This conflict leads to them having negative thoughts on themselves and towards life itself. Awareness on children with CP should be spread all around the world because we need to emphasize on and concern about these children's well-being and quality of life. They deserve to live their life to the fullest with positivity despite facing hurdle physically. CP can have an impact on the children's upper, lower or the combination of both limbs due to its negative effect on the brain's motor cortex which is responsible for relaying signals for movement control. This will lead to them having trouble walking, holding objects, playing sports and carrying out other actions. Therefore, this project focuses on developing an upper extremities interactive rehabilitation device for these children. This device will be incorporated with an interactive feedback system to act as an incentive and motivation for the children to utilize the rehabilitation device. This device requires creative mechanical and electronic designs. Besides, software programming is also needed to produce the graphical user interface to store and display training data related to the patients' condition. For further improvement, these data can be sent online to cloud storage to be accessed by therapists. Physical presence will no longer be required for rehabilitation so data analysis and training sessions planning can be done virtually. This allows proper and consistent monitoring on their latest state and progress. With the help of this rehabilitation device, children with CP can have more hopes and chances in improving their quality of lives.

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CHAPTER 1

INTRODUCTION

1.1 Background

Cerebral palsy (CP) is a neurological disorder and is the most frequently seen disease in children (Wood et al. 2013). It causes physical disability and affects thousands of babies and children every year (CerebralPalsy.org, no date). This disease is due to a problem in the signal relayed from the brain to the nerve and then to the muscles (Bochek, 2016) or so called abnormal brain development which then leads to incapability in using their upper or lower limbs. Therefore, they will have complication in controlling their body muscles. Besides, CP may lead to learning, hearing, visual and speech impairments (Shafer, no date). It affects the victims in different ways but most of the time it has an impact on their movement and posture. For this project, the focus will be on developing an interactive rehabilitation device to help the children in improving their capability in using their upper limbs.

Children with CP usually have really weak limbs to begin with. They are unable to carry out daily activities like the other people. There is no method to cure this disease absolutely, but there are methods to improve this condition (National Institute of Neurological Disorders and Stroke, 2016) where the children will be able to carry out activities with much less help or even independently. In fact, the 25th of March annually is the Cerebral Palsy Awareness Day (Reiter & Walsh, P.C., 2016) and March is being recognized as the National Cerebral Palsy Awareness Month (DeButts, 2015). The initial purpose of this awareness month was to bring realization to the fact that there is no dedicated federal fund to the research on CP. People have to be aware of the available clinical trials and the devices that are accessible to help the victims with CP. Then, there is the world cerebral palsy day fixed on the 1st of October aiming to change the world of people with CP (Rocky bay, 2014). This event is supported by organizations all around the world. Many creative ideas that are able to change the victims' life will be presented.

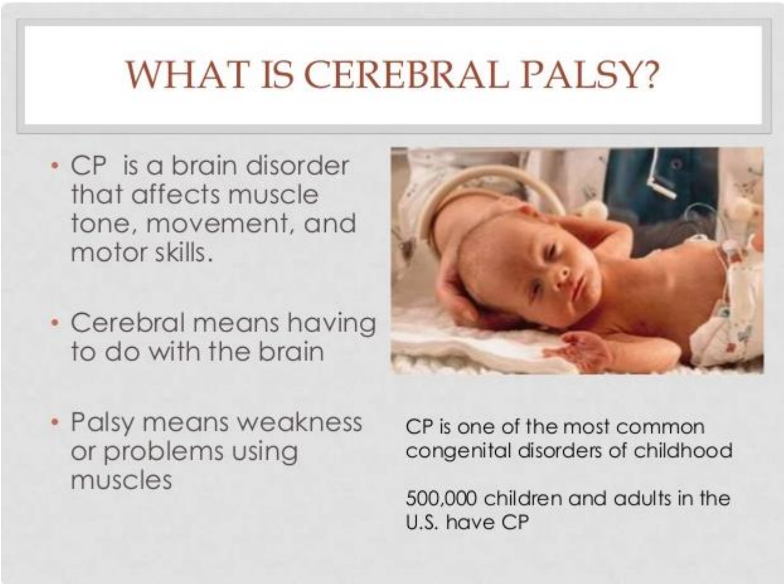


Figure 1.1: What is Cerebral Palsy? (Rolen, 2013)

There are four main types of CP namely dyskinetic, ataxic, spastic and mixed CP. Spastic CP is most commonly seen in the category of CP. The effects of different CP on the victims vary from muscle stiffness, movement complication, coordination and balance and the combination of few of the problems. We can notice and observe the signs of CP in a baby. Possible symptoms are such as difficulty in moving their hands, stiff posture, lopsided crawl and cross-over legs (CerebralPalsy.org, no date).

CP has to be tackled on earlier for better chance of improving the condition. When these symptoms are observed, parents or guardians should bring their child to clinic/hospital for diagnosis. Early diagnosis will benefit the victims.

Figure 1.2: Patient with Cerebral Palsy (Cerebral Palsy.org, no date)

Many people have a misapprehension that there is no opportunity or hope for people with CP to undergo a normal life. Although CP is a non-progressive disorder, there are methods that can be employed to improve the conditions of the victims (National Institute of Neurological Disorders and Stroke, 2016). Different kinds of physiotherapy sessions can be attended to enhance their muscle strength. There are also many researches that have proven the positive effect of rehabilitation device on the children with CP. In fact, there are already many such devices invented to help people with weak upper limbs.

1.2 Aims and Objectives

The main objective of this project is to develop an upper extremities interactive rehabilitation device to aid children with cerebral palsy. The focus is to help in strengthening their upper limbs and improving the quality of life of the children with cerebral palsy.

1.3 Problem Statement

Children diagnosed with cerebral palsy (CP) will face difficulties with their upper, lower or a combination of both limbs. A rehabilitation device will be able to help in improving their motor function, strengthening their limbs' muscles and coordination (CP Daily Living, 2011). The interactive component acts as an incentive for the children to put effort into using the device (Chuchnowska, 2011), (Kwan, 2015). These children who face physical complication will eventually be filled with negativity as they are unable to carry out daily activities like the rest of us.

A rehabilitation device is capable of helping to improve the children's condition although not to fully cure the disease. They are entitled to be stronger and feel better with what they are born with. An interactive rehabilitation device provides a platform for therapy and training with a feedback system which serves a monitoring purpose. With enough effort and perseverance, the children with CP will definitely be able to overcome many obstacles that they are facing.

There are some available interventions to specifically aid children with CP from the perspective of movement complication, difficulties in muscle and joint, communication, intellectual, cognitive learning, pain, emotional issues, senses impairment and others (Cerebral Palsy Alliance, no date). Depending on the severity of these categories in children with CP, different method of interventions can be employed. The children can undergo physical therapy with rehabilitation devices and medication. Some might also undergo surgery to loosen stiff muscles, correct body posture, decrease spasticity and many more. However, it is not advisable to resort to surgery for children as the risk can be higher than for adults (Bochek, 2016).

Different kinds of rehabilitation devices assist in different aspects of training depending on the desired exercises by children with CP. There are several centres in Malaysia such as Spastic Children Association of Selangor and Wilayah Persekutuan (SCASFT), and Spastic Children's Association of Johor which main purpose is to help spastic children.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Cerebral Palsy

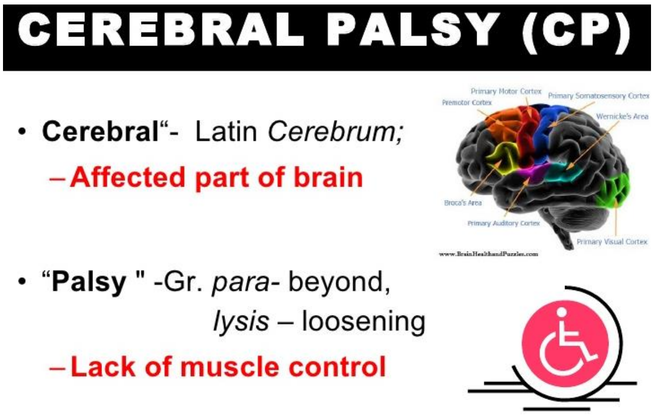


Figure 2.1: Definition of Cerebal Palsy (Williams, 2015)

From the name "cerebral palsy" itself, "cerebral" is related to the brain which makes it a neurological disorder whereas "palsy" relates to the lack of muscle control. Therefore, a person with cerebral palsy (CP) has muscle strength and coordination complication. Pokhariya and colleagues (2007) stated that CP refers to a classification of disorders related to posture and movement development which contribute to non-progressive problem in a developing brain. It is a very common childhood physical disability. According to a journal, CP tops the charts of childhood disorder seen in the comprehensive rehabilitation (Wood et al., 2013). In support of this statement, Reddihough and Collins (2003), and Pokhariya and colleagues (2007) both have also stated that CP is the most occurring physical impairment in children.

CP is a set of disorders that causes impact on a person's body movement and ability to maintain posture and balance. Instead of problems with the muscles or nerves, CP is a consequence of irregularity in the parts of brain that control the muscle movements. It is usually caused by damage to a developing brain of a pre-born or shortly after birth baby. It is usually by the age of 2 or 3 when CP's symptoms can be seen in a baby. While the baby's brain is still developing, the occurrence of abnormal development, brain malformation or brain impairment cause brain damage and eventually leads to CP. However, this brain disorder is non-progressive and usually does not worsen (Pokhariya et al., 2007). This means that the brain damage situation will not continue to aggravate throughout the victims' lives.

In fact, according to a journal titled "Upper Extremity Interventions", it is stated that it is more difficult to regain mobility in the upper extremities than the lower extremities (Foley et al., 2013). Therefore, it will be a good idea to focus this project on the upper extremities. This flaw does not only weaken them physically but also mentally. The fact of not being able to carry out daily routines like the others may also cause them to possess lower self-esteem. Unhealthy mentalities will affect them negatively in the future.

2.2 Types of Cerebral Palsy

There are many types of cerebral palsy (CP) where each of them causes different type of movement disorders. One of the most common ones is spastic CP. Approximately 80% of people with CP are facing spastic CP. The victims will have stiff muscles and exaggerated muscle reflexes because the neural signal to the muscles are sent inaccurately through the damaged part of the brain (Lights and Nelson, 2005). When the victim is affected with spasticity where the muscles are constantly contracted due to damage inflicted on the *corticospinal tracts* and *corticobulbar tracts in the* brain that are in charge of voluntary movement, the quicker the limb is being moved, the stiffer it looks (Cerebral Palsy Alliance, no date). Their voluntary movements can be a little jerky.

The second kind of CP is dyskinetic CP. Dyskinetic refers to the involuntary muscle movements where basal ganglia in the brain are damaged (Cerebral Palsy Alliance, no date). Victims with this type of CP have difficulty controlling their body movements where involuntary and unusual movements in the arms and legs occur (Lights and Nelson, 2005). The involuntary muscle contraction may give rise to repetitive movements or unusual body postures. Other than dyskinetic CP, Light and Nelson (2015) stated that hypotonic CP causes overly relaxed muscles and diminished muscle tone. The arms and legs move very simply and appear to be limping. These victims may have trouble maintaining a proper body posture and face conflict standing and walking without assistance. They have a rag-doll appearance due to floppy muscles.

Besides, there is ataxic CP which is one of the least common types. The word "ataxic" means the lack of coordination and order. This is caused by the damage to the cerebellum which is the balance centre of the brain. This part of the brain fine-tunes the movement commands. Therefore, people with this disease have clumsy, imprecise, unstable and disorderly movements causing them to struggle in maintaining balance (Lights and Nelson, 2005). There is also a mixed CP where the victims develop more than one kind of CP. Usually in the mixed CP, people are exposed to the combination of spastic and dyskinetic CP.

There are many ways to differentiate the types of CP depending on the classification systems. There are classifications based on severity level, topographical distribution (describes body parts affected) and gross motor function (describes the limitation of ability and impairment) (*Types of cerebral palsy*, no date). Figure 2.2 below shows the classification of types of CP based on which parts of the body it affects.

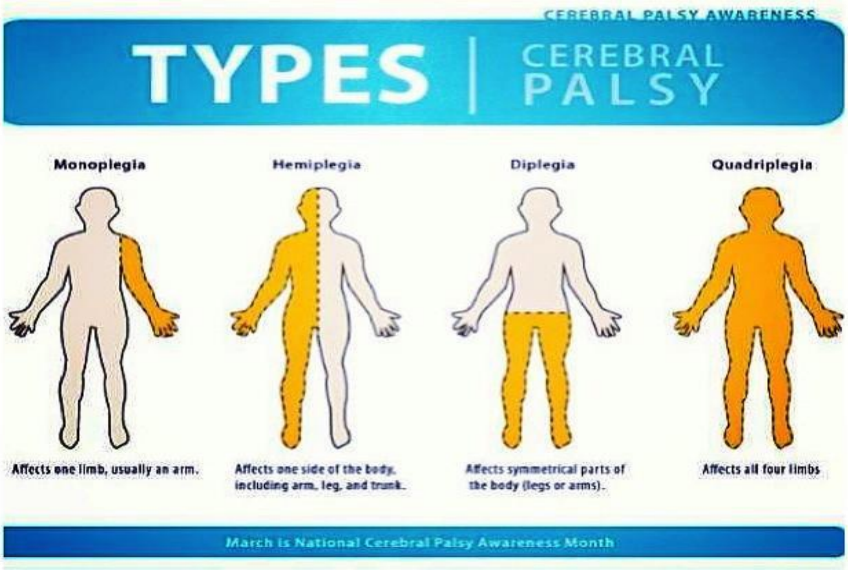


Figure 2.2: Types of Cerebral Palsy (Ability Helpline, 2015)

2.3 Causes of Cerebral Palsy

Most of the time, cerebral palsy (CP) happens to a baby when the fetus is still developing in the mother's womb during pregnancy. One of the risk factors which causes CP is a premature brain of a baby (*Premature birth*, no date). The premature brain may be caused by infections during mother's pregnancy. Premature birth or preterm birth refers to the birth of a less than 37 weeks' gestational age baby. Gestational age is a term used to describe how long a pregnancy is. A full term pregnancy should be around 37 to 42 weeks' gestational age. With premature birth, the baby's premature brain is at high risk of bleeding and when it is critical enough, it will consequently lead to CP (Whyte, 2009). Besides, a baby being born prematurely may develop critical respiratory distress due to poorly formed and immature lungs. This problematic lung will cause reduced oxygen delivered to the brain and possibly result in CP.

Besides, jaundice in infant may cause CP (Centers for Disease Control and Prevention, 2015). Jaundice is a medical condition caused by too much of bilirubin circulating in the blood where bilirubin is a compound produced during the breakdown of haemoglobin from red blood cells (Odle, 2005). Bilirubin has to be processed and filtered out by the liver. Jaundice happens to infants because it takes a few days for newborns to start filtering out bilirubin with their livers effectively. Rh incompatibility between the mother and infant can also cause CP (Cerebral Palsy Alliance, no date). The mother's body will produce antibodies that exterminate the fetus's blood cells. This may consequently lead to brain damage.

Other than that, CP may be caused by intracranial hemorrhage. This refers to the brain's internal bleeding of an unborn baby who is having a stroke. This condition will block the supply of blood to the brain tissue, which then causes it to be damaged.

2.4 Treatment Options

Cerebral palsy (CP) cannot be cured by any means but there are treatments that can definitely improve the child's capabilities (National Institute of Neurological Disorders and Stroke, 2016). A child has better opportunity to overcome further disabilities and learn new ways to achieve tasks that are of challenges to them. There are many sorts of treatment such as physical and occupational therapy, speech therapy, seizure control drug and many more.

For the occupational therapy, it aims to develop the child's ability to carry out daily activities by themselves. It focuses on the motor control improvement, upper body strength and stability. There are occupational therapists available to help the victims with CP. They help children to take part fully in school and social life, and help people to recover from injury to regain certain skills (Devine, 2016).

Speech therapy can also be applied to help children with CP. It helps these children to improve on their oral movements such as chewing, speaking and swallowing (McKee, 2016). Children with CP will then be able to communicate and express their ideas and thoughts, socialize with people and improve their literal skills. Some consume medications to treat CP. These medications can aid in improving muscle stiffness in the body by injection or medicines. Other than that, many undertake surgery to treat and correct muscles within the body.

Besides, a variety of helpful technologies such as electronic pointing devices, alternative keyboard, force-feedback joysticks and touch screens are available in the market to help children with CP (Pokhariya et al. 2007). Mechatronics devices can be created to help improve productivity of these children. In fact, Eckhouse, Leonard and Zhaung (1994) expressed that children with CP can become more productive or even independent with the help of devices that aid in enhancing mobility. For example, their mobility can be improved with the help of a powered wheel chair. In this project, hand cycle will be the device in helping these children to improve their upper extremities.

2.5 Normal Children's Anthropometric Data

It's harder to obtain anthropometric data of children with cerebral palsy because their growth depends a lot on the spasticity of the disease itself. Anthropometric data is the data obtained from the study of human related to the comparison between the measurements of human body parts such as shoulder to shoulder length and shoulder to wrist length (Vagts, 2010).

The spasticity of a children with cerebral palsy causes restrain in muscle growth, muscles stretching, muscle cells protein synthesis, joint and muscle deformities development (Center for Cerebral Palsy Spasticity, no date). Therefore, the rehabilitation device design's ergonomic will use the normal children's anthropometric data as benchmark or reference. Ergonomic here refers to the discipline or field related to the comprehension of interactions between humans and other systems where it applies data to optimise the overall performance of the system (Chartered Institute of Ergonomics & Human Factors, no date). Ergonomic helps to prevent stress or injury of the body.

Therefore, anthropometric data and ergonomic come in hand to hand. The anthropometric data of the children is used to design the ergonomic of the device. For example, the placement of cycling shaft has to be optimised depending on the children's arms' length. Table 2.1 below is the children's anthropometric data extracted from several references.

Table 2.1: Children's Anthropometric Data
(Deros, Yusuff, Darius, Mohamad, & Yusoff, 2013), (Bari, Salleh, Sulaiman, & Othman, 2015), (Ghazilla, Taha, Kamaruddin, & Hasanuddin, 2010), (Dawal et al. 2012)

Age	Gender	Anthropometry	Measurements (cm)
5	Both	Shoulder to shoulder	29.33
		Shoulder to wrist	34.99
6	Both	Shoulder to shoulder	30.85
		Shoulder to wrist	37.18
7-9	Male	Sitting shoulder height	37.19
		Sitting elbow height	12.05
		Shoulder breadth	26.30
		Maximum reach	51.78
7-9	Female	Sitting shoulder height	37.41
		Sitting elbow height	12.42
		Shoulder breadth	26.63
		Maximum reach	52.44
10-12	Male	Sitting shoulder height	44.22
		Sitting elbow height	16.08
		Shoulder breadth	30.39
		Maximum reach	59.50
10-12	Female	Sitting shoulder height	44.87
		Sitting elbow height	17.05
		Shoulder breadth	30.89
		Maximum reach	59.48
High School	Male	Arm reach forward	75.65
		Shoulder to elbow	35.25
		Shoulder breadth	39.28
		Elbow span	86.09

		Span	163.11
High School	Female	Arm reach forward Shoulder to elbow Shoulder breadth Elbow span Span	77.04 33.20 36.48 81.26 155.02

2.6 Rehabilitation Devices Available

Literature review has been done on more than 10 rehabilitation device journals to analyse the devices, how the devices help the people, the devices' features that attract people and also how certain movements are able to help training certain body parts.

2.6.1 Active Video Game Consoles (AVGC)

In a journal by a group of authors, they have implemented AVGC for the rehabilitation of cerebral palsy (Ballaz et al. 2011). Their AVGC Nintendo Wii offers a virtual environment platform for individuals to play numerous kinds of sport games. Each game helps to improve different characteristics of the children. For example, snowboarding and skiing helps to cultivate large center of pressure displacement whereas jogging and biking can induce energy expenditure. The jogging game is highly efficient in increasing energy expenditure and the other games are also helpful in different ways. Ballaz and colleagues (2011) have concluded that the AVGC is a hopeful and promising approach to help children with cerebral palsy in improving aerobic capacity and motor functions. Depending on the type of games, the AVGC is able to train different part of the body muscles.

