DESIGN AND DEVELOPMENT OF A
LOW-COST HAPTIC DEVICE

By

Ahmad Faidz Hamzan

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CERTIFICATION OF APPROVAL

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TRONOH, PERAK

January 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Ahmad Faidz Hamzan

ABSTRACT

This report discusses the research done on the selected topic, which is **"Design and Development of A Low Cost Haptic Device"**. This project shows the importance of haptic feedback and the interaction that will bring benefits towards the user in manipulating the haptic device. The main idea for this project is in designing and constructing a low-cost haptic device that will be used by the individual that would like to enjoy the impact that can be offered by the implementation of a haptic device in the daily activities (include working and learning activities, such as writing). A low cost haptic device that will be built needs to meet these three main functions, which are 'Act, Feel, and Understand'. It is important to design and construct the haptic device which will be based on the nature of the user itself (how they act, how they feel, and how they can understand) in order to support working and learning activities (such as writing and drawing). For the purpose of this report, there will be two main objectives that need to be identified for designing and constructing the low cost haptic device. The main objective for the completion of this report is in investigating the hardware and software requirements that will be used as a guideline. The hardware and software that is required for the designing and constructing a low-cost haptic device is carefully studied and examined in order to produce the compatible (product, price and usage) haptic device. Another objective is to examine the characteristics of current technology (Phantom haptic device) that is readily been offered in the market. The result of the study is mainly used in comparing a low-cost haptic device that will be built with the current technology that is available in the market. The literature review section discusses on the research and other related study that the author had done, which is on the pre-development and post-development of the project itself. The information that has been gathered throughout the completion of the project will be mainly used in designing and constructing a low-cost haptic device. It consists the entire information that are useful in finding the requirements of designing and constructing (hardware and software) of a low-cost haptic device. Besides from that, other useful related information such as the nature of the technology that is currently available. Apart from

that, the requirements that are needed for designing and constructing a low-cost haptic device are also being studied. In addition, the concept of haptic, which includes the understanding about the active force feedback and kinesthetic element also, will be discussed. In the methodology section, the author explained discussed about the process that has been implemented for designing and constructing a low-cost haptic device. The reasons of each process that were involved in the completion of this project will be elaborated in detail. Each process for the creation of a low-cost haptic device will be discussed in detail. This is important towards having a good understanding on the completion of a low-cost haptic device. The Gantt chart also is included in this report, as the main purpose of the Gantt chart is to ensure that the project is completed within the timeline and schedule. The completion of designing and constructing a low-cost haptic device needs to be ensured can be accepted and enjoyed by the individual who is in needed. Therefore, a low-cost haptic device has been tested on the respective individuals. The study findings indicate that the individual can enjoy the benefits that have been produced by the active force feedback from the creation of a low-cost haptic device. Apart from that, the result that has been gathered also will become valuable knowledge and information towards the enhancement and improvement that will be conducted in the future.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Haptic refers to the sense of touch that the human being have and how the human can understand their own physical environment by having the physical contact to the object. The entire senses that embedded in the physical of the human being also will be used in order to help the human to understand things. Apart from visual and auditory, the touch sense, which is also called as kinesthetic will play important role to help the human to understand things, as it is one of the most fundamental feel which will allows the human to have the sensation of the objects.

A haptic device involves physical contact between the computer and the user itself. The physical contact that will be made between the individual and the computer will act as an interaction for having a good understanding about the object that will be touched. Apart from that, the manipulation of the object by using the haptic device also is regarded as one of the important results that can be achieved by the implementation of haptic device. Thus, the implementation of the haptic device is useful towards the user to perform daily activities. The interaction that will be made between the individual and the computer is commonly through an input and output device such as joystick. This kind of interaction is important towards having a sense of the body's movements. In addition, the introduction of a haptic device will not only allow the individual to feed information to the computer but it will allow the individual to receive information from the computer. Therefore, the individual can enjoy the benefits that will be produced, in a form of a felt sensation on some parts of the body.

