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DEVELOPMENT OF DESIGN FOR LOWER EXTREMITY THERAPY FOR CEREBRAL PALSY CHILDREN

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ABSTRACT

Cerebral Palsy (CP) is a condition marked by impaired muscle coordination that may occur before, during or immediately after birth. At this stage, the infant's brain is still developing. Examination of the motor system offers a particularly appealing method for studying cerebral palsy by providing different kinds of treatments. The treatments are usually conducted at the hospital, but sometimes it is conducted at location which is according to patient's guardian preference. 'Computer Assisted Therapy in Lower Extremity for Cerebral Palsy' also can be known as CATLoC mainly focused on children aged from 7-12 years old diagnosed with CP condition. This paper presents the main objective of the project which is to build a device that can be used for lower limb exercise for CP children. Flow of process in completing project is included. This project enables monitoring using the graphical user interface (GUI) system. This project uses Arduino circuit with software programming and magnetic sensor to detect the motion of foot swing. Furthermore, a Bluetooth module is used to ease connection between the device and the user's laptop. CATLoC facilitates the lower extremity therapy process that may be useful for rehabilitation and diagnostic purposes.

Keywords: Cerebral Palsy, Rehabilitation, Lower Extremity, Gui System

INTRODUCTION

Cerebral palsy (CP) is a condition marked by impaired muscle coordination, known as spastic paralysis and other disabilities that occurs from brain injury during the prenatal, perinatal or postnatal periods. CP cannot be cured, but with continuous rehabilitation treatment and from help of assistive devices may ease their movements and improve their lifestyles [1]. About 70-80% of CP person that have affected limbs demonstrate increased in deep tendon reflexes, tremors, muscular hypertonicity, weakness and a characteristic scissor gait with toe-walking. It is known that a person who have CP often faces difficulties in movement due to the muscle tightness, range of motion limitations and sensory impairments. Because of that, physical therapies are beneficial for them to overcome the problems [2]. Another paper written in the year 2012, stated that strength training does give positive impacts in improving muscle strength and it able to improve gait and motor function, but only if the training was done frequently [3]. Basic movements such as standing, walking and running for cp children are limited [4]. Other than that, children with CP has an unstable coordination or less dependent on balance [5]. Therefore, pedals are attached for leg exercise at the walker and is added with seat. There is also a limitation in using GUI system for monitoring progress when doing treatment at home, so Graphical User Interface (GUI) system is used to increase convenience in monitoring the treatment process done by user. GUI system is designed as the chronological order of user input events and consists of text boxes and clickable buttons [6] [7]. Along with the development of time where innovations take place, this patient-operable device should also be able to shorten the meeting time during the check-up appointment since this device also can store memories of the user's progress.

From a paper written in the year of 1999 [8], a paper of design of an exercising device in providing therapy to lower and upper extremity, consist of a frame, a disc mounted to the frame and a hand or feet pedal on both left and right side of the disc. The device is equipped with motor to provide a rotating motion and has two types of mode; active and passive mode where the speed can be adjusted for the passive mode, while in active mode, the resistance is adjustable. Another paper written in the same year by different authors using different method [9]. This invention is related with general exercise, rehabilitation in medical field and toning of the lower extremities' muscles. The difference between previous design is, it used a rocking-type for the foot. There are two pedals attached for left and right foot. The pedal is mounted on a base, while the pivot point is mounted vertically between the base and the pedal. This device can be performed in seated position and the main purpose is to maintain the tone of the muscles of the legs and to encourage blood circulation in the lower extremity part, especially foot and legs. Another method studied is by using functional gait re-trainer that is written in the year of 2015 [10]. This device focused on a person's lower extremity in strengthening the muscles. The inventor suggested that a functional way in exercising is a must to strengthen the lower extremity muscles. It consists of movable belt, horizontal plane and elastic band. The user for this device will perform walking pattern on the plane. When a person performs this exercise, it will create force from their own leg.

The device uses a variety of controllers, processors, computers and user interface. The communication used is with sensors, detectors, systems, processor or with hardwire or wireless.