2.6.2 Hand Cycle

Besides, a clinical trial has been done on 22 victims with tetraplegia where they undergo 24 training sessions on the hand cycle as shown in Figure 2.3 below within 8-12 weeks consistently (Valent et al., 2009). Tetraplegia is one of the effects of cerebral palsy where all the four limbs are affected. According to this journal, the participants have responded that they felt stronger after the training which proves the improvement in muscle tolerance in exercising. Subsided muscle fatigue is a positive effect resulted from the improved muscle tolerance. Valent and collaborator (2009) have concluded that the hand cycle is a good match of assistance to help improving fitness level. It has shown satisfying outcome. However, the hand cycle specifications such as power output and gear ratio are significant in maintaining this positive result. This journal has shown the effectiveness of hand cycle in enhancing the muscle strength of individuals with weak limbs.

Figure 2.3: Hand Cycle (Valent et al., 2009)

2.6.3 Robotic Rehabilitation

Other than the hand cycle, there are contributors who have also implemented robotic rehabilitation in dealing with CP. The robot as shown in Figure 2.4 is driven by servomotor with a digital signal processor controller (Wu et al. 2010). This robot consists of two major modules where the first one provides safe stretching movement driven by intelligent-control algorithm and the second one trains the voluntary movement of the individuals. The torque limit of the robot can be altered according to the patients' needs. Besides, Wu and colleagues (2010) have also incorporated computer game playing as an interactive feedback system to induce active involvement of the individuals in their training. Figure 2.4 below also shows the game interface linked to the robot where the patients can indulge themselves in the game while undergoing the rehabilitation training. The main objective of their training is to exercise the patients' ankle joint. For the game to work, the participant has to push or lift up the robot footplate in order to move the cursor within the game. As assistance, the robot will help to give them a boost if the participants are unable to maneuver through the active range of motion. With a sample size of 12 patients, they have concluded with a positive result that the 6 week training period has shown satisfying improvement in the participants' ankles. This experiment has shown the advantages of robotic rehabilitation along with an interactive feedback.

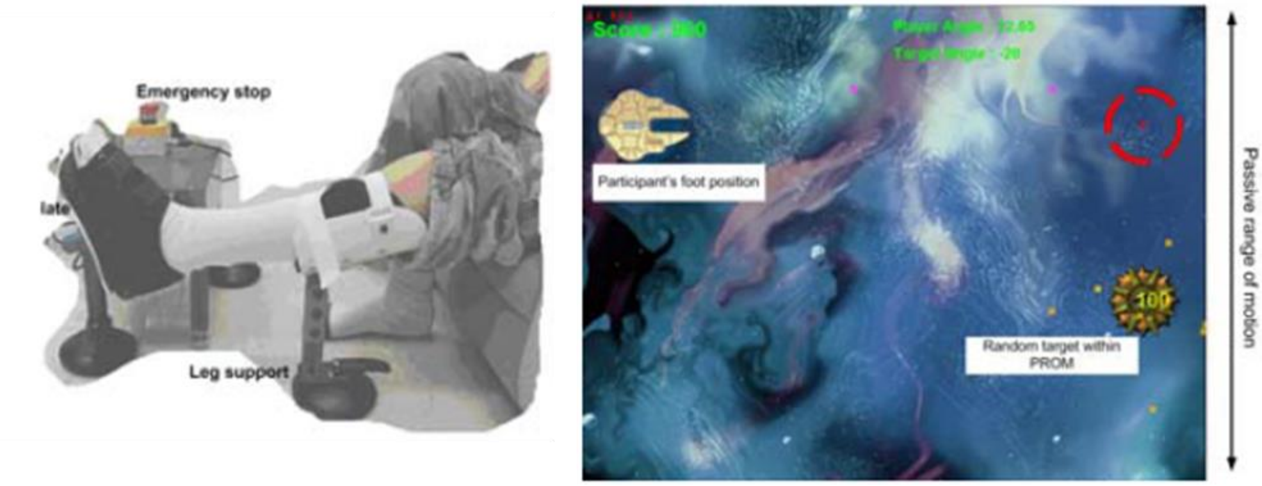


Figure 2.4: Robotic Device and Gaming interface (Wu et al. 2010)

2.6.4 Home-based and Tele-assisted Robotic Rehabilitation

This tele-rehabilitation device has a similar design as the previous robotic rehabilitation as shown in Figure 2.5 below. As for the difference, this device has a biofeedback where it is able to send feedback to the clinician or physiotherapist for data analysis. At the same time, the patient and clinician can communicate through webcams while the data are being sent (Chen et al. 2014). This way, the clinician or therapist can evaluate the patients more often without having to be present physically with the patient. After the evaluation, the user can download the updated training plan uploaded by the therapist to the central rehabilitation center via internet. More than that, Figure 2.5 shows that there is also a game playing interface to create a virtual environment for the user. According to Chen and colleagues (2014), this robot-assisted therapy session was accepted with open arms by the children with cerebral palsy (CP). For the clinical outcome, this device has managed to reduce spasticity which is very significant to individuals with CP. Ankle strength was observed to be increased drastically. There are also improvements in the hip and foot. This tele-rehabilitation device is effective in helping children with CP (Chen et al. 2014). Due to the flexibility in accessing therapy virtually, biofeedback and attractive game interface, tele-rehabilitation device may be very useful in assisting children with CP.

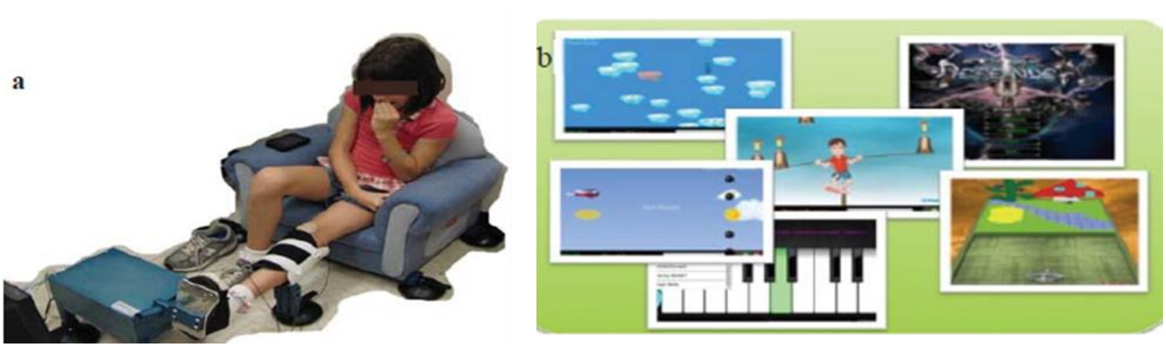


Figure 2.5: Robotic Device and Gaming Interface (Chen et al. 2014)

2.6.5 Computer-aided Music Therapy

Correa and colleagues (2009) have taken a more unique approach of rehabilitation for cerebral palsy, a computer-assisted music therapy. Music therapy is able to cultivate positive physical, mental and social qualities in individuals (Correa et al. 2009). They have invented a software to provide and adjust music access to individuals with upper limb complication. In addition, there will be real objects in collaboration with the software for virtual simulation of music instruments. A certain support adapter may need to be used if the participants have difficulties using the instruments. The music therapy with colour cards containing musical symbols can be seen in Figure 2.6. The cards are placed in the sequence depending on the kind of motor exercises desired for the upper limb. So, the participants will press on the music symbol printed on the card to produce the sound. Then, the symbols on the cards are detected by the software through image processing after being captured by the webcam and are related to the musical instruments' pitch and sound depending on the instrument chosen in the system.

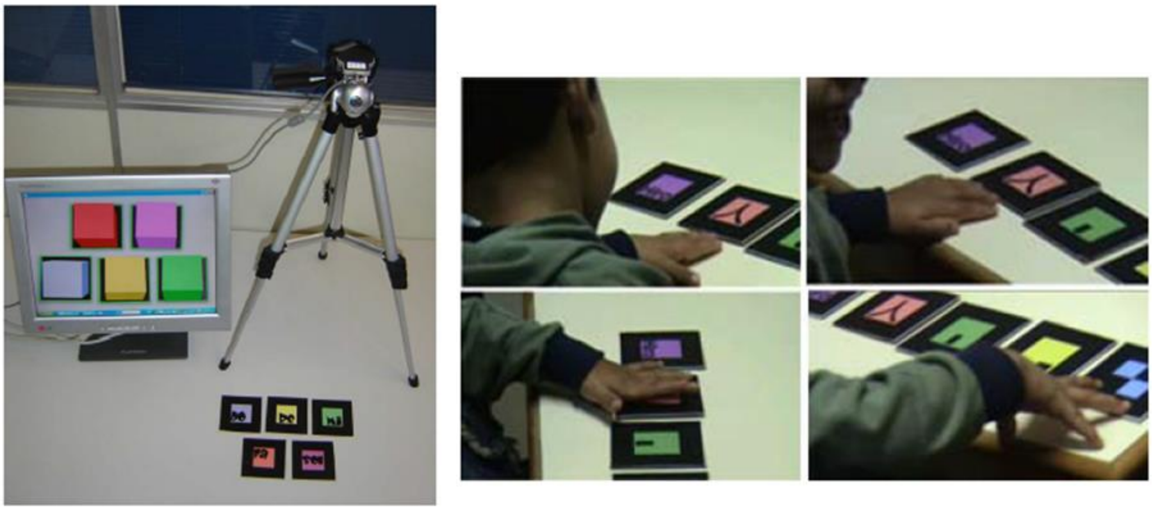


Figure 2.6: Music Therapy with Colour cards and Camera (Correa et al. 2009)

Due to the flexibility in arranging the cards' order, it is possible to come up with many kinds of motor movement exercises in accordance to the patients' motor weakness or limitations. It is also able to improve the wrist movement, visual perception and other. Correa and colleagues (2009) have concluded that this research is able to help individuals in cognitive learning, psychological and motor functions. Despite the unique qualities of this system, this system which consists of only the software, cards and camera has shown its portability. Users will be able to utilize at home and other places.

2.6.6 Virtual Game Device

Instead of focusing on the legs themselves, Barton and friends (2013) emphasized their research on the control of body trunk and pelvic movement. They think that well control of these two body parts is essential for properly regulated leg movements in order to carry out daily activities. They believe that trunk and pelvic play a more significant role in allowing the individuals with cerebral palsy to accomplish daily actions. In order for the game to work as shown in Figure 2.7 below, the participant will have to rotate his pelvic left or right in order for the dragon in the game interface to move left or right. After a six weeks training, it was concluded that the development of improved coupling between the trunk and pelvis was seen (Barton et al. 2013).

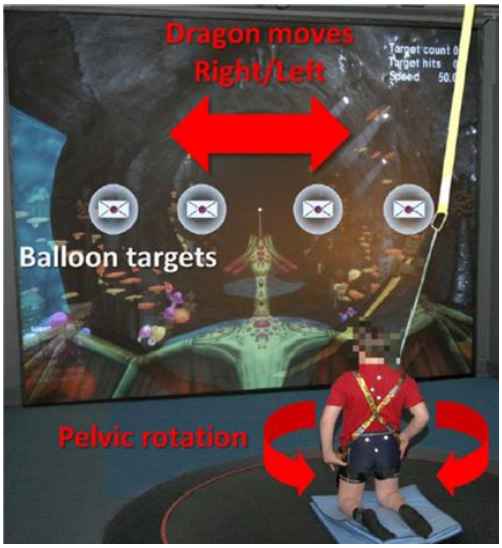


Figure 2.7: Virtual Game Playing Method (Barton et al. 2013)

2.6.7 The Biodex Cyclocentric Semi-Recumbent Cycle

Cycling is a frequently used rehabilitation apparatus to enhance strength and improve cardiorespiratory fitness, and therefore is now elected as a proper exercise to boost up the fitness level of individuals diagnosed with cerebral palsy (Fowler et al. 2007). As Figure 2.8 illustrates, this stationary bicycle permits one to cycle with variable resistance depending on the strength of the lower limbs. This bicycle has two mechanisms namely standard and cyclocentric cycling. For standard cycling, the seat of the bicycle will be fixed in place. Then, there will be two cycling modes - the first one will be an aerobic exercise where power is constant whereas the second one will be the strengthening exercise. As for cyclocentric cycling, the seat is allowed to slide backward and forward linearly along the base track of the bicycle. Up to ten cords with different tension can be fixed to the base of the seat in order to provide pulling force on the seat. Therefore, when the user is cycling, he will have to extend his lower limb to resist the pulling force on the seat which then leads to the flexing of his lower extremities. This shows the positive effect of cycling motion on the lower extremities.

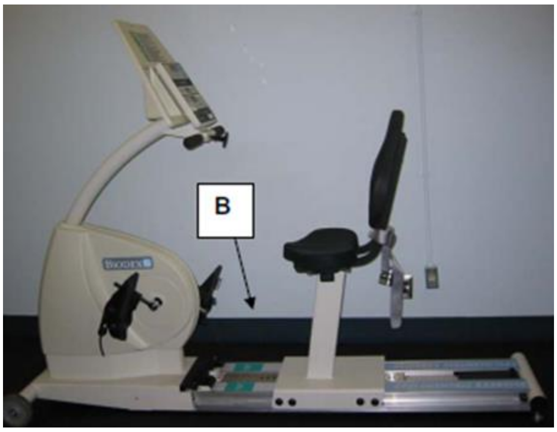


Figure 2.8: Stationary Bicycle (Fowler et al. 2007)

2.6.8 Upper Extremity Assistive Gadget

An upper-limb device was presented in a journal by Gu and colleagues (2015) to help the elderly. The device has a hydraulic cylinder, strain gauge, sensors and other components. They aim to reduce the weight and complexity of their device by reducing the amount of sensors and actuators. Their results have indicated that their device managed to support the person's upper limb in a horizontal and vertical movement (Gu et al., 2015). With a lighter and less complex system, user and also the therapist will be able to use it more easily without the need for the presence of a technician.

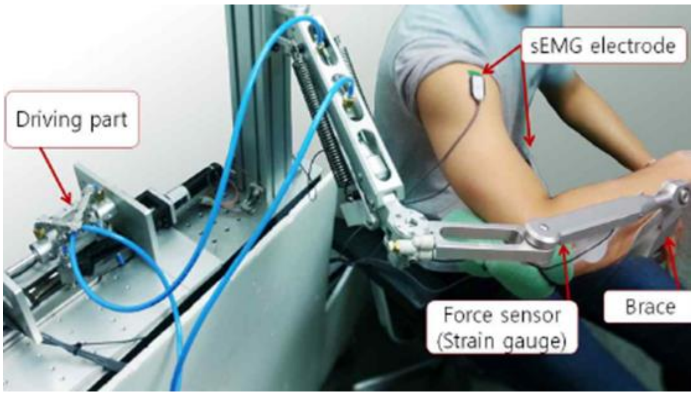


Figure 2.9: Upper Limb Aiding Device (Gu et al. 2015)

2.6.9 Liberi

Hernandez and colleagues (2013) stated in their journal that the children with cerebral palsy (CP) want to play a more fast-paced and action-oriented games. In their opinions, exergames which are video games that require us to carry out aggressive physical activities are the exercises that the children with CP need to improve their motor function. The device named Liberi as shown in Figure 2.10 can be linked to six different mini games. The user will have to cycle the pedals to move the avatars in the game interface. This has proven the possibility of children with CP playing action-oriented exergames. One of the games interface can be seen in Figure 2.10. With an interactive game, the device is able to attract the children and in turn helps to improve their motor function.

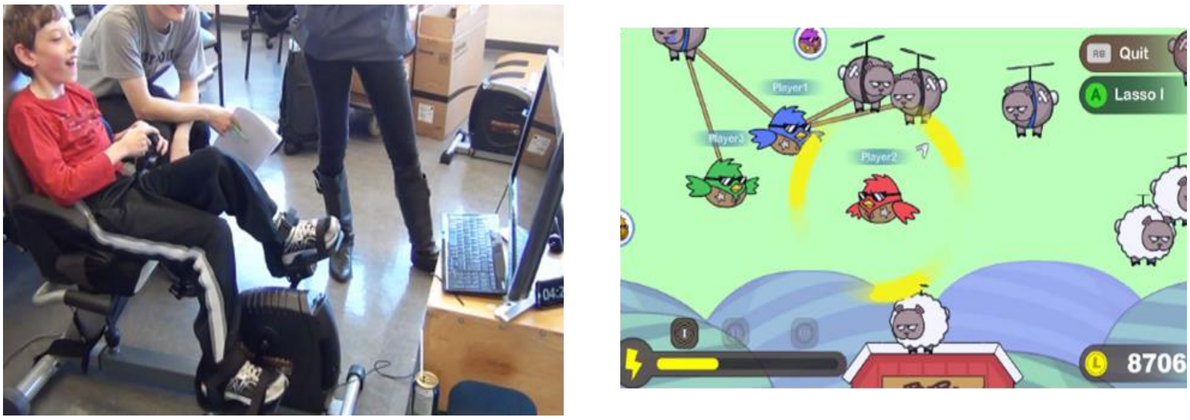


Figure 2.10: Liberi Device and Gaming Interface (Hernandez et al. 2013)

2.6.10 The Haptic Master

Qiu and colleagues (2009) have implemented a robot-assisted virtual rehabilitation (RAVR) system to help children with cerebral palsy. The virtual reality (VR) method of therapy has the capacity to produce an interactive and motivating environment which acts as an incentive for the children to utilize the system. Especially for children, VR has the ability to attract them to carry out the training with the rehabilitation device. A study done on the use of robots as upper extremity rehabilitation device to help children with cerebral palsy shows that it has led to an improvement in the level of impairment in the children (Qiu et al. 2009).

Figure 2.11 shows the Haptic Master device which is a 6 degree of freedom robot consisting of a ring-like object. User will exert force on the ring along with different motion and velocity in order to generate movement in the VR environment. The user will also wear a goggle for the VR simulation interface such as the interfaces shown in Figure 2.11. There are several games namely cup reach, falling objects and bubble explosion. According to this journal, after training for 9 hours in the span of 3 weeks, the subjects of cerebral palsy have shown a substantial amount of improvement in the upper extremity elevation including the shoulder and elbow, efficiency of movement, speed, strength, coordination and several other upper extremities related movements. This research has shown the importance of robotic rehabilitation along with an interactive feedback to charm the children and to make them utilize the device more willingly.

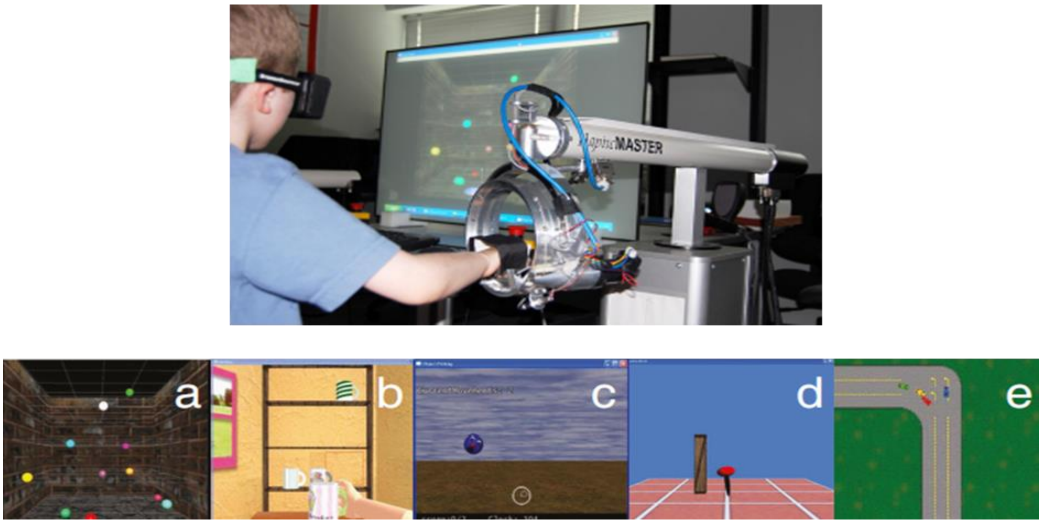


Figure 2.11: Haptic Master Device and Gaming Interface (Qiu et al. 2009)

2.6.11 Multi-touch Display with Accelerometer Feedback

Dunne and colleagues (2010) have designed a multi-touch display system to help children with cerebral palsy in upper extremity rehabilitation. Therapy session for the children with cerebral palsy is able to enhance their muscle strength and endurance, and overall joints' motion range (Dunne et al. 2010). This system as shown in Figure 2.12 below consists of a multi-touch display, real objects as inputs and a wearable accelerometer to detect rotation and movement for the game playing. Besides, this system has a feedback component where when the patient wearing a custom-made vest leans forward in order to compensate for the lack in range of movement, an indicator will be shown on the screen to display their body position relative to the threshold. Therefore, the user can apply self-correction when the threshold is being met. This system utilizes tangible objects of varying sizes as input devices for three types of games. This system is able to help in boosting the patients' strength and the interactive platform acts as an incentive to motivate the children. (Dunne et al. 2010)

Figure 2.12: Multitouch Display Device (Dunne et al. 2010)

2.6.12 Music Glove

Music Glove is an interactive rehabilitation device that has been invented to help elderly with stroke to regain strength in using their hands. For this device to work, the patient wears a custom made glove with sensors at the tip of each finger to detect their hands' movements. Then, he touches the tip of the fingers as shown in Figure 2.13 in order to simulate the buttons in the gaming interface. This device has helped a 2 years stroke patient to regain mobility in his hands (Kwan, 2015). It is hard for patients to continue with therapy after leaving hospital. This device has debuted with an interesting concept where patients will not feel reluctant to undergo therapy. In fact, they will feel like they are playing a game instead of carrying out therapy session.