The kinesthetic element is important towards the individual, as this type of element will enhance the memory of the individual (user) in remembering the objects that have been touched and felt for working and learning activities. The sense of touch will become the vital information for the creation of the haptic device. The kinesthetic elements need to be included in the creation of the haptic device. The kinesthetic elements will allow the sense of ability in which it can control the body

movements and handle objects in a skillful manner. The user of the haptic device can express through the movement that will be made. Therefore a good sense of balance and eye-hand coordination can be achieved. This kind of interaction will allow the user to remember and process information. Apart from that, the kinesthetic elements can be explored for future activities, in which will bring beneficial aspects towards the user.

1.2 Problem Statements

The problem statements of this project in designing and constructing the low cost haptic device are:

- The current technology that is available in the market (example: Phantom), most specifically in the Malaysian market is too expensive towards the user. Besides from that, the price that is needed for acquiring the current technology also will become the main constraint in giving benefits for the user. Since the price in acquiring the current technology is expensive, not the entire user can have the opportunity to utilize the technology that is offered in terms of supporting learning activities. Therefore, a low-cost haptic (which will include the hardware and software, equipments and tools that are required) device will be built to act as another alternative that can be acquired by the user in order to support their working and learning activities.

- The focus will be on designing and constructing a low-cost haptic device to support the user's working and learning activities. The entire requirements that are needed in supporting the working and learning activities for the user need to be identified and carefully studied. This information is useful in building a low-cost haptic device that will be useful towards the user in the future.

- To ensure the characteristics of a low-cost haptic device that will be designed and developed can support or improve the current working and learning activities. A low-cost haptic device needs to be compatible with the current technology that is offered in the market. A low-cost haptic device must be able to response towards the nature of the user itself, where the user must be

able to act, feel and understand the presence of the haptic device in giving support towards the working and learning activities.

1.3 Objectives and Scope of Study

The objectives for developing this project are:

- To examine the current technology that could assist the user in working and learning activities. The information that has been gained will be mainly used in comparison work of study. It is essential towards the designing and constructing work of a low-cost haptic device, as the current technology that is available in the market will be set as a benchmark for a low-cost haptic device that will be built.
- To investigate the hardware and software requirements that is needed for designing and constructing a low-cost haptic device. The investigation work needs to be carefully studied. The study is important for making a decision towards the completion of the low-cost haptic device.
- To have a test on the value proposition that can be offered by the low-cost haptic device that will be built towards the user for working and learning activities. A low-cost haptic device needs to be able to assist the user in future activities and applications.

For the purpose of this report, the scope of study is focusing on the process and the requirements that are needed for designing and constructing the haptic device, mainly for supporting the working and learning activities towards the user. In addition to that, the nature of the dyslexic children also will be studied in order to come out with the suitable haptic device that can be used in the future. The study on the kinesthetic element, which is one of the important elements, which are helpful towards giving a support for working and leaning activities of the user, also will be carried. In this project, the author will use the research project that has been developed by Bill Verplank, a Professor from the music department of Standford University. The 'Plank', which is a simple haptic controller, will be used as a reference towards the author in designing and constructing a simple and a low-cost haptic device that will be used to support the working and learning activities for the user in the future.

CHAPTER 2

LITERATURE REVIEW

2.2 Haptic Technology

2.2.1 Definition of Haptic

Salisbury, Conti and Barbagli (2004) state haptic refers to touch interactions (which can be defined to as physical contact) that will occur for the purpose of perception or manipulation of objects. Haptic refer to annual interactions with environments, such as exploration and extraction of information that will be gained from the environment or the manipulation for modifying the environment and these kind of interactions may be accomplished by the physical contact made by human and the environment can be real or virtual (Srinivasan and Basdogan, 1997). Nowadays, most of the current virtual environments are well equipped with display devices, haptic devices (such as gloves) and also sound devices. These three devices are needed for having a simulation or giving the real environment experiences to the user in the virtual environment. In addition, haptic display that comes with force or tactile feedback can bring additional factors towards the user's experience of having an interaction with the virtual environment. The feelings or experiences that can be acquired by touching and physically manipulating objects in the virtual environment will provide a better representation for the real world towards the user. Srinivasan and Basdogan (1997) state some of the most popular application of haptic and virtual reality in today's technology is:-

- *Medicine*: surgical simulators for medical training, manipulating micro and macro robots for minimally invasive surgery, remote diagnosis for telemedicine, aids for the disabled such as haptic interfaces for the blind.
- *Entertainment*: video games and simulators that enable the user to feel and manipulate virtual solids, fluids, tools and avatars.
- *Education*: giving students to feel the phenomena at nano, macro or astronomical scales, 'what if' scenarios for non-terrestrial physics, experiencing complex data sets.