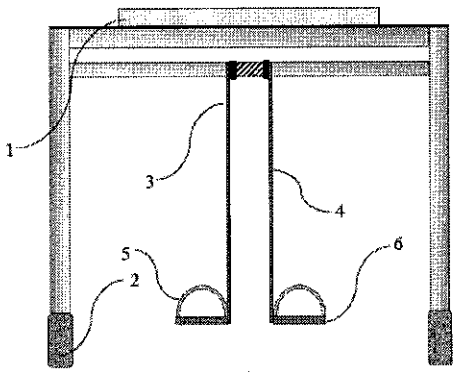
METHODOLOGY

In this methodology part, a complete process in developing lower extremity therapy is shown. The process includes the development of hardware and software is elaborated and method used in collecting data is also mentioned in this section.

2.1 Development of CATLoC Hardware

This project will undergo the process of design development. The process of designing is one of the crucial parts in developing CATLoC. The condition of a person with CP such as their muscle pattern or activity, stability and others must be put attention to. The initial design of this project is shown in the Figure 1 below:

Figure 1 : Front View Of Sketch Design For ATLoC



Referring from Figure 1 above, we have labelled the item required to form CATLoC. The name of each item can is in Table 1 below:

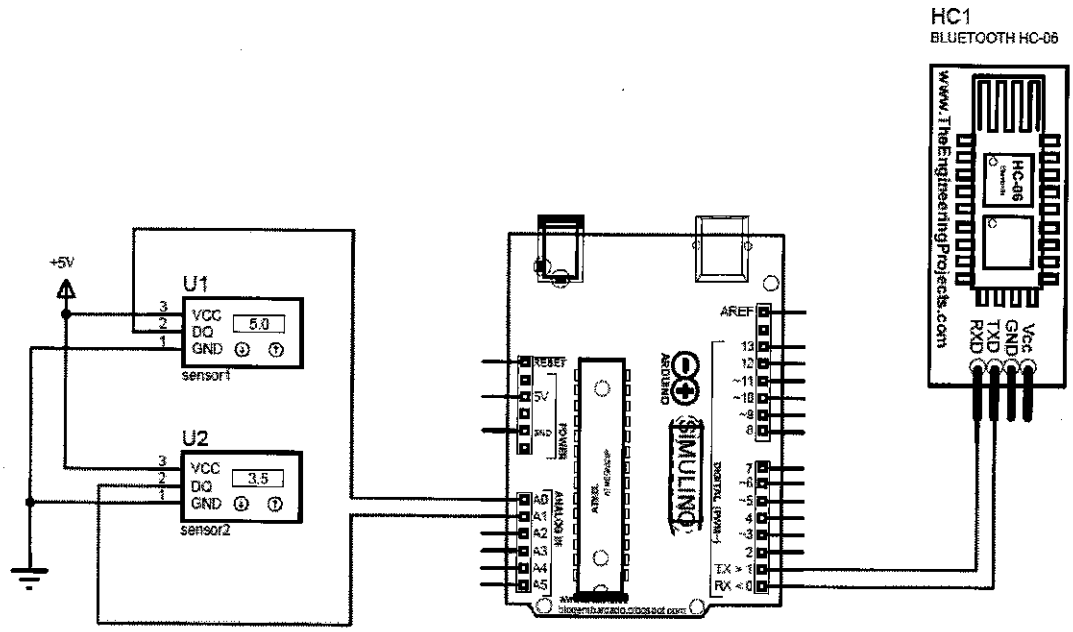
Table 1: Item labelled from prototype Figure 1

NO.	ITEM
1	Seat
2	Wheel
3	Hex nut
4	Extendable flat rod
5	Velcro strap
6	Foot paddle

CATLoC comes from of a normal walker frame that is used to assist a person in walking. Referring to the Figure 1 above, the walker is equipped with a seat to provide a comfortable seating position when user wants to perform the exercise. The function of hex nut is to tighten or loosen the flat rod. The tighter it is, the higher force is needed for the user to perform swing motion and vice versa. Considering that every person has a different height, it is recommended to have an extendable flat rod to suits everyone comfortability. It will also have Velcro strap to ensure that the foot is correctly placed on the foot paddle.