Figure 2.13: Music Glove in Action (Kwan, 2015)

2.6.13 Summary of Rehabilitation Device

Table 2.2 below is the summary of all the rehabilitation devices.

Table 2.2: Summary of Rehabilitation Devices
(Ballaz et al. 2011), (Valent et al., 2009), (Wu et al. 2010), (Chen et al. 2014), (Correa et al. 2009), (Barton et al. 2013), (Fowler et al. 2007), (Gu et al. 2015), (Hernandez et al. 2013), (Qiu et al. 2009), (Dunne et al. 2010), (Kwan, 2015)

No.	Device	Attributes	Contribution
1	Active Video Game Consoles	- has virtual games environment	- increase energy expenditure

	(AVGC)	platform - has numerous games interfaces	- improve aerobic capacity - improve motor functions
2	Hand Cycle	- like a tricycle - requires user to undergo cycling movement	- improves muscle tolerance - subsides muscle fatigue - enhances muscle strength - improves fitness level
3	Robotic Rehabilitation	- provides safe stretching movement - train voluntary movement - flexible robot’s torque limit alteration - linked computer game playing as interactive feedback	- improves ankles joints
4	Home-based Tele-assisted Robotic Rehabilitation	- has biofeedback - has game playing interface	- able to attract children - reduce spasticity - enhance ankle strength - improve hip and foot
5	Computer-aided Music Therapy	- has software to provide music access - has real objects as input to create virtual environment - flexible card placing depending on the upper limbs exercises desired	- improve wrist movement - improve visual perception - help cognitive learning - improve motor functions
6	Virtual Game Device	- emphasizes body trunk and pelvic movement	- improves pelvis and trunk coupling

		- has game interface	
7	The Biodex Cyclocentric Semi-Recumbent Cycle	- has variable resistance depending on lower limbs strength	- improves strength - improves cardiorespiratory fitness
8	Upper Extremity Assistive Gadget	- for the elderly - light and less complex	- support upper limbs - users can utilize It easier
9	The Haptic Master	- utilizes a 6 degree of freedom robot - has virtual reality interface	- improves upper extremity elevation - improves efficiency of movement - improves speed - improves strength - improves coordination
10	Multi-touch Display with Accelerometer Feedback	- has an interactive display - uses real objects as inputs - has feedback system to prevent incorrect body position	- enhance muscle strength - enhance muscle endurance - improves overall joints motion range
11	Liberi	- promotes more vigorous action-based games - has game interface as interactive feedback	- improves motor function - able to attract children to play use the device
12	Music Glove	- play game with a custom made glove with sensors at the tips of fingers - has gaming interface	- improves hands' mobility - improves arms' mobility - improves fingers' mobility

CHAPTER 3

Conceptual Designs

3.1 Interactive Box Controller (IBC)

3.1.1 Mechanical Design

This is the 1st conceptual design for upper extremity rehabilitation device called IBC. IBC will be connected to a game interface. For the product description, it looks similar to a treasure box with the dimension of approximately 30x15x10 cm as shown in Figure 3.1. Since this device is for the children, it doesn't have to be too large in size. The body of this device can be fabricated easily with wood.

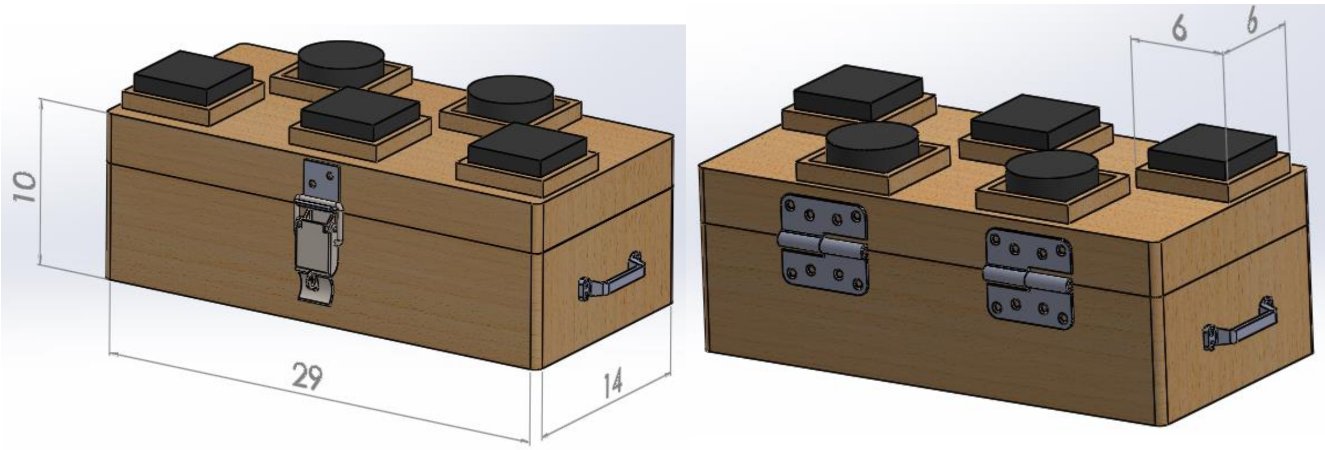


Figure 3.1: Interactive Box Controller (IBC)

There are two hinges installed on the back portion of the device to combine the upper and lower part of the box. Then, the inner space can act as a storage site for the electronic boards and wirings. The safety lock on the front portion of the device prevents other people from accessing the internal components freely and cause system fault. Besides, the box allows easy maintenance of the electronics components and wirings. The handles on both sides of the device allow us to maneuver the device more conveniently.

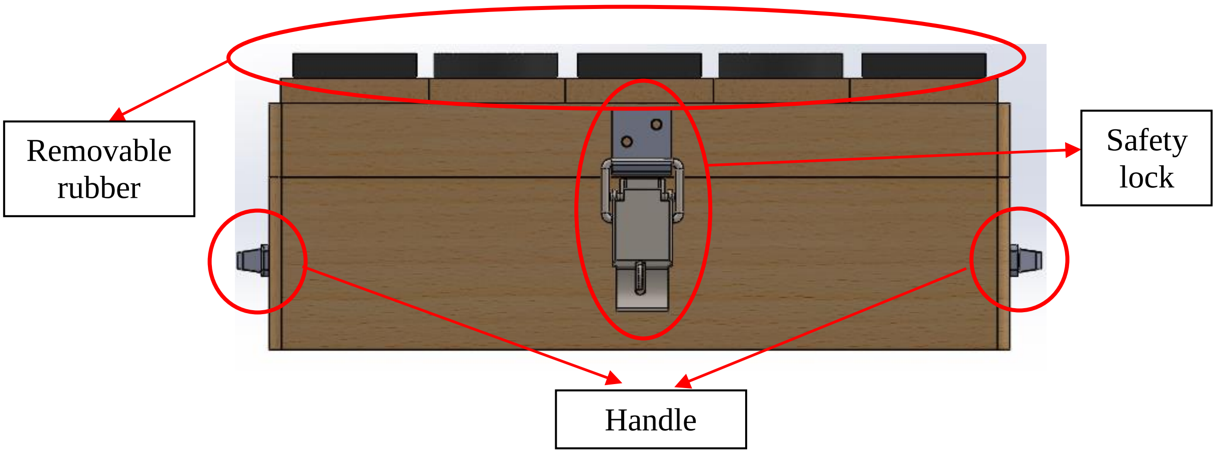


Figure 3.2: Front View

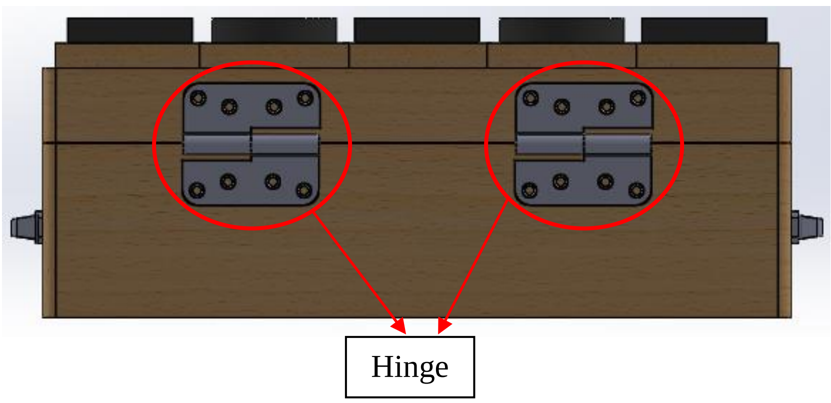


Figure 3.3: Back View

The game interface will serve as an attraction and incentive for the children to utilize this device. The removable rubbers in Figure 3.4 act input buttons for the game interface. For example, this device can be connected to the “Guitar Hero” game interface in Figure 3.4 where the buttons on the device act as a controller for this game. Therefore, a variety of upper limbs motor movement exercises can be produced depending on the game interface design. We can simulate different difficulties of motor movement exercises depending on the patients’ upper limbs’ capabilities. This can help to improve the patients’ movement coordination and reflexes.

Figure 3.4: Gaming Interface (for illustration) (Klepek, 2015) and “Container”

Beneath the rubber buttons will be tact switches which are linked to the electronic board to control the inputs for the game interface. The electronics components will be kept within the box as shown in Figure 3.5. So, we indirectly press the tact switches by exerting force on the rubber buttons.

Other than that, the rubber buttons have several available modifications. These rubber buttons can be placed and removed from the wood “container” as illustrated in Figure 3.4. The purpose of this removable buttons is so that we can replace the rubbers with different shapes, colors or objects for beautification in order to attract the users. Besides decoration, the rubber buttons’ hardness can be changed depending on the capability and progress of the users. If the button is changed to a softer rubber or object, more force will have to be exerted on it to be able to press the tact switch. In order to exert more force, the users will need to use more upper limb power which then leads to the strengthening of the upper limbs muscles.

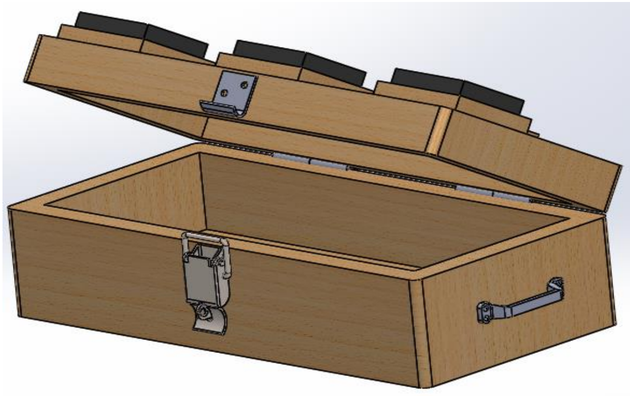


Figure 3.5: IBC with opened cover

3.1.2 Electronics and Software Design

The electronics design for this device will be quite simple where 5 tact switches are connected to a Raspberry Pi 3 board. It will be more complicated on the programming side. With the available Bluetooth module on Raspberry Pi 3, this will be the communication method between the device and the game interface on an Android device. Android device will also have a graphical user interface to display certain data such as the number of times each button is pressed and the length of training. This data is useful for therapist to analyze the patients' training progress and results.

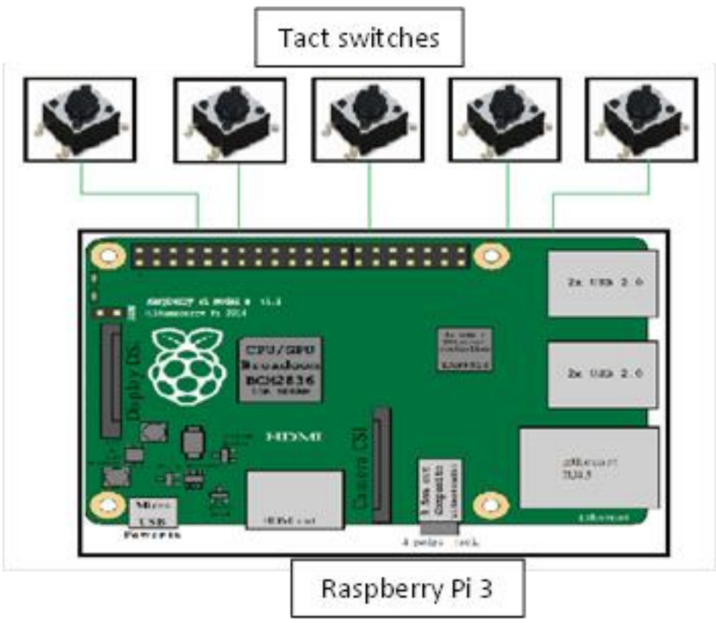


Figure 3.6: Electronics Components Connection

The latest Raspberry Pi 3 model also has a Wi-Fi module which can be used to transfer and store the training data to cloud storage. This data will be accessible to the therapist virtually where they can analyze the data and come up with an improved training plan for the patient. The training plan can be downloaded from the cloud storage. This allows a virtual communication between the therapist and the patient where they do not have to be present to each other physically. Data and training plan can be sent and received online through cloud storage.

3.1.3 Program Flowchart

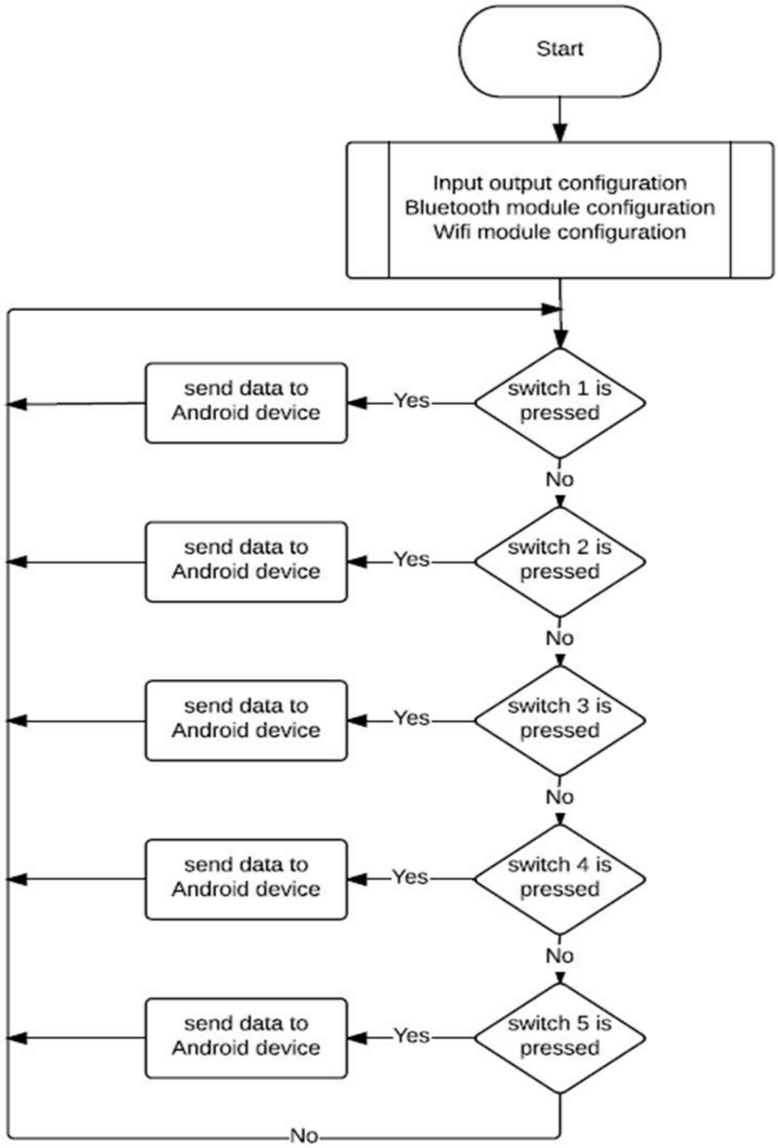


Figure 3.7: Flowchart 1

3.2 Tele-Interactive Hand Cycle (TIHC)

3.2.1 Mechanical Design

For the second conceptual design, it is a tele-interactive hand cycle (TIHC) where user can utilize this device to play game on an Android device. The game interface serves the purpose of attracting the children to use this device. A few of the many characteristics which are incorporated into this mechanical design are light, portable and transformable. As illustrated in Figure 3.8, the TIHC has a dimension of approximately 30x28x23 cm to be suited for the children. The main body of the hand cycle is made mostly of aluminium bars, Perspex and metal plate.

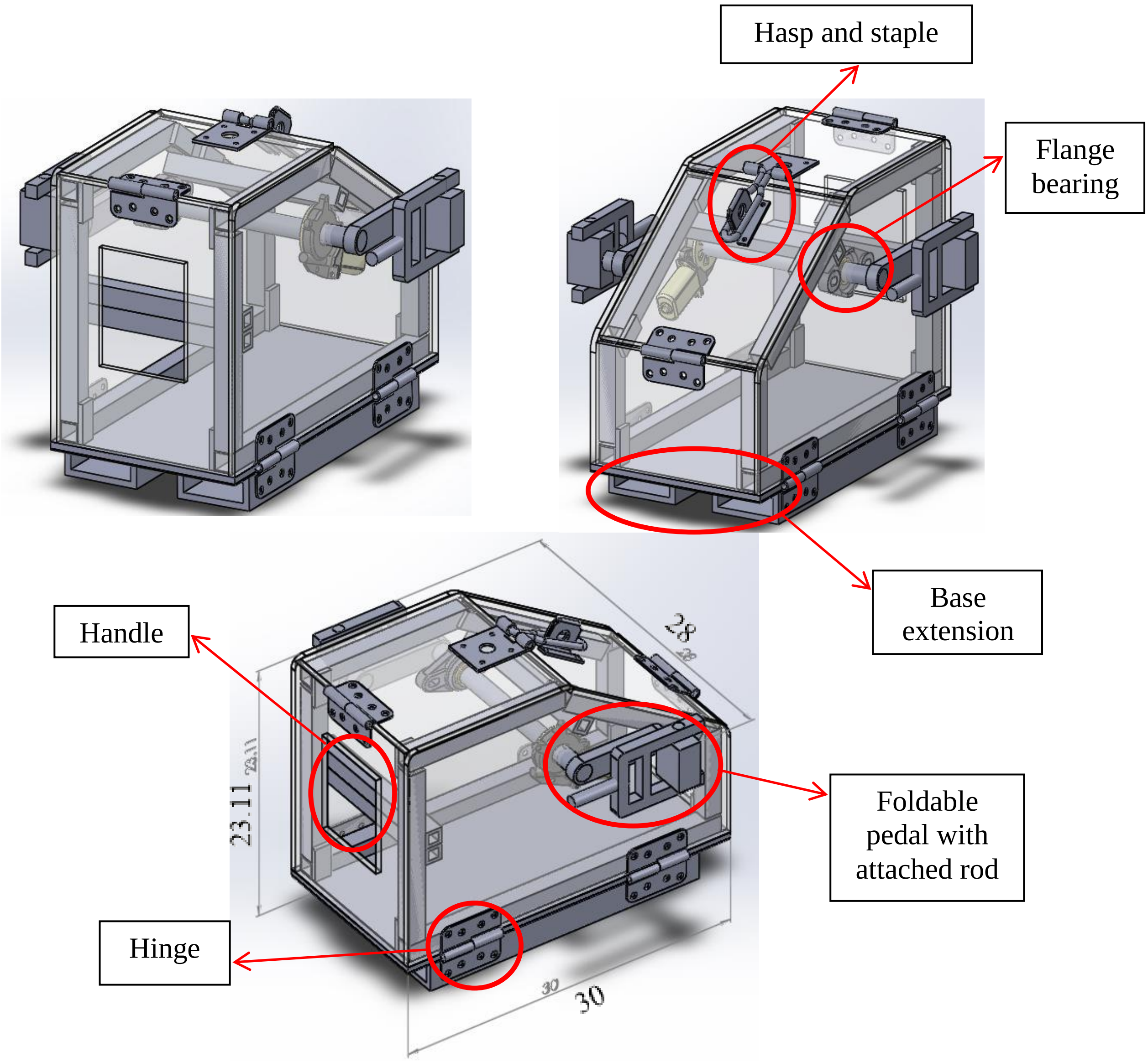


Figure 3.8: TIHC

For portability, there is a handle as shown in Figure 3.8 for convenience in carrying this hand cycle around. This TIHC's body is made mostly of Perspex which makes it lighter so it is easier to be carried around.