- *Industry*: integration of haptic into CAD systems such that a designer can freely manipulate the mechanical components of an assembly in an immersive environment.
- *Graphic arts*: virtual art exhibits, concert rooms, and museums in which the user can log in remotely to play the musical instruments, and to touch and feel the haptic attributes of the displays, individual or cooperative virtual sculpturing across the internet.

The stimulation real or imaginary scenes can be strived from the implications of virtual reality, where it will allows the user to have an interaction and perceiving the effects on every action that user does in a real time. Ideally, the user can only interacts with the stimulation via the entire five senses, but in most today's typical virtual reality applications will be relying on a smaller subset, typically vision, hearing and most recently, touch (Salisbury, and Conti, 2004).

Salisbury, Conti and Barbagli (2004) state that the touch interactions (physical contact made by human) can be between:-

- Human hand and a real object.
- Robot-end effect or and a real object.
- Human hand and a stimulate object (bio haptic interface device).
- Variety of a combination of human and machine interactions with real, remote and variety objects.

The interaction between human users and haptic interfaces are shown in detail in the figure below (Srinivasan and Basdogan, 1997):-
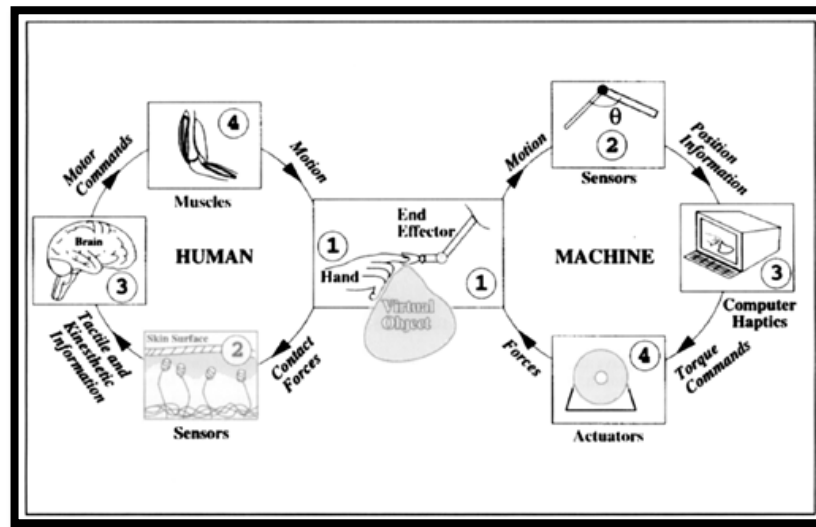
Figure 1: Human Users & Haptic Interfaces

- *Human sensory motor loop*: when the user touches the virtual object in the interface, the skin will feel the forces imposed by the device. As the skin feels the force/touch, this information will be sent to the brain, thus the brain will create a perception based upon the information. The brain responds by activating the muscles and resulting in the hand and arm motion of the user.

- *Machine sensory motor loop*: when the user manipulates the haptic device, the tip position of the device will be sent to the computer by the position sensors. A calculation of the torque commands to the actuators of the haptic device will be done by the models of objects in the computer in real time once they receive this input, thus resulting in the appropriate reaction forces to the user. This will let the user to feel the actual perception of virtual objects.

Besides from the information that are described above, another important information that needs to be acknowledged is the human haptic system consists of the entire sensory, motor and cognitive components that made of the body-brain system for the human. Haptic device provides a position input towards the user as an example of mouse that will stimulates the senses of touch by applying the output towards the user in the form of forces. Oakley, McGee, Browster, and Gray describe two important aspects of haptic terminology:-

- Kinesthetic: meaning the feeling of motion. It relates to sensation originating on muscles, tendons and joints.
- Force Feedback: it relates to the mechanical production of information which is sensed by the human kinesthetic systems.