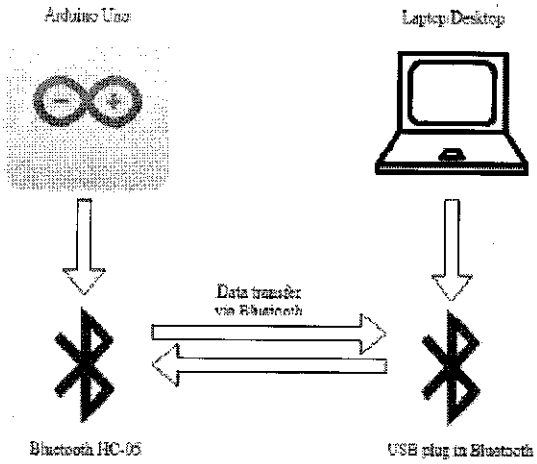
The circuit operation for this project is by using two pairs of magnetic sensor [11], Arduino Uno that has been set up using IDE software [12][13], HC-05-bluetooth [14]. Magnetic sensor was located at the flat rod area and will function as a detector for the user's foot motion. There are two pairs of magnetic sensors, both carries the same function but for different region; left and right foot. During the foot swinging, the increasing number will be recorded from the sensor and the data will then be processed by Arduino Uno. Two Bluetooth are prepared which will act as a transmitter and receiver. Circuit diagram is shown in Figure 2 below.

Figure 2: Schematic Diagram Of Circuit Used For CATLoC



Referring to Figure 3 below is the simple diagram of connection established in this project. The data will be transferred using Bluetooth HC-05. There are two Bluetooth that is responsible in transferring data. The first Bluetooth is the one that connects with the Arduino Uno, while the second one, we use a USB plug in Bluetooth for the laptop or desktop which will receive the data. The connection established for communication in CATLoC operation is briefly summarized in Figure 3 below.

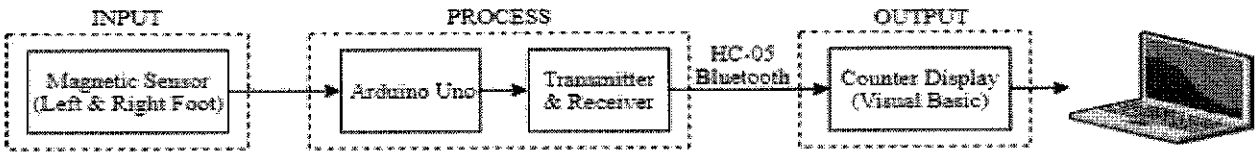
Figure 3: Connection of devices for data transfer



2.2 Development of CATLoC software

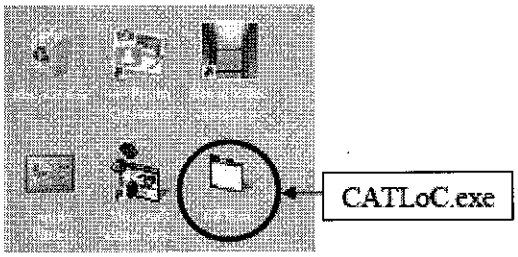
For the development of CATLoC in terms of their software, it involves with the programming and coding. For the GUI system, we use Visual Basic software to create GUI display and Arduino IDE software to program the Arduino Uno. Referring to the block diagram below (Figure 4), only with correct programming written in Visual Basic software and Arduino IDE software, the project is successfully functioned. Starts with the input from a magnetic sensor, the process of collecting data will be going through the Arduino Uno and Bluetooth and after that it will be displayed on the GUI display at the laptop.