As for transformability, the base extension and pedals are foldable. The device in Figure 3.9 is the TIHC in operation mode with extended pedals and base. The purpose of the extended base is so that the device will not be tilted sideways when the user is cycling the pedals. The pedals are chosen to be foldable in order to reduce the dimension of the device. The foldable pedals can be purchased and an external cylinder rod can be attached to the pedal to act as a handle for cycling. Smaller dimension will help to enhance the portability of the device.

The power window functions to run the pedals in varying speed when the users require more energy to cycle. It also helps to keep the shaft in place along with the help of a flange bearing.

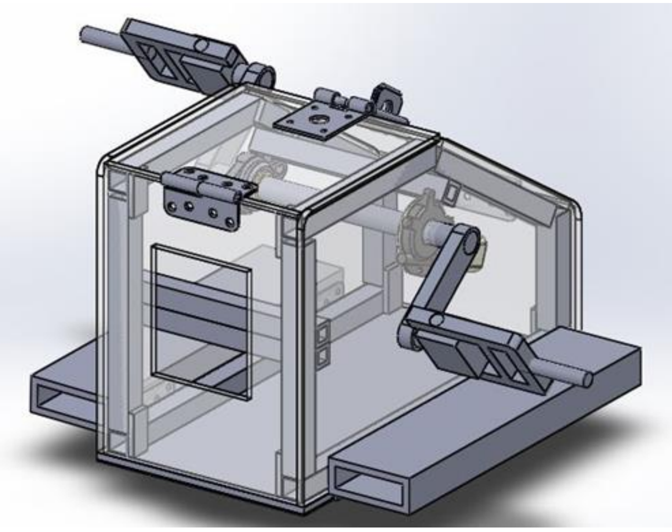


Figure 3.9: TIHC in Operation Mode

For easy maintenance, the top portion of the device is made to be openable as depicted in Figure 3.9 so the internal components such as electronic components can be accessed, maintained or fixed. This openable covers can also be locked so the internal components cannot be accessed by anyone to prevent accidental damage to the components.

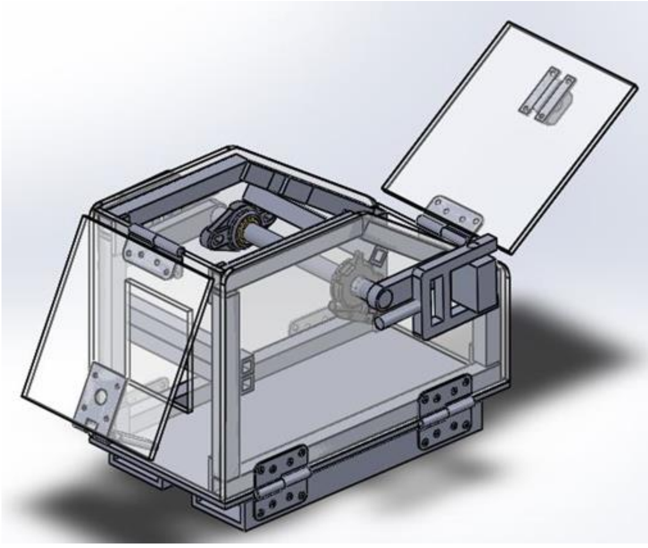


Figure 3.10: TIHC with Opened Cover

3.2.2 Electronics and Software Design

The electronics design for this device will also be simple where only a power window and two switches are connected to the Raspberry Pi 3 board. The speed sensor will detect the rotational speed of the cycling pedals. Therefore, when the cycling speed is too slow, the power window acting as an actuator will be activated to provide help to the user in cycling. The tact switches will be placed one on each side of the rod handle connected to the pedal. These switches act as input devices for the game interface in an Android device.

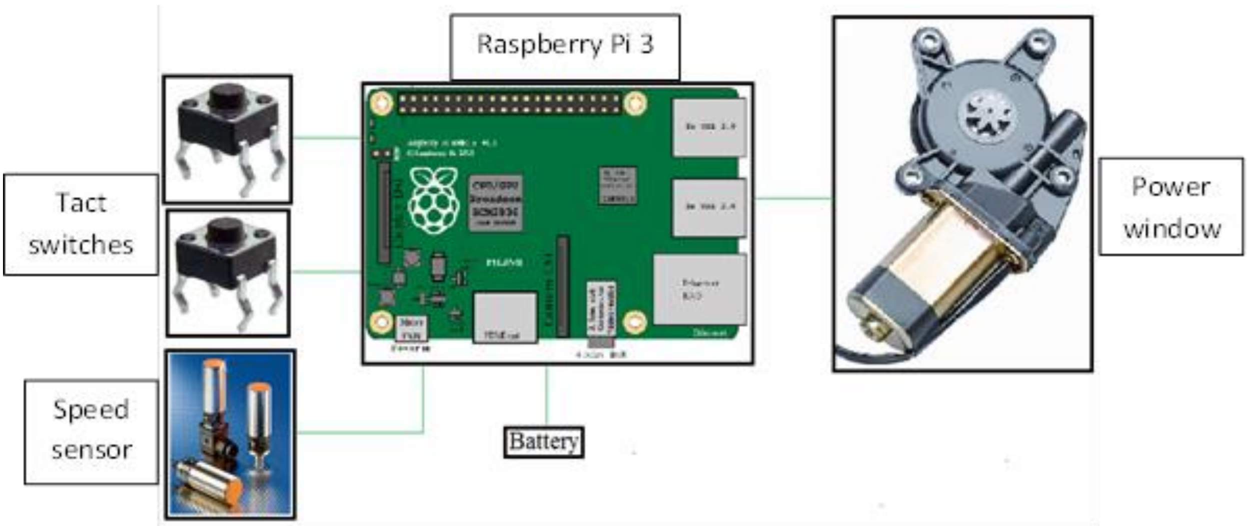


Figure 3.11: Electronics Components Connection

With the built-in Bluetooth module in Raspberry Pi 3, data can be sent from the board to the android device for gaming purpose and also data collection. These data can be displayed on the graphical user interface in android device for monitoring purpose. Data such as the cycling speed and distance cycled are important for therapist to analyze the patients’ progress and condition. For remote monitoring, the data collected by the board can be sent to the cloud storage through the Wi-Fi module. Then, therapist can access these data online and make new training plan based on them. Remote monitoring may deem the training more efficient as the therapist can monitor their progress more frequently and consistently without requiring physical presence.

3.2.3 Program Flowchart

Rotational speed refers to the cycling speed whereas motor speed refers to the speed of power window.

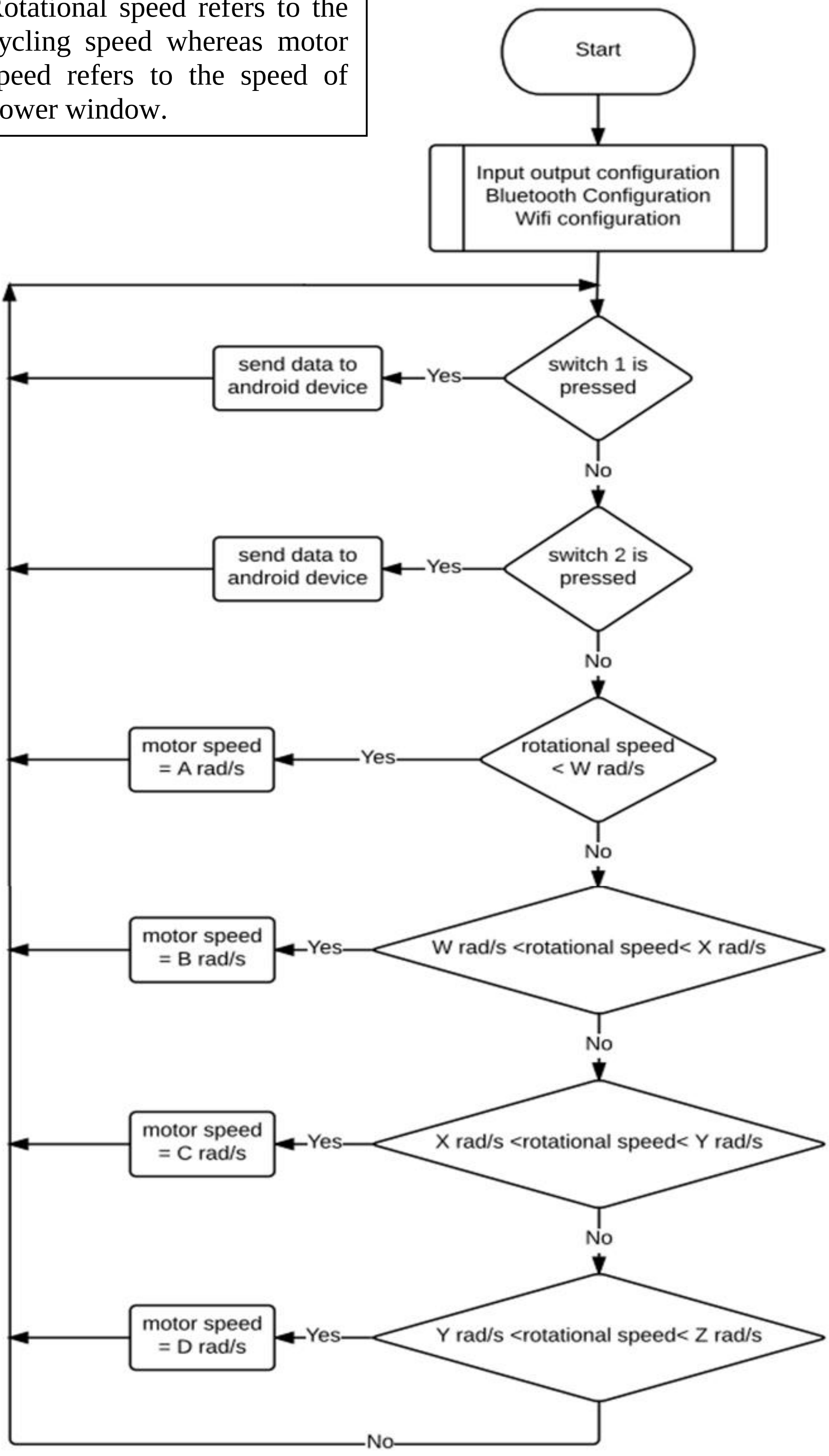


Figure 3.12: Flowchart 2

CHAPTER 4

Time Plan

Figure 4.1: Gantt Chart

Table 4.1: Tasks to be Completed

Tasks to be completed	
No.	Tasks
1	Mechanical and electronic components purchase
2	Mechanical device fabrication
3	Electronics design implementation
4	Graphical user interface programming
5	Full system integration
6	System test

CHAPTER 5

Results and Discussion

5.1 Introduction

Based on the two conceptual designs IBC and TIHC made, the second design which is the TIHC is being selected to be constructed. The reasons are as stated below.

Both the IBC and TIHC can help to train the upper limbs with their own designated movement training. However, IBC focuses more on the hand pressing strength and less on the whole limbs' movement. On the other hand, the TIHC is able to provide training for the whole two limbs due to the cycling. Gripping strength can also be cultivated from the user gripping on both the handles of the TIHC. In contrast, for IBC, both of the limbs cannot be trained simultaneously like the TIHC because only one hand is used each time to pressed the button. It allows the training of only one hand at a time.

Certain amendments were done to the initial design for improvement and also to solve some mechanical design problems. The final results are as shown in the following sections.

5.2 Final Mechanical Design (SolidWorks)

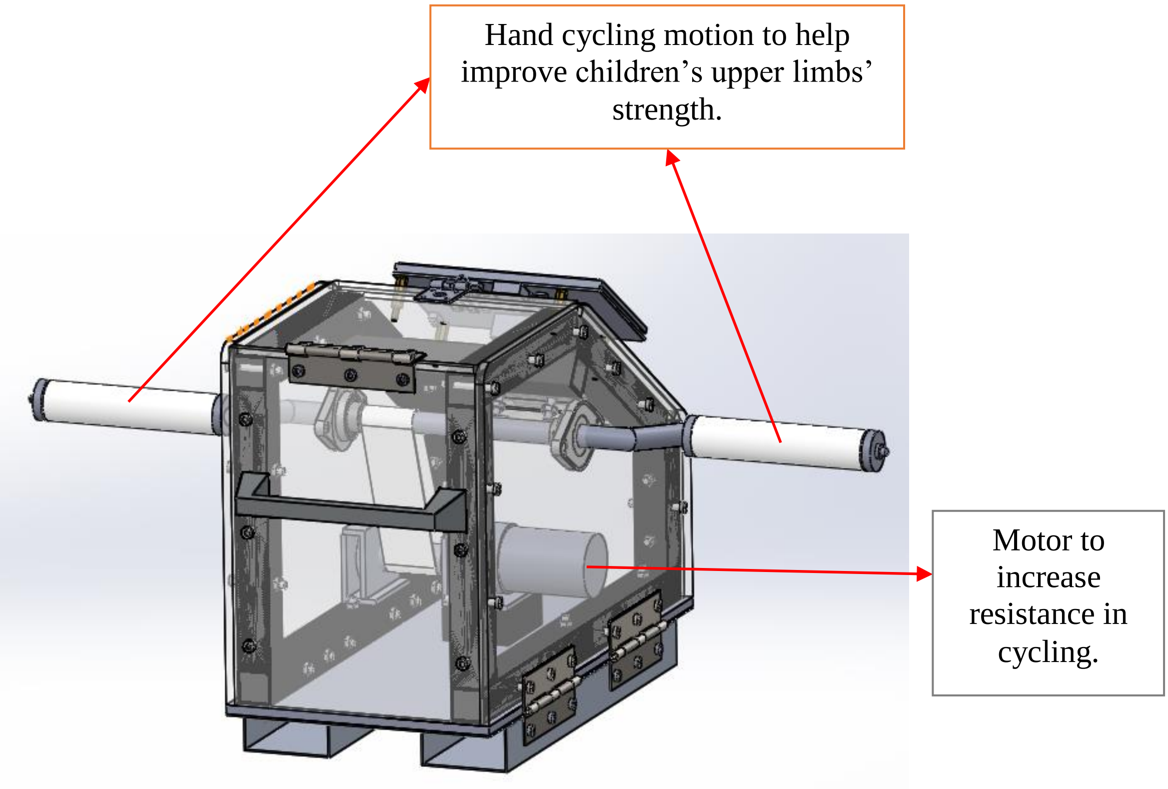


Figure 5.1: Final Design

Based on the children's anthropometric data stated in literature review, the cycling shaft has been mounted at around 16 cm from the back. Based on Table 2.1, the shoulder to wrist length is 34.99 cm for a 5 years old child and 37.18 cm for a 6 years old child. As for a male child of 7 to 9 years old, the maximum reach is 51.78 cm and 52.44 cm for a female child of the same age. Then, the maximum reach for a 10 to 12 years old male and female child is 59.5 cm and 59.48 cm respectively. Lastly, the reach for a high school male and female students are 75.65 cm and 77.04 cm respectively.

Therefore, the cycling shaft is placed at approximately 16cm from the back so that the youngest children of the target market will be able to reach the handles. Although this device is meant for children, the design is made in such a way that teenagers will still be able to benefit from its functions. Based on the shoulder breadth from the same table, the width of the device is set at around 15 cm.

With the help of the anthropometric data of the children, the ergonomic of the TIHC can be designed to avoid stress or injury of the children's upper limbs.

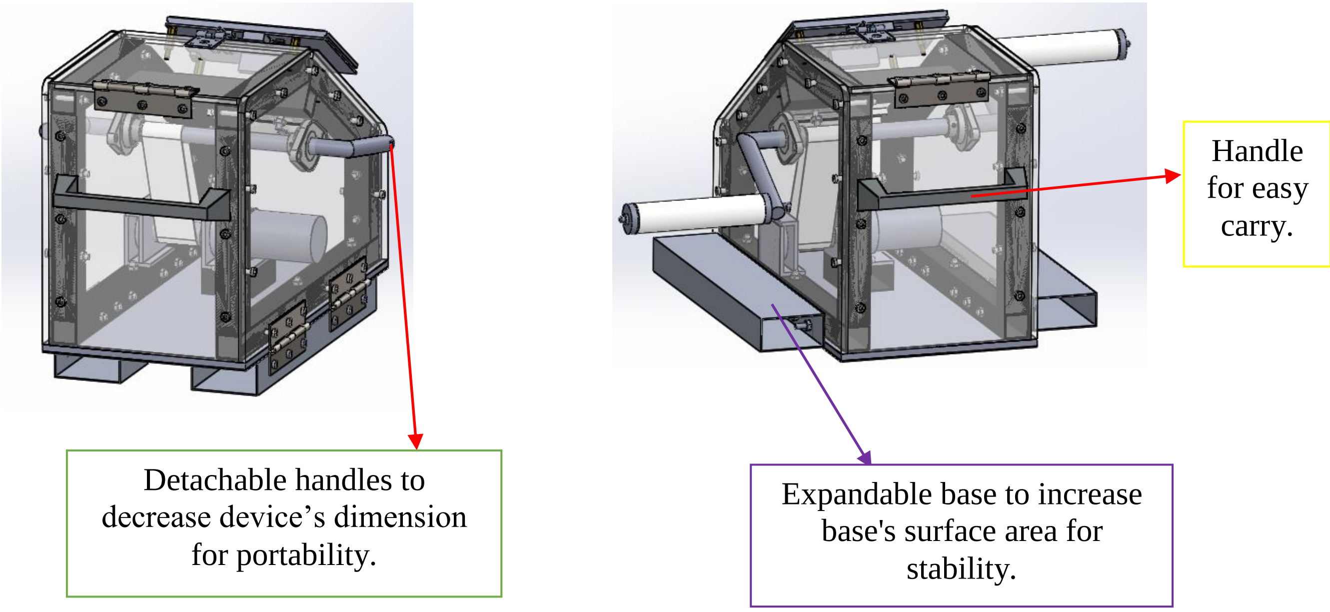


Figure 5.2: Final Design

The openable upper lids as shown in Figure 5.3 are to enable easy maintenance of the electronic components in the device.