2.2.2 Haptic Interfaces

In interacting with virtual environments using haptic interface, the human user conveys desired motor actions by physically manipulating the interface, which in turn, displays tactual sensory information to the user by appropriately simulating user's tactile and kinesthetic sensory systems (Srinivasan and Basdogan, 1997). Some of the devices that can be used in describing simple haptic devices are keyboard, mouse and trackballs. These devices are commonly used and known by most of the people nowadays, as the usage of computers in the daily life is generally known. In other hand, the complex haptic device can be in the manner of gloves, exoskeleton that will track the movement of the body and suits. However, these kind of examples (both simple and complex haptic devices) cannot convey the touch and feel of objects towards its user. This is mainly due to the characteristics of these haptic devices as they could only be conveyed by tactile or force feedback.

According to Srinivasan and Basdogan (1997), there are two types of distinction among haptic interfaces. The first method to differentiate two types of distinction is on determining whether they are tactile displays or net force displays. Net force displays are basically haptic interfaces in which the simulation or the feeling of the virtual world is only done through a rigid stick (tool). On the other hand, tactile displays are more difficult because it simulates direct contact with objects and it requires a capability to distribute the net forces and torque appropriately over the region of contact between the object and the skin. The second method that can be used in differentiating haptic interfaces is to determine whether the interface is ground-based or body-based. Ground-based haptic interfaces like force reflecting joysticks are interfaces that reside on the ground while the user is using and or interacting with the joysticks whereas body-based haptic interfaces like the exoskeleton resides on the user's body while he or she is using or interacting with it.

In order to achieve the high performance of haptic devices, the human study needs to be performed as the performance of haptic devices rely on the human's (which will become the user) abilities and limitations. The haptic interfaces that can stimulate the virtual environment closest to the real environment, accurate and approximate will be the most preferable one. Ground-based force-reflecting devices such as PHANTOM (designed by SensAble Technologies, Inc.) and the The Impulse Engine (owned by Immersion Corp.) are currently regarded as the best performance of haptic interfaces (Srinivasan and Basdogan, 1997). Salisbury, Conti and Barbagli (2004) state characteristics that are commonly are considered as desirable for haptic interfaces are:-

- Low back-drive inertia and friction.
- Minimal constraints on motor which are imposed by the device kinematics, resulting the free motion to feel free.
- Symmetric inertia, friction, stiffness and resonate frequency properties.
- Balanced range, resolution and bandwidth of position sensing and force reflection.
- Proper ergonomics that left the human operator focuses wearing or manipulating the haptic interfaces as pain, or even discomfort, as it can bring the distraction towards the user, thus will reduce the performance.

2.2.3 Phantom Haptic Device

Salisbury, Conti and Barbagli (2004) state the rendering as the process in which the desired sensor stimuli are imposed on the user with the main focus for conveying information about a virtual haptic object. The main objective for designing a haptic rendering method in the early stage was only focusing on displaying simple, right and frictionless objects. Massie and Salisbury have been developed the Phanton haptic interface device and had proposed a point-based method which the main usage of this method is primarily for rendering primitive objects such as cube, cylinder and sphere (Srinivasan and Basdogan, 1997).

Figure 2: Phantom Haptic device

The Phantom Haptic device is a device that will let the user to literally feel virtual objects with the user's hands (Salisbury, Srinivasan, 1997). The Phantom haptic device literally looks a miniature desk lamp and it allows the user to have an interaction in the same manner as if the user holds the pen, and using the pen to touch objects and shapes. By using the Phantom haptic device, the user will be able to have feelings on the shape of the object (tactile display) by moving the pen around, as if the pen touches the object.