Figure 4: Block diagram for CATLoC



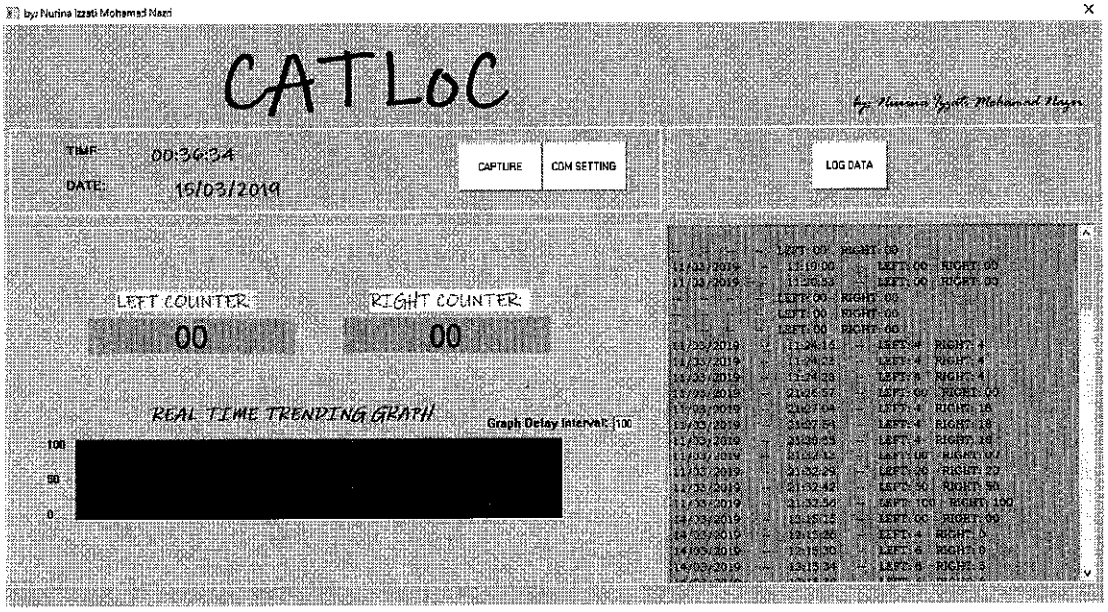
GUI system, which can be known as 'Graphical User Interface'. GUI testing can be defined as a GUI based application, that has a graphical-user interface front-end and is tested by performing an arrangement of a story on GUI widgets. The events that involving the GUI usually will take input from users and change the state or condition of its widgets. The widgets can be in a form of any buttons that has its own function, opening menu, or typing in a window [6]. GUI takes events as input from users and then changes the state of its widget [3]. Once the connection between Bluetooth has been established, user should open the executed program for CATLoC (Figure 5) and insert the correct number of ports used.

Figure 5: CATLoC Program In User's Laptop



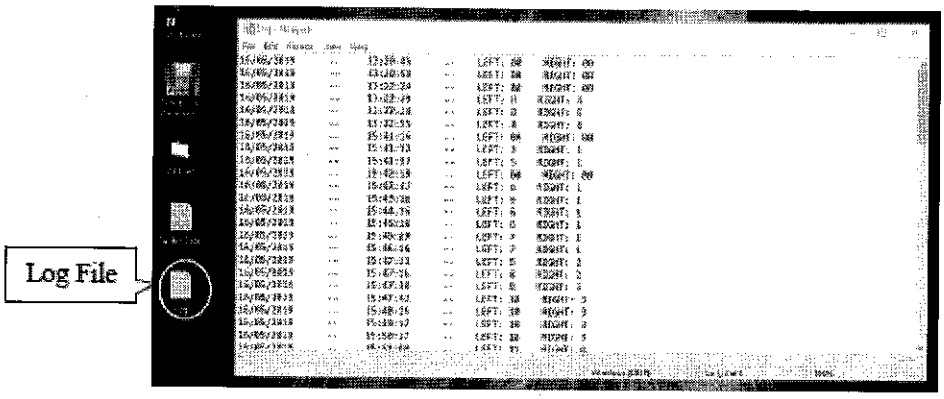
After all this process using the laptop is completed, user can start performing the exercise by swinging their left and right foot. From the exercise made, number of progress for both left and right foot from the user will be shown at the GUI display (Figure 6).