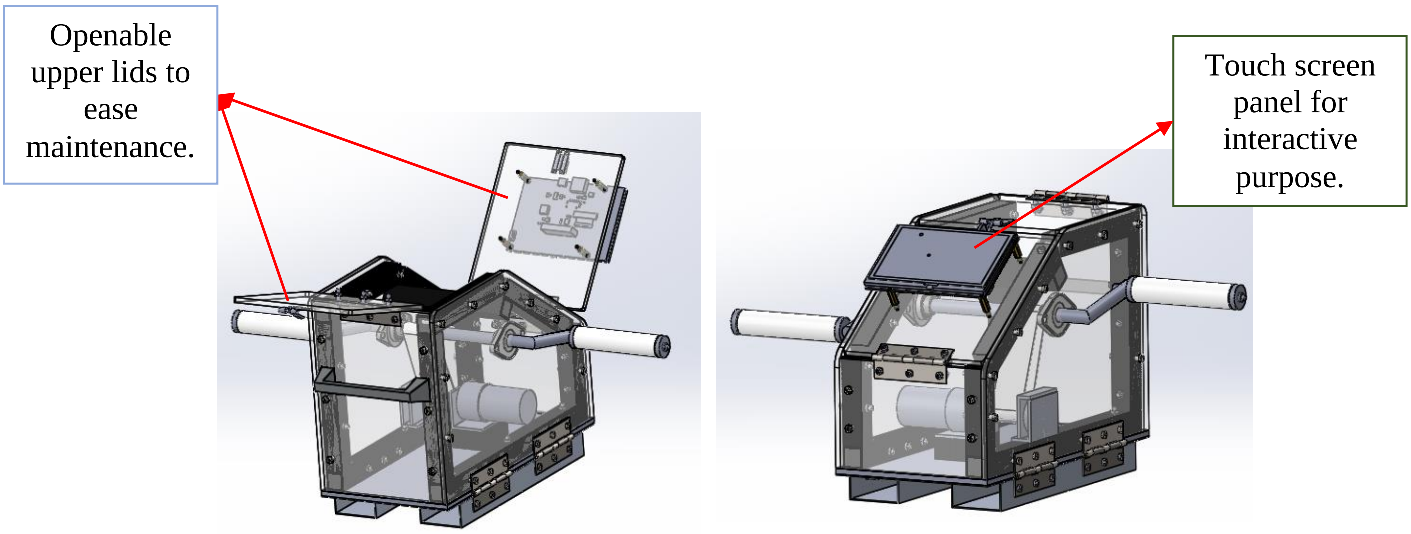
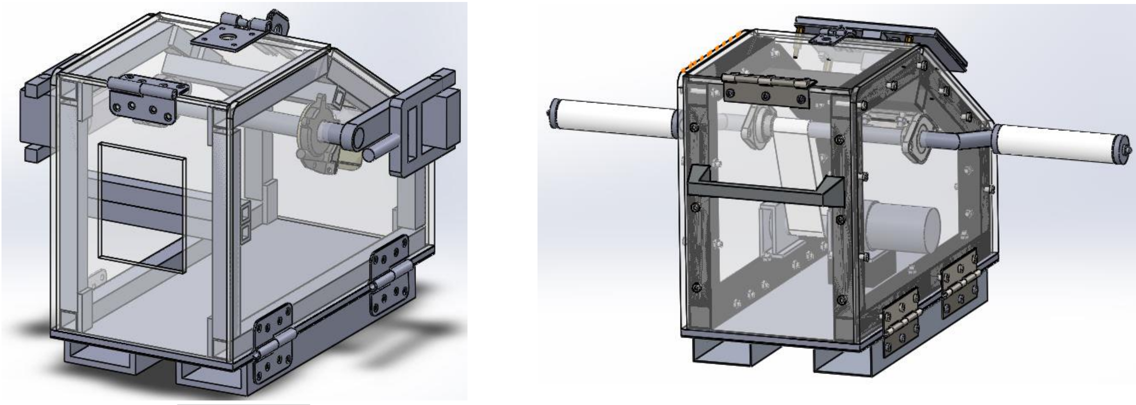


Figure 5.3: Final Design

5.2.1 Mechanical Improvisations (as compared to initial design)

Figure 5.4 below shows the difference between the initial design and final design. For aesthetic purpose, black-coloured aluminium bars were chosen instead of the usual silver aluminium bars.



Before After

Figure 5.4: Comparison between Initial and Final Design

First of all, the cycling handles' design of the TIHC has been changed. The initial idea was to buy and mount two foldable bicycle pedals to the shaft, then mounting a cylinder rod to the other end of the pedal for gripping. However, it was discovered that the foldable bicycle pedals were quite costly and are hard to be mounted or connected to the cycling shaft as the pedals are usually made of plastics. Figure 5.5 below shows the improvised design of the cycling handles. The white hollow cylinder is made of PVC and is allowed to rotate freely around the steel cylinder for cycling purpose. The choice of PVC is due to its softer material in order to allow comfortable gripping. Although this handle's design does not allow folding mechanism, the handles can still be attached and detached from the cycling shaft easily.

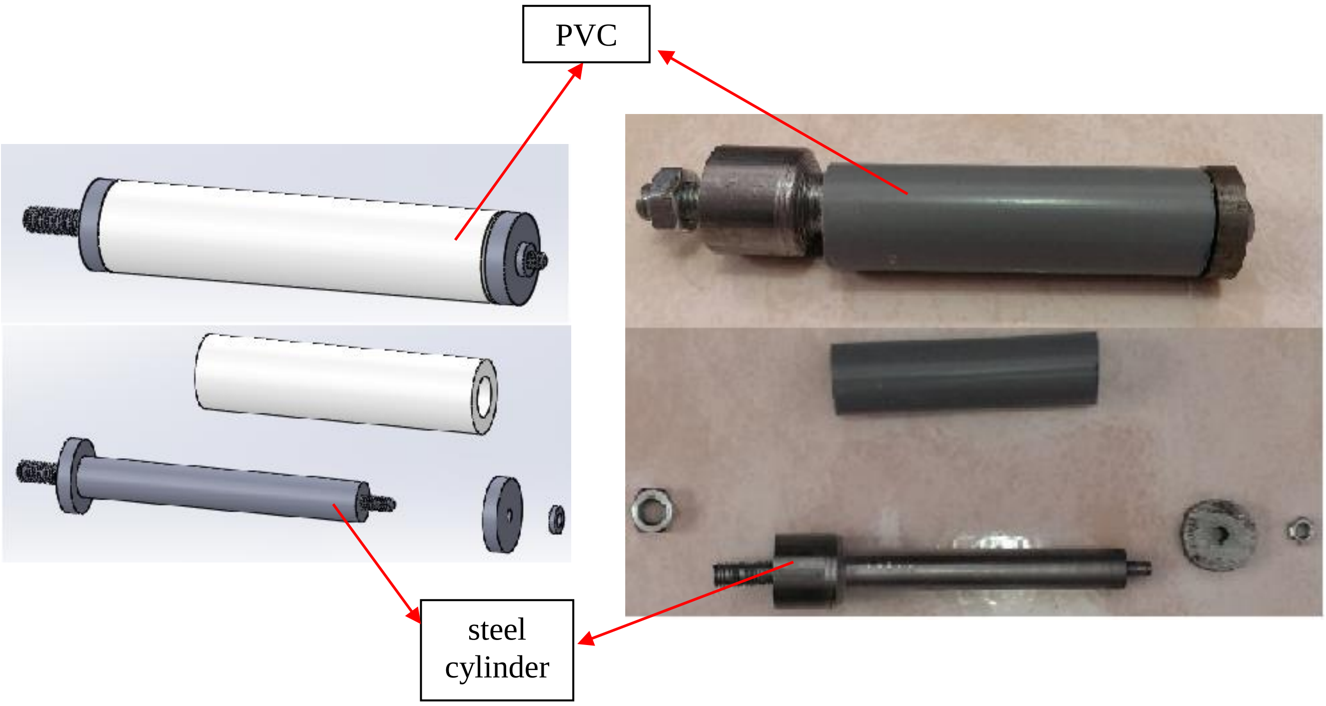


Figure 5.5: Cycling Handle

Figure 5.6 illustrates the difference in the cycling shaft design for the old and new drawings. Initially, bicycle crank is being connected to the cycling shaft. Similar to the cycling handles, the cost is higher and bicycle crank mounting to the shaft will not be easy. Therefore, the welding process of welding a cylinder rod to the shaft is much easier. Welding also helps to make the connection stronger and more rigid, which is crucial because the cycling motion depends a lot on the shaft.

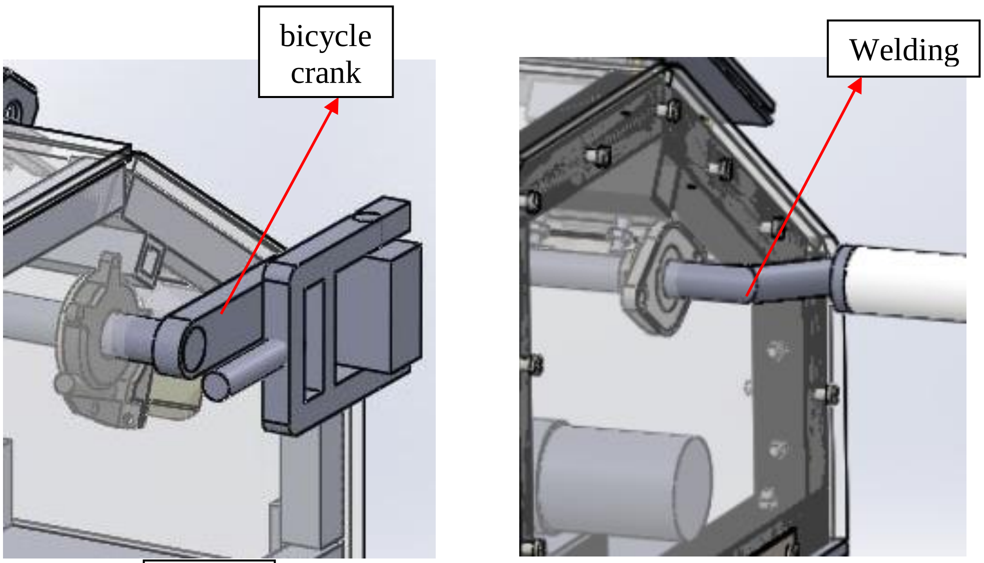


Figure 5.6: Cycling Shaft

Besides, the handles as shown in Figure 5.7 has also been altered. Instead of having to mill a large hole on a Perspex and mounting two aluminium bars within the device to function as a handle, a simple door handle can be utilized. This helps to save more time and cost. It is also easier to carry the handle which are being placed on the outer side of the device instead of the inner side.

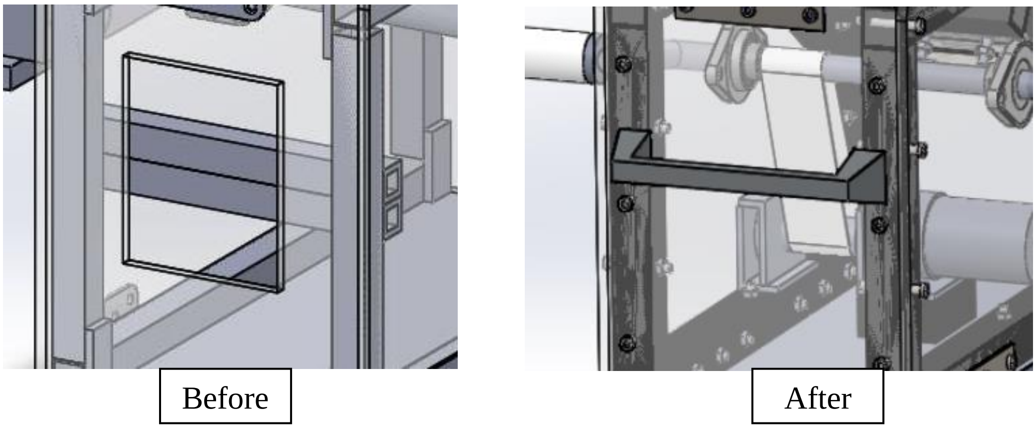


Figure 5.7: Handle

The small metal plates mounted on many parts of the aluminium bars as shown in Figure 5.8 are to ensure stability of the whole device by connecting each aluminium bars. For the improvised design, the aluminium bars are mounted to the Perspex with screws going through all sides of the bar. In this case, the metal plates will be redundant because the screws are able to withstand a large amount of weight.

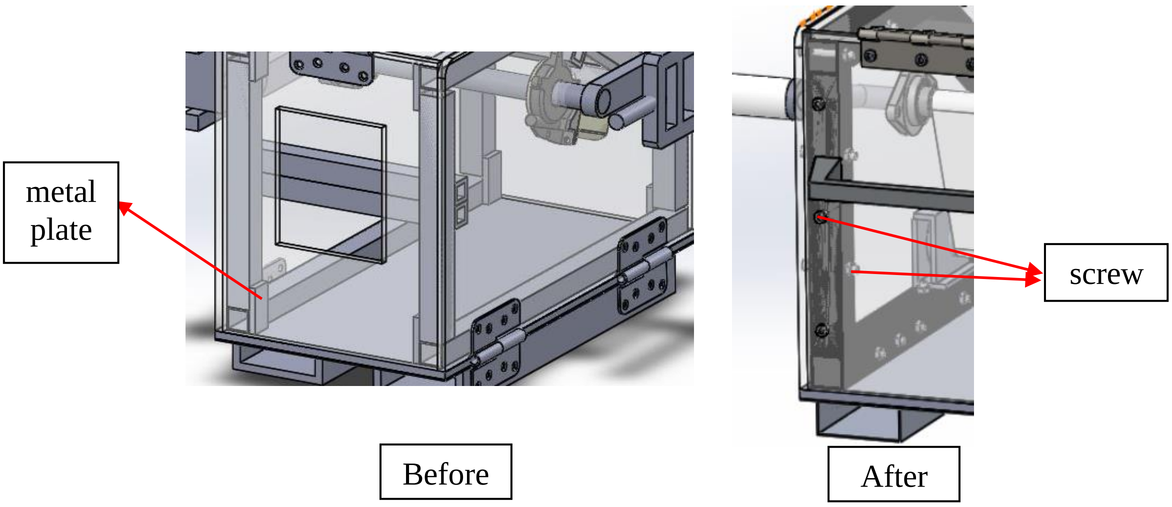


Figure 5.8: Aluminium Bars Mounting

Other than that, the dimensions for hasp and staple, and hinge were also revised based on the dimension of the real materials bought.

5.2.2 Electronic Improvisations (As compared to initial design)

For the electronic part, the motor choice was changed from power window to a DC motor. Several reasons amounted to this modification. It may not be too stable to mount a power window directly to the Perspex which might then leads to vibration and noise. It is also hard to mount the shaft straight through the center of the power window due to the 1.2cm diameter of the shaft. The center hole on the power window is smaller than that. Therefore, a DC motor is used instead.

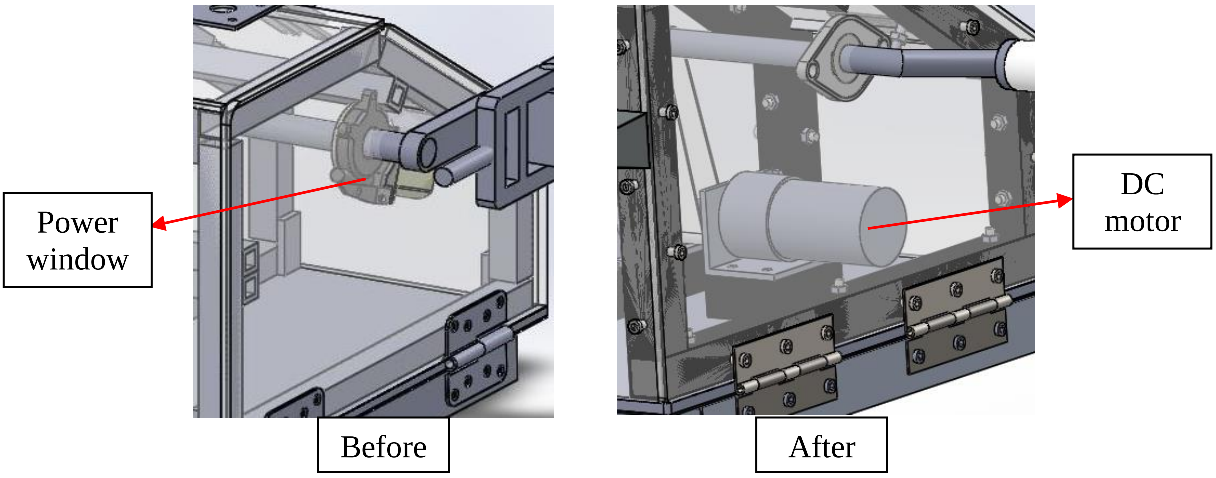


Figure 5.9: Motors

For the electronic part, the motor choice was changed from power window to a DC motor. Several reasons amounted to this modification. It may not be too stable to mount a power window directly to the Perspex which might then leads to vibration and noise. It is also hard to mount the shaft straight through the center of the power window due to the 1.2cm diameter of the shaft. The center hole on the power window is smaller than that. Therefore, a DC motor is used instead.

The model of the DC motor used is SPG50-20K. It is one of the models with the most balanced proportion between speed and torque. The motor speed is inversely proportional to the torque. Therefore, when the speed of the motor is high, the torque will be low and vice versa. For this model, the speed is 170 rpm whereas the torque is 196 Nm. The specifications for other models can be referred to in the appendix. The torque which is the moment of force is the tendency of twisting force to cause an object to rotate about an axis. Torque is essential to bring the motor up to the desired speed especially when the load is high. In this case, the load will be the force applied by the user of the hand cycle. However, this device is meant for the children with cerebral palsy, their limbs are weak to exert high force on the cycling shaft. Therefore, the device does not require a high speed motor.

A belt will be connected from the motor shaft to the cycling shaft with the sole purpose of creating resistance in cycling for the user when the cycling becomes easier for them. The belt used is made of cellophane tape as shown in Figure 5.10 below. The cellophane tape has a rough back surface which is suitable to create friction between it and the cycling shaft. Belt with teeth was not used in order to prevent the motor from malfunctioning. This type of belt will create too much opposing force for the motor and consequently spoil the motor. Besides, the device is also not meant to create too much opposing force in cycling for the children with weak limbs. Therefore, the chosen belt was used to produce enough resistance in cycling.

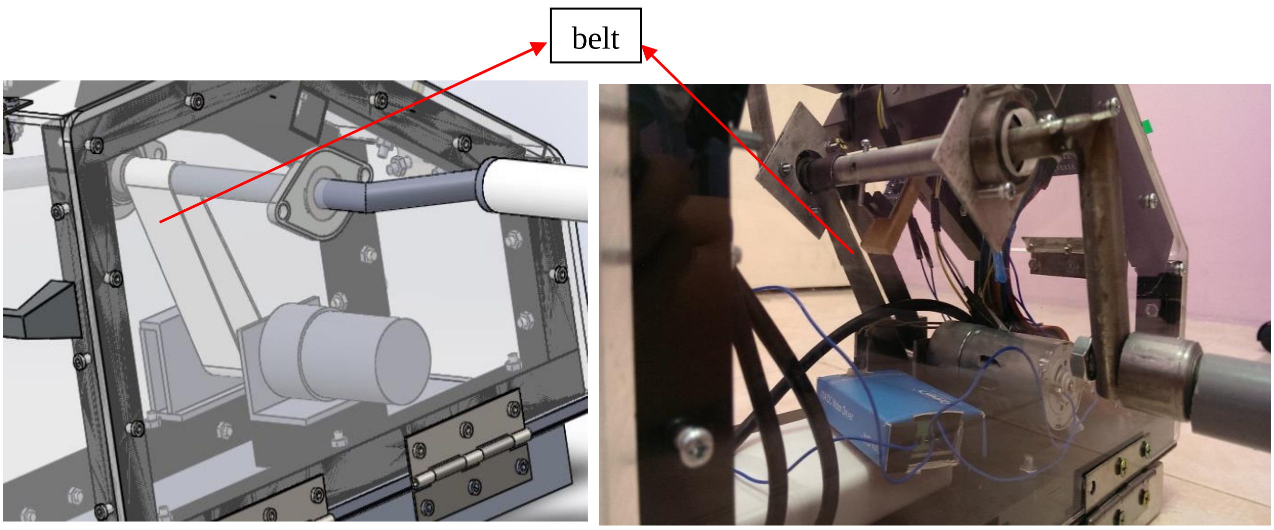


Figure 5.10: Belt

An extra display panel is being added onto the device. It is mounted on the back of the device as appeared in Figure 5.11. The display screen is for interactive purpose where the children can play a simple game while cycling. Various kinds of games can be designed depending on the children's interest. For further improvement, the display panel can be used for many more purposes such as displaying user's cycling performance graph and many more. The slanted surface's angle where the display panel is being mounted on is also suitable for the user's vision while cycling.