Figure 6: GUI Display Made For CATLoC



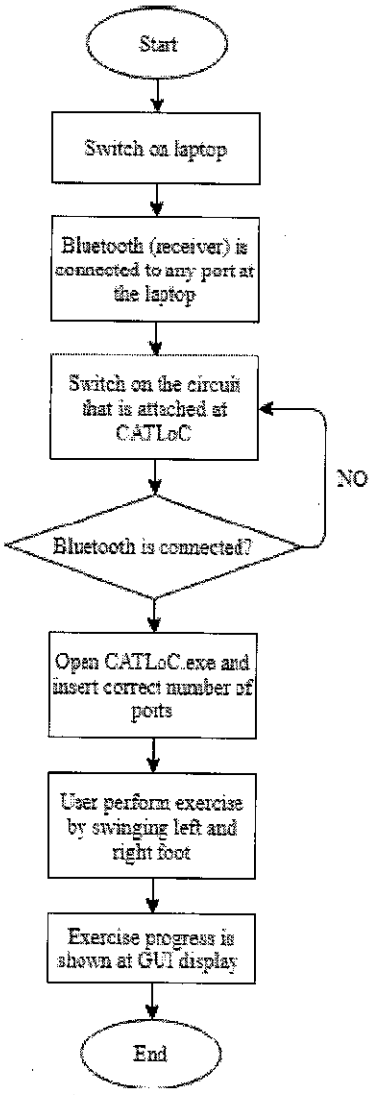
Our GUI display have interesting features that were made with vibrant colors and attractive fonts. Other than that, the GUI display will have project's title on the top of the window. A real-time and date will also show at the window for the user's reference. The main feature for this GUI is the swing counter for both left and right foot. But other than that, we also have a real trending graph. This can be use if the guardian or the user want to check the progress history whether the activity increases or declining. On the right side of the GUI, we have the data shown about number of swing exercise made by the user. Once CATLoC's user exit the executed application, they can still see the history of progress activity which is stored as log file (Figure 7).

Figure 7: History Record For Progress Activity



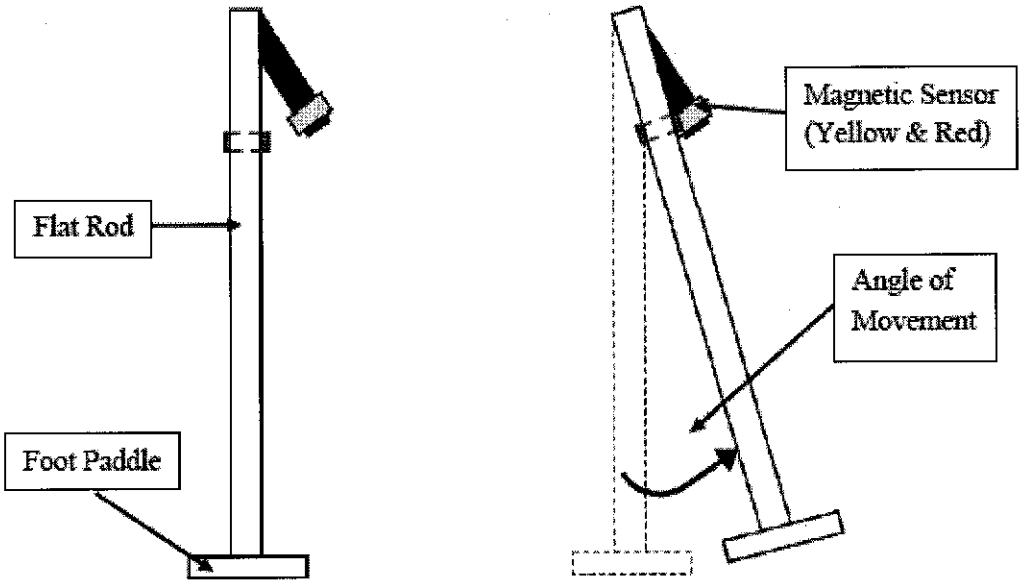
A flowchart is used to show steps in using the CATLoC. The operation of this project should be done accordingly by following the correct steps. Referring to the flowchart above, the operation will start by switching on the laptop. The Bluetooth, which is the receiver part, is connected into any ports at the user's laptop. In this process, the LED at the Bluetooth will keep on blinking continuously. This indicates that the Bluetooth has no connection with anything. After that, switch on the circuit that is in the circuit box at the walker. Once the circuit is on, both Bluetooth, receiver and transmitter should connect with each other. During this time, user can check the connection by observing the Bluetooth, it will blink slower or show no blink at all. Figure 8 below shows the flowchart for CATLoC's operation from the beginning operation until the completion of process:

Figure 8: CATLoC's Flowchart Of Operation



The usage in CATLoC is for detecting the foot motion, where each side of left and right side will have a pair of magnetic sensors. Referring from Figure 9 above, it is a rough diagram of side view of CATLoC's foot paddle. Notice that there are two magnetic sensor which in here is identified colored as yellow and red. Both sensors are located with a difference in angle. The user should swing their foot in a specified angle of movement. Once the magnetic sensor is side by side, there will be a counting occurred. This is because, a magnetic sensor produces a magnetic field around it, and if another magnetic field interfere that comes from another magnetic sensor, a disturbance occurred and that will be taken as a counter. Due to this act, a change and increasing of number will show at the GUI display.

Figure 9: Side View of Foot Paddle's Swinging



2.3 Quantitative and Qualitative Analysis

Method of analysis used during this project is quantitative and qualitative analysis. As can be seen in next chapters, we can see there are visual aids such were used to display about data collected. From this method, a more understandable to represent our result can be observed. Few stages involve in analyzing quantitative data; data validation, data editing and data coding. We calculated percentage of respondents' working status for questionnaires and summarization of interview conducted.

RESULTS AND DISCUSSIONS

The development of this project is finished by completing final prototype and has undergoes few evaluations such as questionnaires and interviews.

A. Final Prototype

As for CATLoC, we built a prototype that has a real function just like how has been described previously. The completed prototype is shown in Figure 10 and the specification is in Table 2:

Figure 10 : Front View and Side View of CATLoC

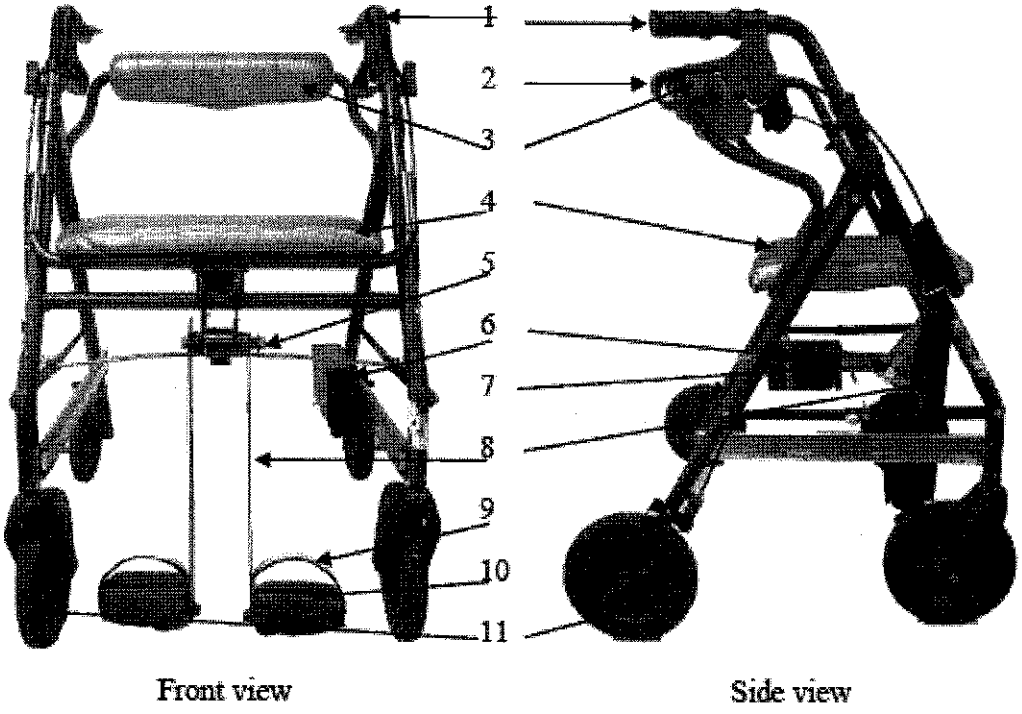


Table 3.7 below shows the dimensions of CATLoC:

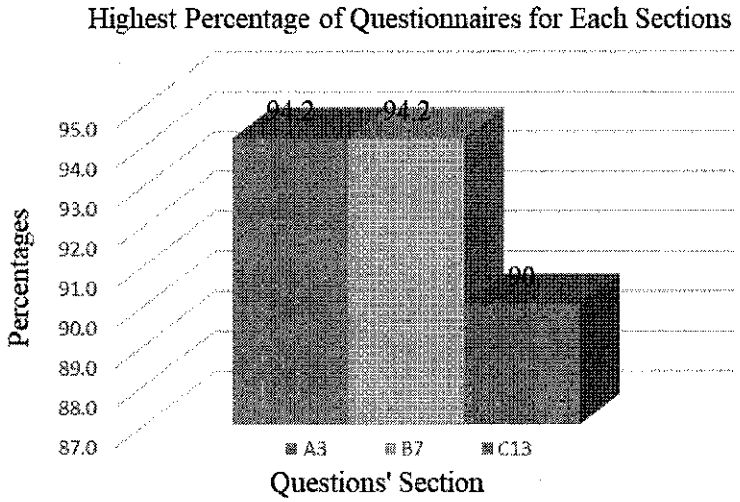
Table 1: Item labelled from prototype Figure 1

ITEM	DIMENSIONS
Height	80 cm (min) - 90 cm (max)
Width	60 cm
Length	48 cm
Height from ground to seat	55 cm
Flat rod	29 cm
Radius of wheel	9 cm
Seat's thickness	2.5 cm
Foot paddle height	3 cm
Foot paddle length	10 cm
Foot paddle width	7 cm

B. Questionnaire

The main purpose that we create questionnaires is to see the project from a different view of many people with different background. Data is collected from different ways such as set of questionnaires, and interviews. Based from all method use to do data collection, we have evaluated the results and is elaborated as follows. Questionnaires is divided into three sections; (A) Device Design, (B) GUI Program, and (C) Display and Gait in Cerebral Palsy (walking ability). The feedback collected is from a total of 24 respondents, 75% of them has a working status.

Figure 11: Graphical View of Questionnaires Analysis for Each Sections



Referring to Figure 11 above, it shows the highest percentage reached for each section. In section (A), the highest percentage reached for the first part is 94.17% where our respondents mostly agree on question 3 that asked whether CATLoC is suitable to be used for indoor activities. 87.5% of respondents stated that they would recommend this device to their acquaintance. 90.83% believed that CATLoC may ease the physiotherapy process for CP children. Other than that, 87.50% said that CATLoC is safe and suitable to be used by CP children. The lowest percentage hits 85.83% is about the usage of CATLoC as outdoor activities.

As for the second section (B) on the GUI program and Display, the highest percentage scored is also 94.17%. The question that gain highest score is about the application of GUI system. Respondents were asked whether the usage of GUI system for CATLoC is very helpful in this process. This result shows a very good result because our main features for this project is about creating the GUI display. Second highest percentage is 93.3% that is about the relevancy of GUI system to be used nowadays.