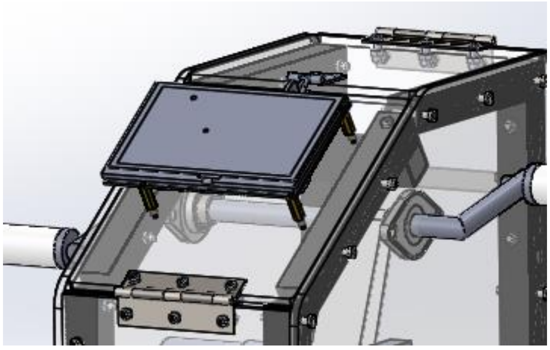


Figure 5.11: Display Panel

5.2.3 Electronic Components

1) XIAOMI 20000mah Power Bank
2) IR Encoder Speed Motion Sensor Module
3) 12 V Lead Acid battery
4) 10Amp DC Motor Driver
5) SPG50-20K DC Motor
6) Raspberry Pi 3 Model B
7) Raspberry Pi 5 Inch LCD Display
8) Micro Switch Lever

5.2.4 Electronic Circuit Design (Block Diagram)

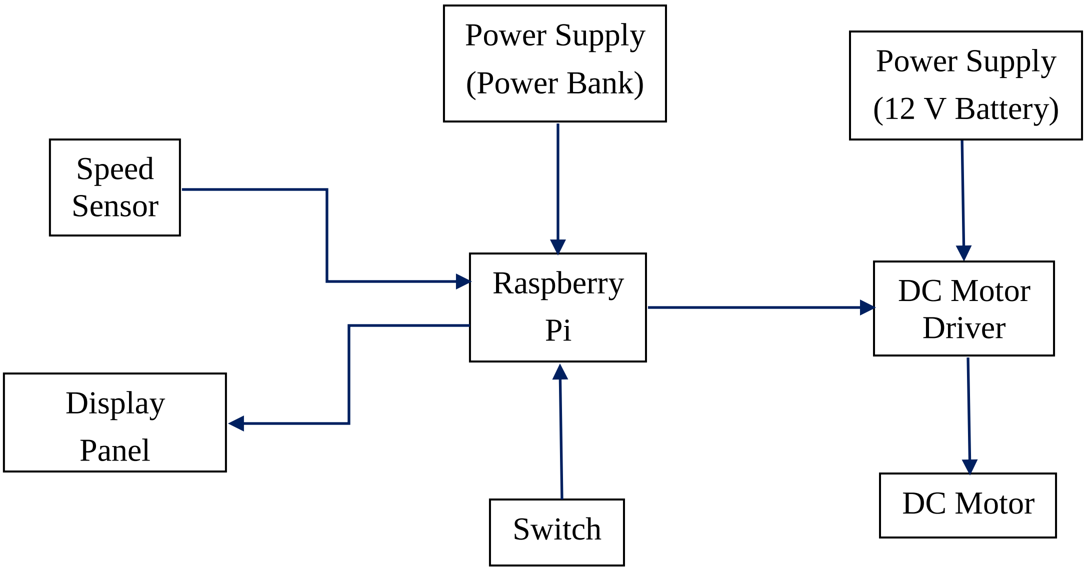


Figure 5.12: Circuit Block Diagram

5.3 Prototype – Tele-Interactive Hand Cycle (TIHC)

The functionality of Tele-Interactive Hand Cycle (TIHC) will be explained based on 3 parts - tele, interactive and hand cycle part.

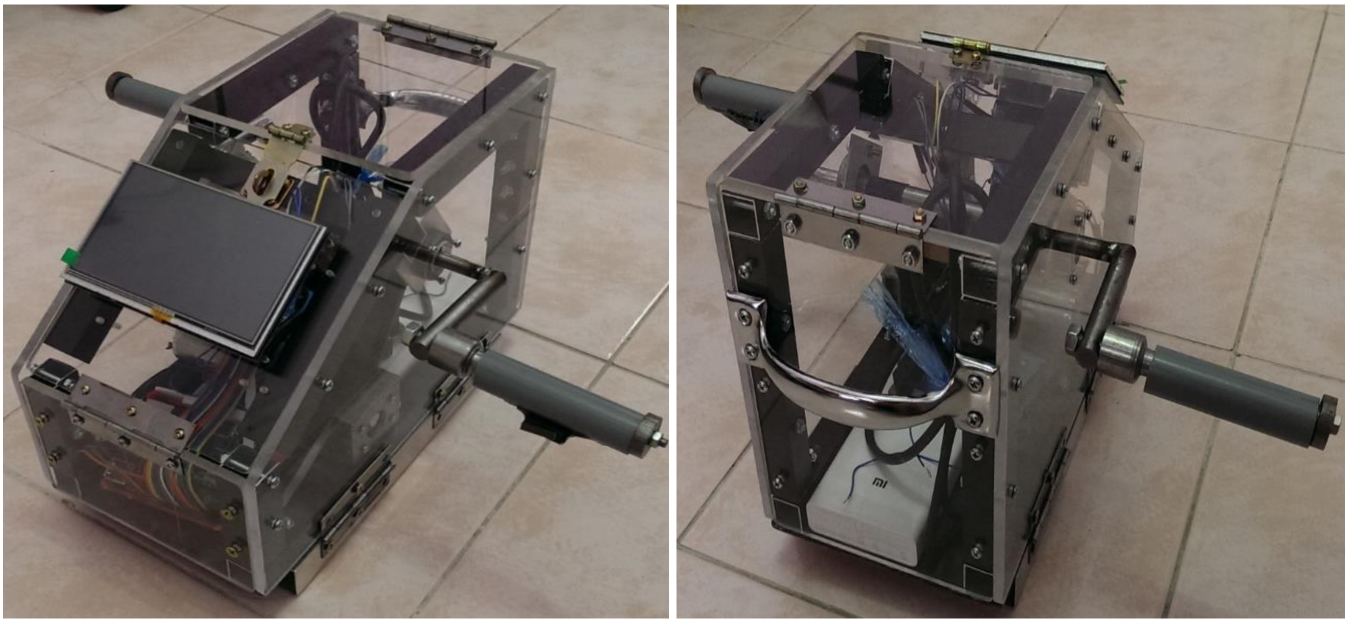


Figure 5.13: TIHC Prototype

5.3.1 Hand Cycle Part

The main purpose of the hand cycle is for children with cerebral palsy to carry out the cycling motion in order to strengthen their arms. The cycling is done by holding on to these detachable handles connected to the shaft as shown in Figure 5.14 below. The detachable cycling handles decrease the dimension of the TIHC as to ease carrying it around.

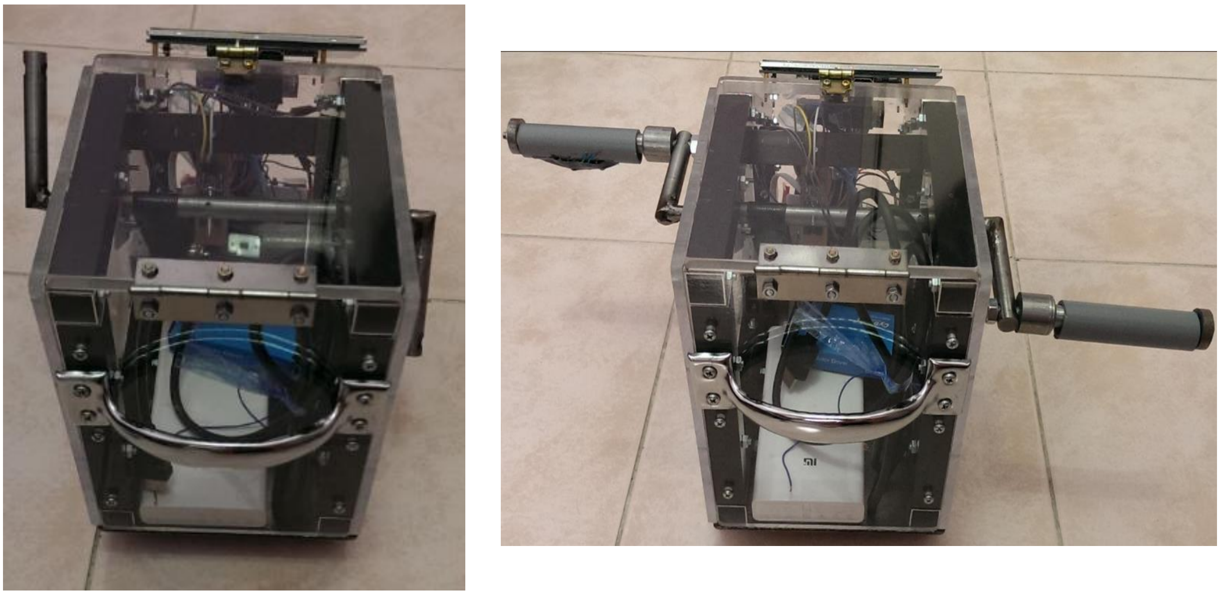


Figure 5.14: Detachable Cycling Handles

A thicker size of Perspex at 0.5cm is used because the device constitutes mainly of Perspex and therefore, the material has to be thick enough to ensure a strong and rigid hand cycle.

With the help of two bearings connecting to the cycling shaft, it may be a little easy to cycle for some children. Therefore, as demonstrated in Figure 5.15 below, there is a belt connected to the motor shaft and the cycling shaft. The purpose of this belt is to provide resistance when the cycling becomes a little too easy.

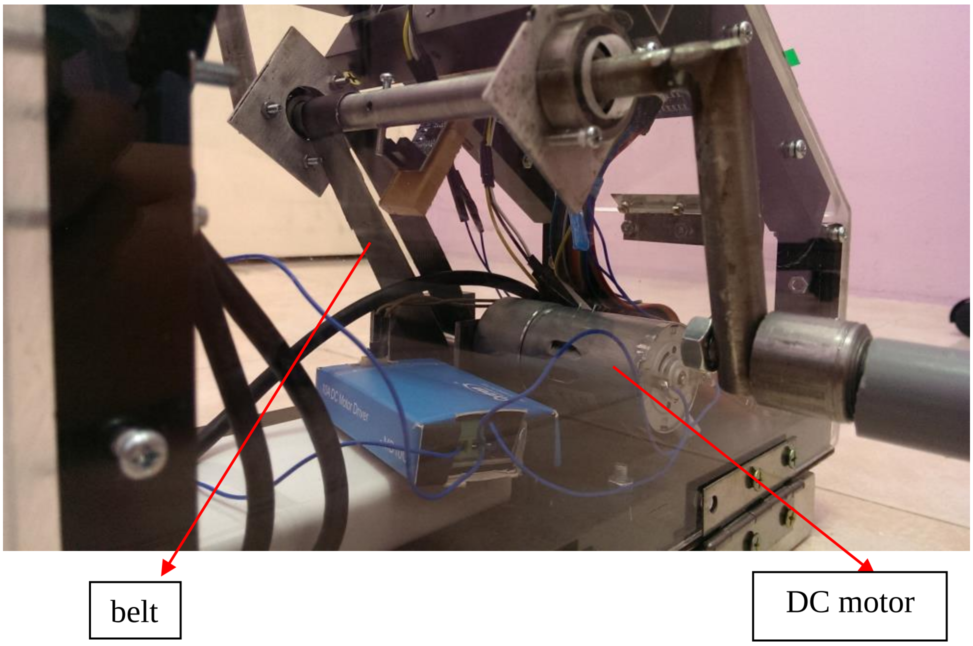


Figure 5.15: DC Motor and Belt

When the speed sensor as displayed in Figure 5.16 detects a high rotational speed for the cycling shaft, the motor will be activated and run the belt in the opposite direction of the cycling shaft movement in order to increase the difficulty in cycling. This helps to increase the user's upper limbs strength further. The speed sensor has a simple working mechanism because it gives out a binary output.

As shown in the figure below, the speed sensor detects signal when an object passes through the U-shaped plastic. For the TIHC, a screw is used for that purpose. The screw will pass through the speed sensor when the cycling shaft rotates for one round. Therefore, the cycling shaft speed can be calculated. For example, the stopwatch in Raspberry Pi will be started and after 3 rounds of cycling, the stopwatch is stopped 10 seconds. Then, the rotational speed (RPM) can be calculated by dividing 3 rounds with 10/60 minutes.

Besides, the diameter of the cycling shaft has been measured at 5cm with a Vernier calliper. Therefore, it can be estimated that one round of cycling equals to a 5 cm cycling distance. With this formula, the cycling distance of the user can be computed.

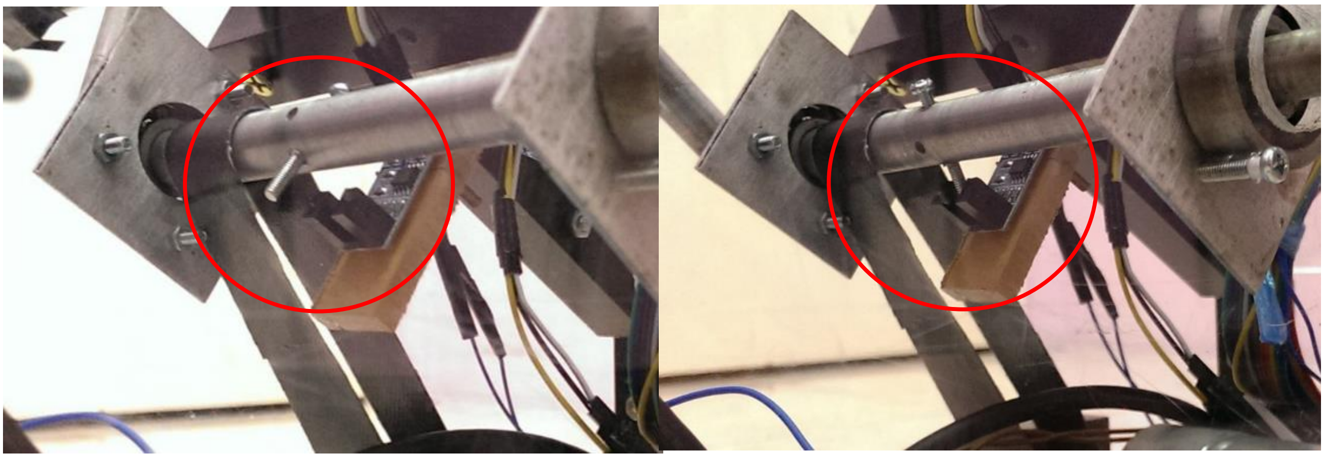


Figure 5.16: Speed Sensor

Other than that, there are rubber pads at the base of the TIHC to prevent the device from slipping during operation. Or else, the aluminium bar has less friction in contact with a table.

Figure 5.17: Rubber Pads

As for the expandable base, there are magnets to keep them in place when the TIHC is being carried. Usually, the base doesn't have to be expanded unless the cycling force is stronger for some children. The expandable base helps to decrease the centre of gravity and increase the base surface area of the TIHC. So, it will be more stable for stronger children who are able to cycle faster.

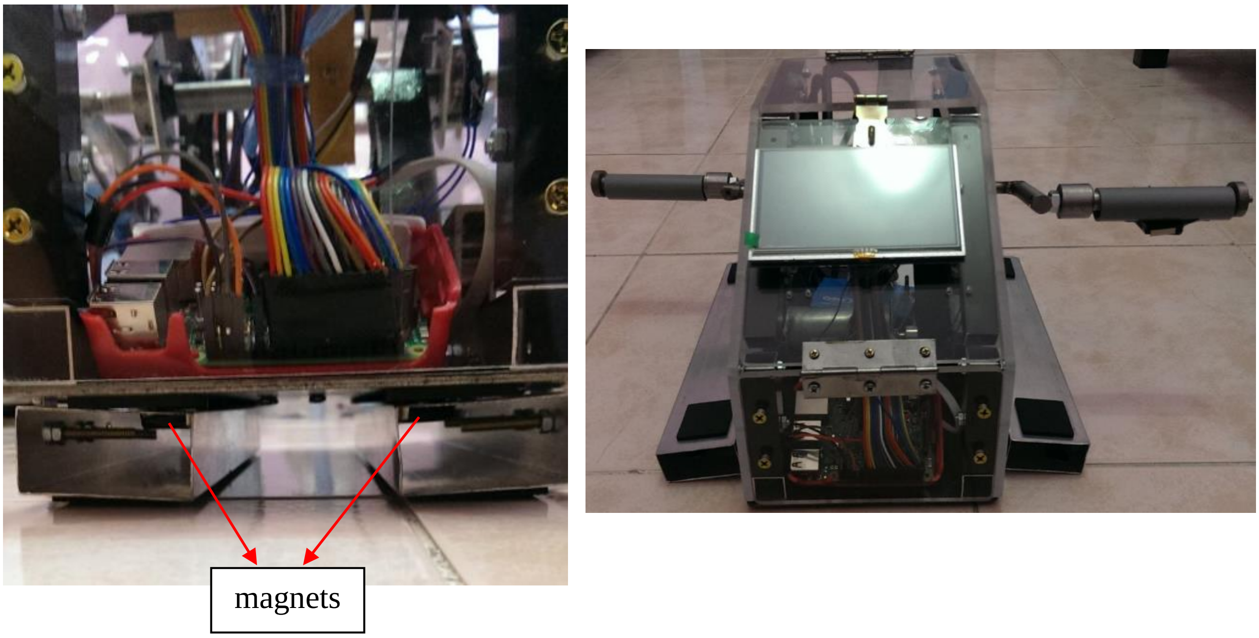


Figure 5.18: Magnets and Expandable Base

5.3.2 Tele Part

The word tele is taken from the word telemedicine where tele means at a certain distance and telemedicine refers to remote monitoring or diagnosis. Telemedicine requires the usage of electronic communication to exchange patient's information.

Therefore, taking little steps towards the Internet of Things (IoT), PubNub which is a global Data Stream Network (DSN) or so called a cloud storage is utilized to carry out the mission of transferring data online. PubNub enables its users to create and manage realtime functionality for IoT devices and phone applications. With PubNub, the TIHC is able to upload cycling data such as time, date, cycling distance and cycling speed online to the cloud storage for remote monitoring purpose. Physiotherapist will be able to access, monitor and analyze the users' performance remotely.

What is Internet of Things (IoT)?

IoT is a system of interrelated physical devices, mechanical machines, digital machines and computing devices. These connected devices will be capable of transferring or exchanging data over a network or cloud storage without needing human-human or human-computer interaction. It revolves around the communication between machines with cloud computing and data collecting sensors. Besides, all these devices can be controlled from far via Wi-Fi.

However, with the interconnected devices, cyber security becomes a big issue and it'll be a challenge to ensure that all the information flowing through these devices stay secure. There are many platforms for Iot such as Microsoft Azure, IBM IoT Foundation Device Cloud and many more. The platform used for this project is PubNub.

Many things or works can be automated. For example, if a coffee maker is connected to an alarm clock, the coffee maker can be activated to brew the coffee depending on the alarm time set for the user to wake up. On a larger scale, according to Burrus (no date), a bridge in Minnesota collapsed in the year of 2007. With IoT, the bridge can be rebuilt with smart cement where the cement has built-in sensors to monitor the cracks, stresses and other characteristics. These sensors can notify or alert us to correct problems before they lead to a major crisis.

PubNub

In PubNub, each messages sent is associated with a channel. This basically means that if a user publishes a message to a channel, a different user can only receive it if he subscribes to that particular channel. With this arrangement, the users subscribe to a specific channel and listen only to the data relevant to them. Private or global channels can be setup depending on the requirement of the project or application.

In order to employ PubNub in Raspberry pi, the 3 lines of code in Figure 5.19 are executed in the terminal window to install the necessary libraries for PubNub and PubNub itself.

```
sudo apt-get update
sudo apt-get install python-dev python-pip
sudo pip install pubnub
```

Figure 5.19: PubNub Libraries

Then, the code line in Figure 5.20 has to be initialized at the start of the program script to include or import the PubNub library installed.

```
from pubnub import Pubnub
```

Figure 5.20: Import PubNub Libraries

Figure 5.21 below exhibits the PubNub programming code for Raspberry Pi. As illustrated, a user will be given with a publish_key and subscribe_key when he signs up with PubNub. In the programming code, a client will need to include both of these keys if the objective is to publish or send data to the cloud storage. The publish_key, subsribe_key and channel have to be initialized in the codes. As for the callback function defined in the code, the purpose of it is for the Raspberry Pi to print out notifications or alerts from PubNub such as failure of publishing messages onto the terminal.

```
pubnub = Pubnub(publish_key="pub-c-0480e7ed-ab0f-4b0a-847a-1b6fa3e62494",
                subscribe_key="sub-c-66370b60-2fb2-11e6-bfbc-02ee2ddab7fe")
channel='pub'

def callback(m):
        print(m)
```

Figure 5.21: PubNub Initialization

As shown in Figure 5.22 below, a phone application with a simple interface was developed with Android Studio software. By typing words in the textbox and pressing the “SEND” button, the application will upload this data to the PubNub cloud storage. By clicking on the “HISTORY” button, the application will transition into a second page as shown in the right photo in Figure. Then, clicking the “RECEIVE” button will initiate the application to retrieve messages from the PubNub cloud storage. Depending on the programming codes, a fixed number of messages can be retrieved at once.