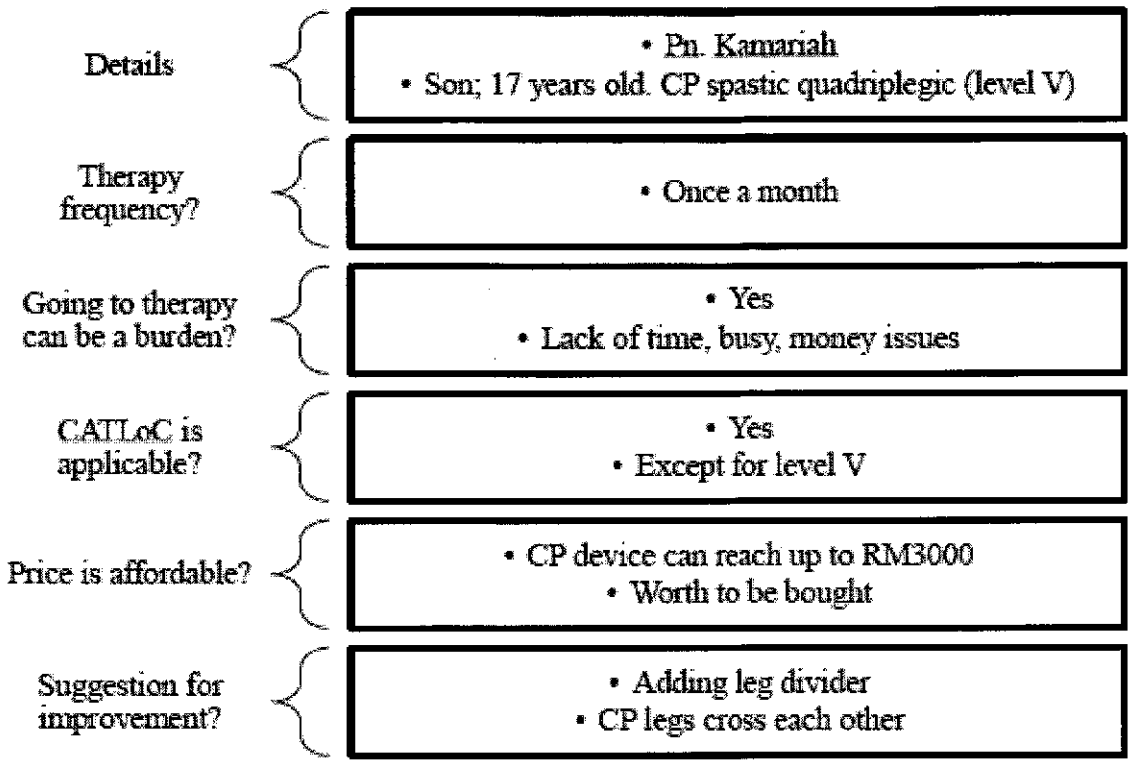
Besides that, scores that reached 90% relates with questions about the easiness to use the device. In this part there are two questions with the same lowest percentage which is 89.17%, are about the sufficiency of information displayed and the combination of GUI system and device is worth to be bought.

The last section of this questionnaires, section (C) is about gait in CP or their walking ability. Only this part consists 4 sub questions to be answered. The highest percentage is 90% that agrees on the usage of foot pedal on CATLoC can train and increase functionality of the foot muscle. Second highest percentage for this part reaches 89.17% for the question about frequent usage of CATLoC can improve CP children's walking ability. Next, 85% scored for the questions that relates with their knowledge about CP children's walking pattern is different compared to normal children. While for the lowest percentage is 78.33%, is about whether our respondents know about CP.

C. Interviews

After completion of product, we conducted a meeting with a parent who have a son with CP. We interviewed with consent and few questions were asked regarding their son's condition and therapy, and also about their view on CATLoC. The overall interview is summarized in Figure 12 below.

Figure 12: Summarization of interviewSections



CONCLUSIONS

CATLoC has undergoes various phases into its' completion. Starting from by brainstorming for the design, studies conducted based from previous research paper about CP and the problem existed for them and the family. With the usage of GUI system, it helps a lot in monitoring the user's activity. By using Visual Basic software, we have successfully created a GUI system that has main features to display the monitoring progress for swinging activity and can also keep previous data in log file.

In the data collection phase, we use few methods such as questionnaires and interview, we have collected quite a satisfying feedback for our data collection. Results from questionnaires shows that the highest percentage is about the usage for indoor activities, application of GUI and they believe that this training can increase CP's foot muscle functionality. Besides questionnaires, we also made a few feedback forms to be answered by the respondents. An interview was purposely made for us to see from the eyes of the parents who has CP children regarding this device. However, a further study should be made to ensure the effectiveness of using this project frequently. Future research should include an experimental procedure to test the product's durability and effectiveness. The procedure will start from before using the device until after using the device.

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