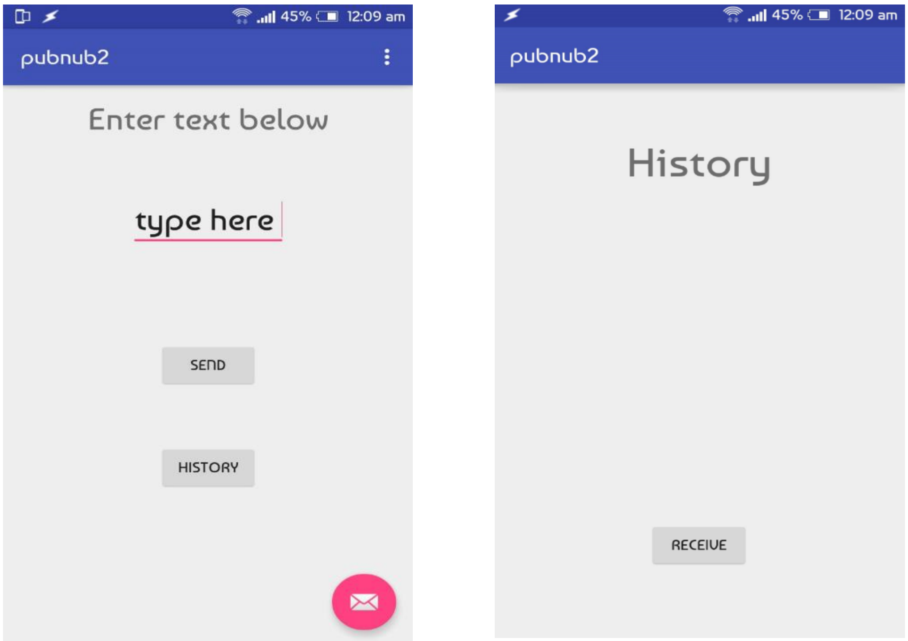


Figure 5.22: Phone Application Interface

Similar to the PubNub programming codes for Raspberry Pi, the packages for PubNub have to be installed in Android Studio. Then, the publish_key, subscribe_key and channel have to be initialized in codes. In order to subscribe to the channel, the code function in Figure 5.23 has to be written. Then, Figure 5.24 below shows the code function to publish message onto PubNub cloud storage from the phone application after subscribing to a channel.

```
public void subscribe(){
    try {
        this.mPubnub.subscribe(CHANNEL, new Callback() {
            @Override
            public void successCallback(String channel, Object message) {
                Log.d("PUBNUB","SUBSCRIBE : " + channel + " : "
                        + message.getClass() + " : " + message.toString());
            }
        });

    } catch (Exception e) {
        e.printStackTrace();
    }

}
```

Figure 5.23: Subscribing to PubNub

```
public void publish(String lol){

   Callback callback = new Callback() {
        public void successCallback(String channel, Object response) {
            Log.d("PUBNUB",response.toString());
        }
    };
    this.mPubNub.publish(CHANNEL, lol, callback);
}
```

Figure 5.24: Publishing to PubNub

As to retrieve messages from the cloud storage, the code function is as shown in Figure 5.25 below. The parameters at the second line can be changed depending on which channel to subscribe to, how many messages to be retrieved and whether to retrieve messages starting from the latest or earliest. Other than that, the messages in PubNub cloud storage exists in the form of JavaScript Object Notation(JSON) which is data interchange format. Therefore, lines 7, 8, 12 and 13 have to be done to extract the messages from the JSON format before converting them into string for display on the phone application.

```
    public void history() {
        this.mPubnub.history(CHANNEL, 3, false, new Callback() {
            @Override
            public void successCallback(String channel, Object message) {

                try {
                    JSONArray json = (JSONArray) message;
                    final JSONArray messages = json.getJSONArray(0);

                     mes.setText(messages.toString());

                } catch (JSONException e) {
                     e.printStackTrace();
                 }}

            @Override
             public void errorCallback(String channel, PubnubError error) {
                 Log.d("History", error.toString());
             }
         });
    }
}
```

Figure 5.25: Receiving from PubNub

Therefore, when the “RECEIVE” button is pressed in the phone application, the information as shown in Figure 5.26 will be retrieved. The date, time, cycling speed and cycling distance of the user will be displayed. If these data are being monitored and recorded, a graph can be plotted to analyse the users’ cycling performance. Improvement in strength can be observed and new training plan can be implemented.

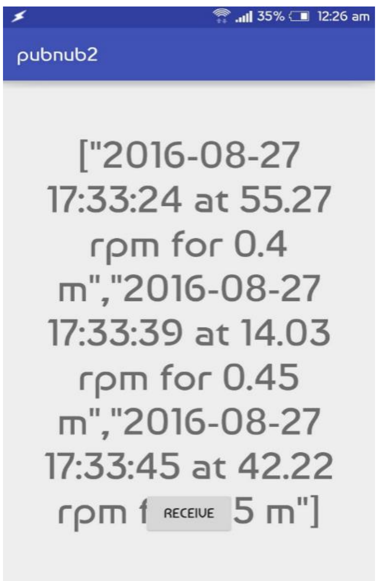


Figure 5.26: Receiving from PubNub

Results

Table 5.1 and 5.2 below indicate the results or data collected for the IoT transmission. The purpose of this data collection is to prove that the cycling data are being transmitted in real time. For Table 5.1, the rotational speed is updated in Raspberry Pi each time the user cycles for 3 rounds. The IoT rotational speed is calculated by the Raspberry Pi and then transmitted online to cloud whereas the calculated rotational speed is computed by recording the time of 3 cycling rounds with a stopwatch. The lowest and highest percentage of discrepancy between the two parameters are 0.18% and 8.77%, respectively.

Table 5.1: Rotational Speed after 3 cycling rounds

Date (DD/MM/YY)	**Time (HH:MM:SS)**	**Distance (m)**	**IoT Rotational Speed (rpm)**	**Recorded time (s)**	**Calculated rotational speed (rpm)**	**Percentage of Discrepancy (%)**
28/8/16	16:25:45	0.05	48.57	3.9	46.15	4.98
28/8/16	16:28:20	0.10	54.44	3.4	52.94	2.76
28/8/16	16:29:55	0.15	25.48	7.0	25.71	0.90
28/8/16	16:31:08	0.30	15.10	12.1	14.88	1.46
28/8/16	16:35:00	0.45	16.49	10.9	16.51	0.12
28/8/16	16:37:52	0.85	35.23	5.6	32.14	8.77
28/8/16	16:41:08	0.05	31.25	5.6	32.14	2.85
28/8/16	16:44:21	1.55	45.49	3.9	46.15	1.45
28/8/16	16:45:10	0.40	30.46	5.8	31.03	1.87
28/8/16	16:46:59	0.60	11.13	16.2	11.11	0.18

Sample calculation (first data):

IoT rotational speed = 48.57 rpm

3 cycling rounds, recorded time = 3.9 seconds,

So, calculated rotational speed = $\frac{3}{3.9/60}$

= 46.15 rpm

Percentage of discrepancy = $\frac{48.57 - 46.15}{48.57}$ x 100 = 4.98 %

As for Table 5.2, the rotational speed is updated in Raspberry Pi each time the user cycles for 5 rounds. The lowest and highest percentage of discrepancy are recorded at 0.51% and 12.56% respectively.

Table 5.2: Rotational Speed after 5 cycling rounds

Date (DD/MM/YY)	Time (HH:MM:SS)	Distance (m)	Rotational Speed (rpm)	Recorded time (s)	Calculated rotational speed (rpm)	Percentage of Discrepancy (%)
28/8/16	16:25:45	1.90	31.8	9.2	32.61	2.55
28/8/16	16:51:29	0.10	44.05	6.7	44.78	1.66
28/8/16	16:55:12	2.50	28.98	10.3	29.13	0.52
28/8/16	17:12:50	0.05	41.31	7.3	41.10	0.51
28/8/16	17:19:33	0.05	61.96	5.1	58.82	5.07
28/8/16	17:20:05	0.15	24.12	13.1	22.90	5.14
28/8/16	17:20:53	0.25	38.63	6.9	43.48	12.56
28/8/16	17:21:45	0.30	17.49	16.5	18.18	3.95
28/8/16	17:22:36	0.45	79.36	3.7	81.08	2.17
28/8/16	17:30:12	0.60	28.45	10.8	27.78	2.36

The percentage of discrepancy is due to human inaccuracy. It is hard to start the stopwatch time right at the point where the speed sensor detects signal. Therefore, there may be a certain error in recording. Besides, there was also a serious error during the data recording process. After recording for the first set of data in Table 5.1, the programming script is stopped and altered to run for the second set. However, it was discovered that when the new script is run, the previous script was also running in the background causing the data collected to be inaccurate. Therefore, the previous script has to be killed in the task manager of the Raspberry Pi.

As a precaution, before starting to record a new set data, a few trial runs of data observation are done to ensure the accuracy and consistency of the data first. However, there’s a problem which is harder to be prevented. If the internet connection is weak or slow, the transmission of data will also be delayed. This has to be taken note of in order to prevent one from recording the wrong data.

5.3.3 Interactive Part

With the features that the device has now, how can we boost the children's desire to actually use it? All the features designed are no doubt to help the children to strengthen their upper limbs. However, a certain motivation has to be present for the children to utilize the TIHC.

Therefore, as an incentive for the children to use the TIHC, a simple game as demonstrated in Figure below was developed with ScratchGPIO7 software in Raspberry Pi to act as an interactive feedback. The way the game works is simple. When the speed sensor picks up signal which means that the user starts cycling, all the cats and the bullseye will start moving randomly in the screen. Then, if the user presses the switch on the handle when a cat and bullseye meet at the same position, the cat will disappear.

Figure 5.27: Interactive Game

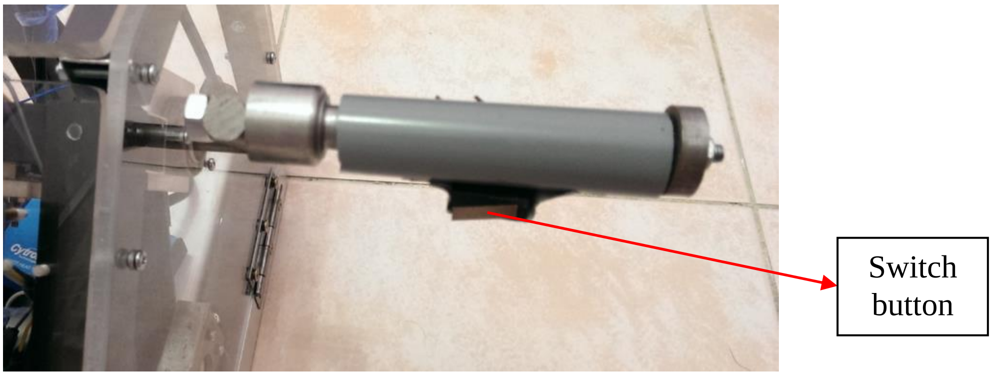


Figure 5.28: Switch Button

Besides, the game will stop as in the cats and bullseye will stop moving when the user stops cycling because the speed sensor does not pick up any signal. This will prevent the user from only playing the game with the switch without actually carrying out the main purpose of the TIHC.

The interface of ScratchGPIO7 software is as displayed in Figure 5.29. The codes are dragged from the column on the left into the programming scripts in the middle. The right interface is the preview for the game programmed.

Figure 5.29: ScratchGPIO7

In order to control the game subjects with switch connected to the IO pin, several important code lines have to be initialized. Firstly, the GPIO server has to be switched on as shown in the second line of code in Figure 5.30. Then, the IO pin number has to be configured whether as input or output. At line 3 and 4, pin 26 and pin 16 are both initialized as input pins.

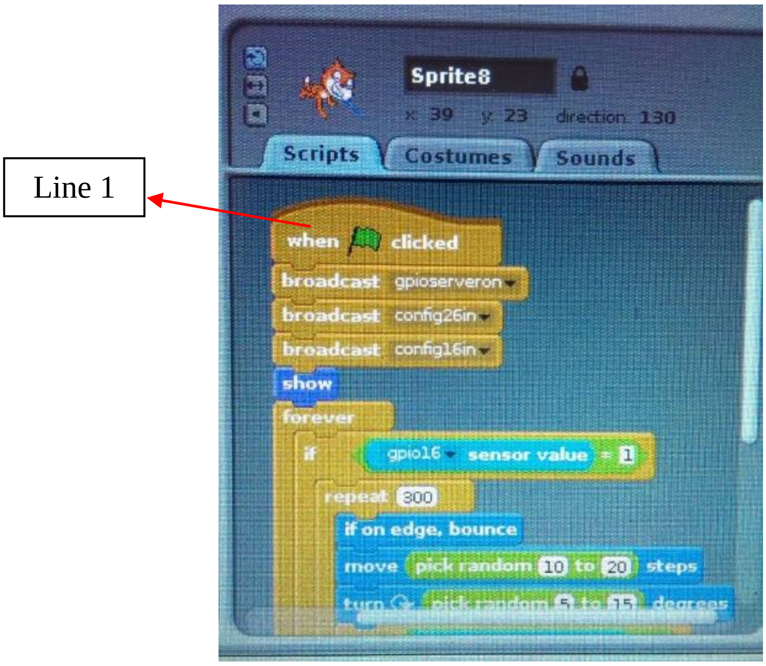


Figure 5.30: Game Programming Codes

5.3.4 TIHC's Function as a Whole

Basically, the main purpose of the TIHC is for the children with cerebral palsy to carry out cycling motion. While the cycling motion is taking place, the speed sensor will read the rotational speed and decide on the motor speed to be activated in order to provide resistance in cycling. At the same time, the reading from the speed sensor can be translated into cycling speed and cycling distance. Then, these data will be uploaded onto the cloud storage.

For remote monitoring purpose, a physiotherapist can access these data through a phone application to check and monitor the patients' performance. A simple way to analyse if there is an improvement is by looking at the increased or decreased cycling distance. If the cycling distance increases over a period of time, it could mean that the user's upper limbs have increased in strength.

Besides, while cycling, the user is able to play a simple game on the display panel. The game which will only start if the user cycles ensures that the user doesn't play the game without training his upper limb. He'll have to keep cycling in order to play the game. The switch on one of the handles used to play the game is also good to train their gripping strength. However, there is only one switch. Therefore, the detachable handle can be switched sides to train the gripping strength of another hand. The decision of using one switch instead of two is due to the fact that children with CP have poor control of muscle and reflex. It can be harder for them to control two switches at a time.

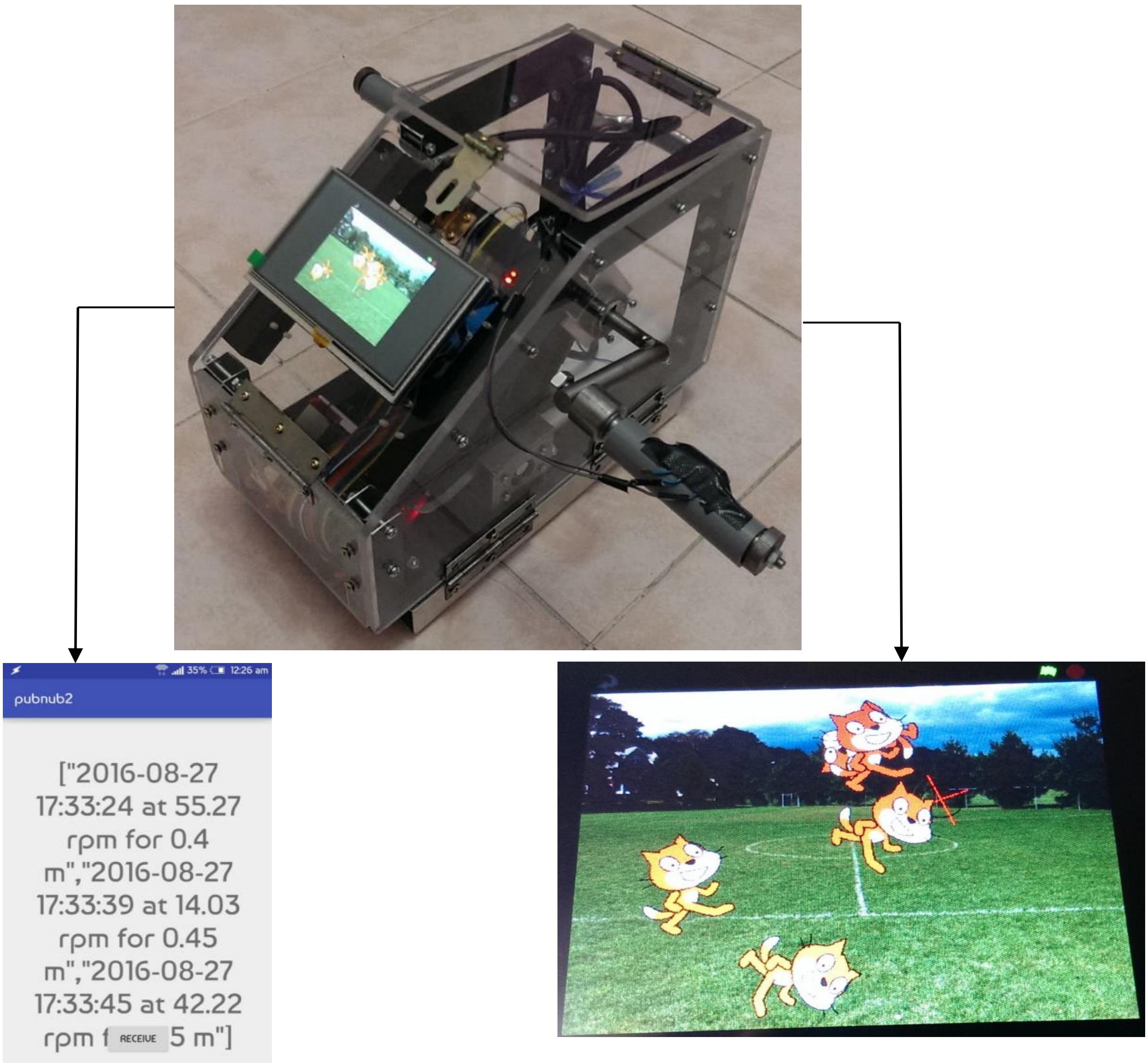


Figure 5.31: TIHC

How does the TIHC differ from the others?

Unlike most of the rehabilitation devices shown in literature review, the TIHC is designed for better portability. Many of those devices are bulky and heavy that they have to be mounted or placed in a designated area. Especially for devices with an interactive surface, a separate monitor or screen is being used. As for the TIHC, the display screen is mounted on the device itself with a trade-off of a smaller screen. However, with this improved portability, instead of having the children to attend to the device, the TIHC can be brought to them.

As compared to traditional devices, the TIHC has an interactive game interface similarly to many more advanced devices nowadays. It helps in motivating the users to carry out the training because the exercise will not be as dull anymore.

Other than portability and gaming interface, one the main distinguished features is the IoT capability as the field of telemedicine is still on its blooming stage. A phone application is developed to contribute to the IoT features which enables physiotherapists to access patients’ data anywhere as long they have a smart phone.

Program Flow Chart

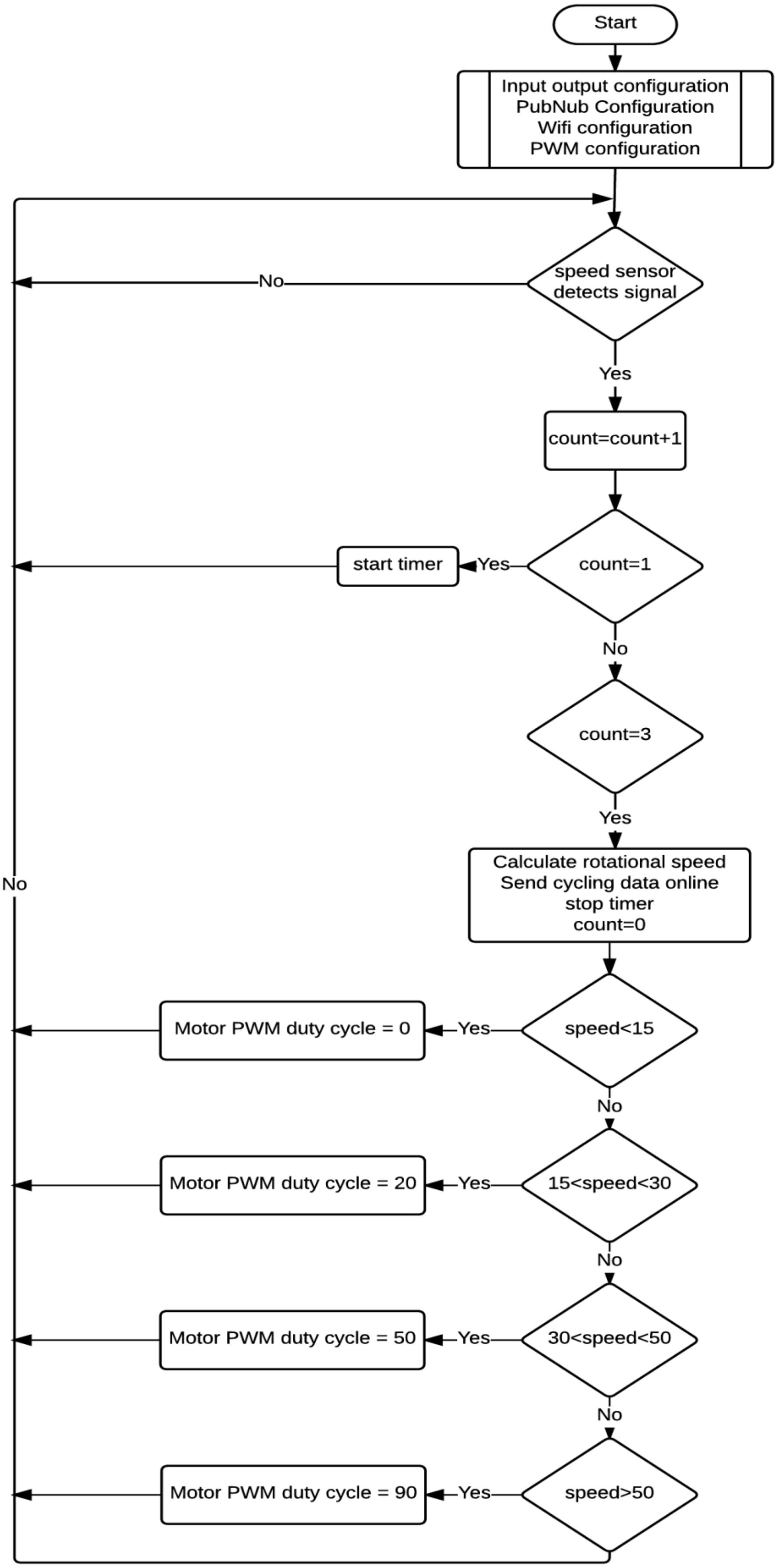


Figure 5.32: Flowchart

5.4 Future Improvement

For improvement, the mechanical design of the TIHC can be further simplified in order to ease manufacturing. For this project, the design has to be considered and done in a way that the prototype can be developed in the workshop by oneself. This means that the design cannot be too complicated due to limited resources and manufacturing processes. Therefore, the design can be simplified further for future development. For example, less screws can be used by implementing bending process of the aluminium bar. As shown in Figure, the aluminium bars at the side of the current prototype are all separated. One single aluminium bar can be bent into the similar shape and consequently helps to simplify the design.

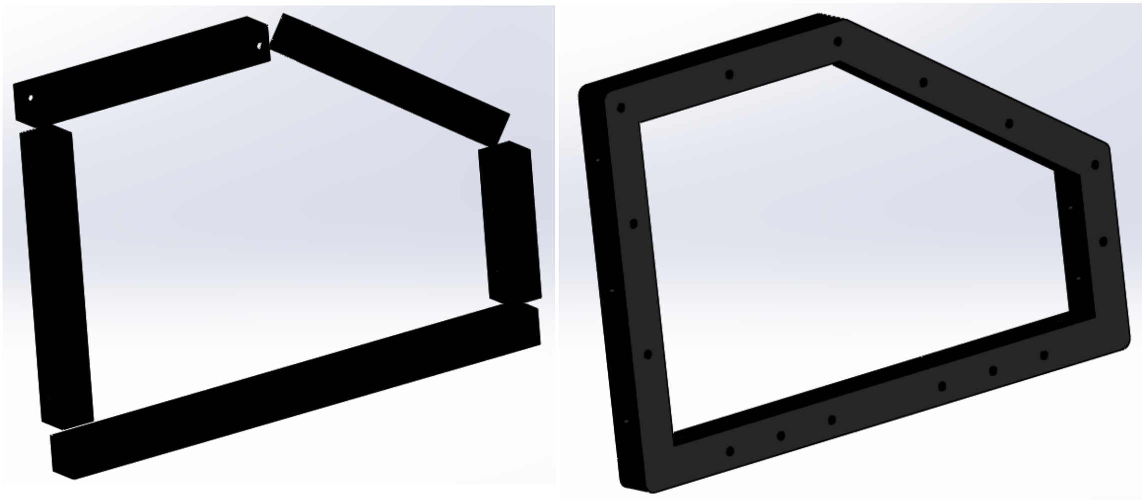


Figure 5.33: Aluminium Bar Design

Furthermore, more sensors such as enzyme-based sensor and accelerometer as shown in Figure 5.34 can be incorporated into the TIHC. Enzyme-based sensor is able to detect and foresee muscle fatigue. When the body of a human undergoes vigorous exercise, the lactate is produced at a faster rate. Therefore, by sensing the lactate levels, we can predict potentially complex conditions such as stress, dehydration and muscle fatigue (Staller, 2016). Besides, the accelerometer can be used to measure the angle of the user's cycling movement. This helps to discover the bad cycling posture of the users to prevent stress or injury on the body. With these sensors, all the information can be gathered and transmitted online to cloud for remote diagnosis. They can be very useful for physiotherapist to monitor and analyse their body condition and performance before, during and after cycling.

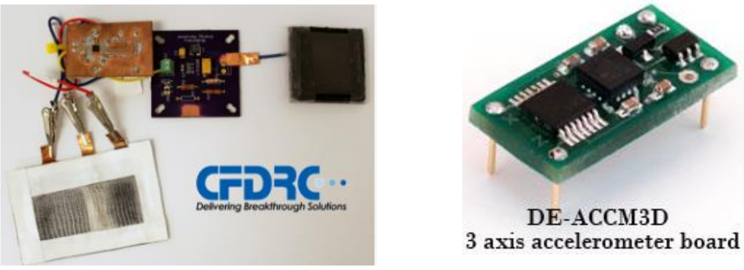


Figure 5.34: Enzyme-based Sensor (Staller, 2016) and Accelerometer

Other than that, more games can be written on the display panel to suit different interests of the children. They can choose the games which they prefer more or play a different one when they are bored with the previous game. As for the switch button used for playing game, it can be changed to a wireless Bluetooth pressure transducer as illustrated in Figure 5.35 below. This will eliminate wiring to the outer part of the device which is evident in Figure 5.36. Besides, the gripping force of the children can be trained since they'll have to grip the handle to exert enough force on the pressure transducer.

Figure 5.35: Pressure Transducer (Transducers Direct, no date)

Figure 5.36: Wiring to Switch

5.5 Business Plan

A simple business plan has been written for the purpose of commercializing the TIHC and any future designs. The target market of the company will be children with cerebral palsy of age 6 and above. The company has an objective to help and provide them with a means to improve their quality of life. The product of the company will an improved version of the TIHC. The difference between the TIHC and the usual hand cycle in the market is the interactive and IoT component. IoT component helps physiotherapist in remote monitoring and diagnosis. These processes can be done virtually without the need of being present face-to-face. Depending on the number of sensors incorporated, more information can be gathered for the physiotherapist to analyze the patients' conditions.

For the company team, skillful people from different fields such as marketing, electronic engineering, mechanical engineering, business and administration and more will be needed to establish a good team. Depending on the size of networking, people can be approached. Since this product is made by an engineer, the weakness of the company will be the marketing strategy. Besides, a biomedical engineer may also be needed because they have more knowledge on the biology side and the disease itself.

As for marketing strategy, walk-in method can be used to approach different spastic centre. Committee of the spastic centre will be allowed to utilize the device in order to understand and realize the strength and practicality of the device. Other than that, the company can also join more competitions and conference to promote the TIHC. This is a fact that the creator of the TIHC realized from joining the Second Telemedicine Innovation Challenge (conference). Many people have approached and asked about the functionality of the TIHC. Other than that, the usual marketing strategy such as television advertisements and online advertisements can be implemented.

Lastly, the total production cost of the TIHC is around RM 994.65. However, due to the availability of funding from a competition for this device, the components and materials bought were of good qualities. After cutting cost on the unnecessary components, the production cost can be estimated at RM779.81. At mass production, the cost can be cut further to an estimation of RM 650 or even lower due to materials purchase in bulk and better manufacturing processes.

The challenge will be to obtain funding for the company. The company can propose its project idea to investor companies such as Khazanah Nasional, Agensi Inovasi Malaysia and many more. The opportunity comes when there is a company which is interested in the project.

CHAPTER 6

Conclusion

The TIHC has gone through the 8 steps of engineering design. The first step is defining the problem and for this project, the problem is cerebral palsy disease. Children with cerebral palsy are born with weak limbs and are not capable of carrying out daily routines normally. Therefore, the second steps of conducting background research has been done on the disease itself and the rehabilitation devices that are able to assist the children in living a better life. The information gathered from this research was able to help in designing the rehabilitation device after obtaining a better apprehension of the disease.

After that, the third step is where the requirements have to be specified. The dimension, ergonomic and cycling capability along with the interactive and IoT components of the device have been stated. The project proceeded to the next step of coming up with solutions. Both conceptual designs, IBC and TIHC were designed with their respective attributes to help the children with cerebral palsy. Comparison of strong and weak points have led to the decision of choosing TIHC as the ultimate rehabilitation device.

Both development work and prototype building steps were carried out. The prototype was built and assembled according to the design made earlier. Stages of obstacles were faced and solved along the rough road of prototyping. Then, the TIHC has finally emerged. The final step of testing and redesigning was also done to make sure that the TIHC are able to function as a whole and to solve any further complications.

After all the tough work, the TIHC was able to secure a third place in the open category of the Second Telemedicine Innovation Challenge carried out by Monash University at the Swan Convention Centre of Sunway Medical Centre on 16-18 August 2016. The certificate can be referred to in the last page appendix. This achievement is a good stepping stone for the TIHC in future development or commercialization.

Lastly, as a lesson learnt, when you’re backed against a wall, break the wall down.

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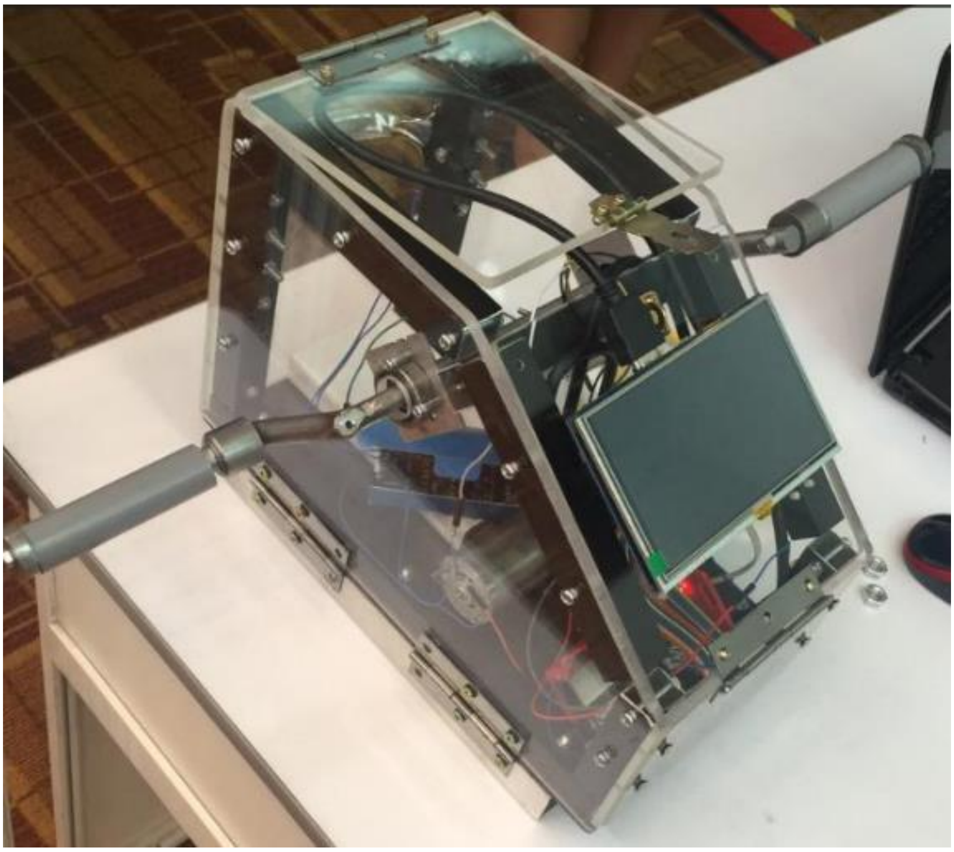
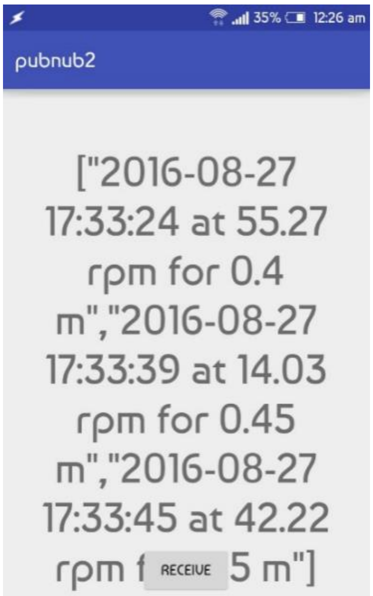
APPENDICES



TIHC



Phone Application Interface

Raspberry Pi Programming Codes

```
import RPi.GPIO as GPIO          #import GPIO library

import time, datetime

import sys                       #import system library

from pubnub import Pubnub        #import PubNub library



pubnub = Pubnub(publish_key="pub-c-0480e7ed-ab0f-4b0a-847a-1b6fa3e62494",
subscribe_key="sub-c-66370b60-2fb2-11e6-bfbc-02ee2ddab7fe")

channel='pub'



def callback(m):

        print(m)



GPIO.setmode(GPIO.BCM)

GPIO.setup(15, GPIO.IN)

GPIO.setup(18, GPIO.OUT)

GPIO.setwarnings(False)



dateString = '%Y-%m-%d %H:%M:%S'

var=0

dis=0

prev_input=0

p=GPIO.PWM(18, 1)        #set PWM pin and frequency

p.start(0)               #start PWM at 0 duty cycle
```

```
while True:
        input=GPIO.input(15)                #save speed sensor in variable

        if ((not prev_input) and input):
                var=var+1

                if var==1:
                        start_time=time.time()

                if var==5:
                        dis=dis+0.05
                        end_time=time.time()
                        total_time=(end_time-start_time)/60
                        rpm=var/total_time
                        speed=float("{0:.2f}".format(rpm))

                        pubnub.publish(channel,
datetime.datetime.now().strftime(dateString) + " at " + str(speed)+" rpm " + "for " +
str(dis) + " m", callback=callback, error=callback)
                        var=0
                        if rpm>50:
                                p.ChangeDutyCycle(50)
                        elif rpm<50:
                                p.ChangeDutyCycle(100)

        prev_input=input
        time.sleep(0.05)
```

Android Studio Programming Codes (phone application)

For the first page of the phone application,

```
package com.example.user.pubnub2;

import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.util.Log;
import android.view.View;
import android.widget.Button;
import android.widget.TextView;
import android.widget.Toast;
import com.pubnub.api.Callback;
import com.pubnub.api.Pubnub;
import com.pubnub.api.PubnubError;

import org.json.JSONArray;
import org.json.JSONException;
import org.json.JSONObject;

public class DisplayMessageActivity extends AppCompatActivity {

    private Pubnub mPubnub;
    public static final String PUBLISH_KEY = "pub-c-0480e7ed-ab0f-4b0a-847a-
1b6fa3e62494";
    public static final String SUBSCRIBE_KEY = "sub-c-66370b60-2fb2-11e6-bfbc-
02ee2ddab7fe";
    public static final String CHANNEL = "pub";
    TextView mes;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_display_message);
```

```
        mes = (TextView) findViewById(R.id.mes);

        initPubNub();

        Button rechis = (Button) findViewById(R.id.rechis);
        rechis.setOnClickListener(new View.OnClickListener(){
            @Override
            public void onClick(View view){
                history();
                Toast.makeText(getApplicationContext(),       "Retrieving       history",
Toast.LENGTH_SHORT). show();
            }
        });
    }


    public void initPubNub(){
        this.mPubnub = new Pubnub(
                PUBLISH_KEY,
                SUBSCRIBE_KEY
        );
        this.mPubnub.setUUID("AndroidPHue");
        subscribe();
    }

    public void subscribe(){
        try {
            this.mPubnub.subscribe(CHANNEL, new Callback() {
                @Override
                public void successCallback(String channel, Object message) {
                    Log.d("PUBNUB","SUBSCRIBE : " + channel + " : "
                            + message.getClass() + " : " + message.toString());
```

```
                }
            });

        } catch (Exception e) {
            e.printStackTrace();
        }

    }

    public void history() {
        this.mPubnub.history(CHANNEL, 3, false, new Callback() {
            @Override
            public void successCallback(String channel, Object message) {

                try {
                    JSONArray json = (JSONArray) message;
                    final JSONArray messages = json.getJSONArray(0);



                    mes.setText(messages.toString());

                } catch (JSONException e) {
                    e.printStackTrace();
                }}



            @Override
            public void errorCallback(String channel, PubnubError error) {
                Log.d("History", error.toString());
            }
        });
    }
}
```

For the second page of the phone application,

```
package com.example.user.pubnub2;

import android.content.Intent;
import android.os.Bundle;
import android.support.design.widget.FloatingActionButton;
import android.support.design.widget.Snackbar;
import android.support.v7.app.AppCompatActivity;
import android.support.v7.widget.Toolbar;
import android.util.Log;
import android.view.View;
import android.view.Menu;
import android.view.MenuItem;
import android.widget.Button;
import android.widget.EditText;
import android.widget.TextView;
import android.widget.Toast;

import com.pubnub.api.Callback;
import com.pubnub.api.Pubnub;
import com.pubnub.api.PubnubError;

import org.json.JSONArray;
import org.json.JSONException;
import org.json.JSONObject;

import java.util.ArrayList;
import java.util.List;


public class MainActivity extends AppCompatActivity {

    private Pubnub mPubNub;
```

```
    public static final String PUBLISH_KEY = "pub-c-0480e7ed-ab0f-4b0a-847a-
1b6fa3e62494";
    public static final String SUBSCRIBE_KEY = "sub-c-66370b60-2fb2-11e6-bfbc-
02ee2ddab7fe";
    public static final String CHANNEL = "pub";
    EditText haha;


    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);
        Toolbar toolbar = (Toolbar) findViewById(R.id.toolbar);
        setSupportActionBar(toolbar);

        haha = (EditText) findViewById(R.id.haha);

        initPubNub();

        Button sen = (Button) findViewById(R.id.sen);
        sen.setOnClickListener(new View.OnClickListener(){
            @Override
            public void onClick(View view){
                String lol = haha.getText().toString();
                publish(lol);
                Toast.makeText(getApplicationContext(), "message sent",
Toast.LENGTH_SHORT). show();
            }
        });


        Button rbut = (Button) findViewById(R.id.rbut);
        rbut.setOnClickListener(new View.OnClickListener(){
            @Override
```

```
        public void onClick(View view){
            displayMsg(view);
        }
    });

}

public void displayMsg(View view){
    Intent startNewActivity = new Intent(this, DisplayMessageActivity.class);
    startActivity(startNewActivity);
}

public void initPubNub(){
    this.mPubNub = new Pubnub(
            PUBLISH_KEY,
            SUBSCRIBE_KEY
    );
    this.mPubNub.setUUID("AndroidPHue");
    subscribe();
}

public void subscribe(){
    try {
        this.mPubNub.subscribe(CHANNEL, new Callback() {
            @Override
            public void successCallback(String channel, Object message) {
                Log.d("PUBNUB","SUBSCRIBE : " + channel + " : "
                        + message.getClass() + " : " + message.toString());
            }
        });

    } catch (Exception e) {
        e.printStackTrace();
    }
```

```
    }

    public void publish(String lol){

        Callback callback = new Callback() {
            public void successCallback(String channel, Object response) {
                Log.d("PUBNUB",response.toString());
            }
        };
        this.mPubNub.publish(CHANNEL, lol, callback);
    }



    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
                getMenuInflater().inflate(R.menu.menu_main, menu);
        return true;
    }

    @Override
    public boolean onOptionsItemSelected(MenuItem item) {
        // Handle action bar item clicks here. The action bar will
        // automatically handle clicks on the Home/Up button, so long
        // as you specify a parent activity in AndroidManifest.xml.
        int id = item.getItemId();

        //noinspection SimplifiableIfStatement
        if (id == R.id.action_settings) {
            return true;
        }
        return super.onOptionsItemSelected(item);
    }
}
```

<u>ScratchGPIO7 Programming Codes (Game Interface)</u>

Programming codes for the cat

Programming codes for the bullseye