The sense of touch or haptic interaction is one of the basic ways that can be implemented by the human being to have an interaction with the world. The main reason for this is mainly due to the human understanding about the things that are available with their senses. The most important senses that human being has in order to have a good understanding about the physical world is a touch feedback. The creation and establishment The Phantom haptic device in the market is widely considered as another effort that can be utilized in order to create or integrate the human's understanding and or interaction towards the physical world into virtual and or stimulated world.
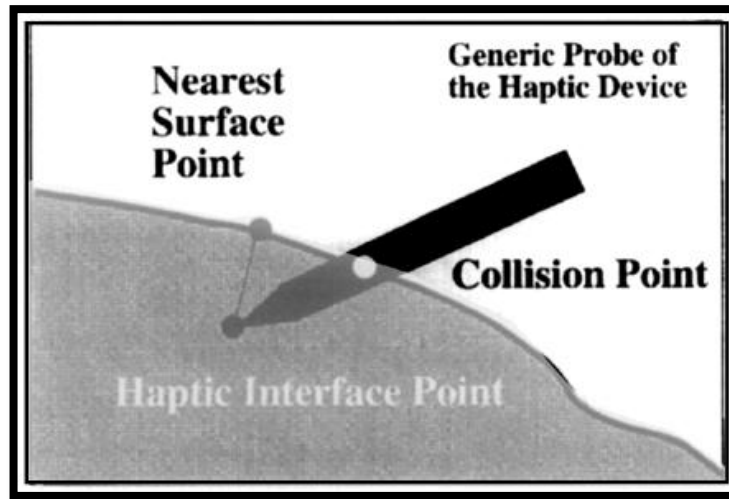
Figure 3: The Haptic Interface Point

The important figure and or value proposition for the Phantom haptic device is mainly due to the distance between the 'Haptic Interface Point' and 'Nearest Surface Point'. The calculation is involved for determining the force vector. Besides from that, the Phantom haptic device also involved the division (dividing) of the objects into sub-spaces which are associated with particular portions of the object's surface. A virtual scene can be constructed when superposition of surface normal will be used for calculating the resultant force vector once the 'Haptic Interface Point' enters the region shared by multiple sub-spaces. However, there are problems which are related with this kind of haptic approach. First, it will be really hard to divide objects into sub-spaces or to construct a virtual environment from the primitive objects and secondly, the superposition of force vectors will breaks down for thin or complex shaped objects (Srinivasan, Basdogan, 1997).

The Phantom haptic device delivers some advantages towards the user. It does not constrain motions within its workspace. The user of the Phantom haptic device will certainly not feel distracted while using the device, as the inertia and friction that are designed are low, which will bring the result of free motion, feels free and comfortable. In addition, the Phantom haptic device provides a very convincing display of object impact, rigidity and close realistic sensation to its users and it is mainly due to its relatively large dynamic rang in force output (is the ration of the largest to the smallest displayable force) and a compatible match with human resolution and bandwidth.

The Phantom haptic device will certainly have great impacts towards the user for working and learning activities. Besides, the Phantom haptic device also will deliver the amount of beneficial aspects that can be acquired by the user in every activity that are designed towards their own development progress of working and learning activities, in terms of interactivity. The user will also be able to have a good understanding on every subjects or information that will be given towards them, and be able to remember better about subjects or information that have been learned previously by implementing the Phantom haptic device in their learning activities. This can be achieved as the kinesthetic values are designed in the Phantom haptic device and it is certainly helps the working and learning process of the user (visual and auditory input).

2.3 Haptic Controller

2.3.1 Simple Haptic Controller

The 'Plank' or a simple haptic controller is an idea that has been designed by Bill Verplank, a researcher from Music Department, Stanford University. The 'Plank' is made from the old hard disk drive, and will be focusing on the usage of the head-positioning voice-coil actuator to move a cylindrical surface of it by removing the disk from the hard disk drive (Verplank, and Georg, 2011). The concept of the 'Plank' is by utilizing an active force feedback that will hold the potential for having the precision and rapid controls. Verplank, Gurevich, and Mathews (2002) state that the high performance device can actually be built from the surplus disk drive and it can be controlled from an inexpensive controller. Therefore, an axis force-feedback of the plank will certainly will be the main focused on designing the 'Plank' as the axis will comes with a limited range of motion.

Figure 4: The 'Plank'. Disk Drive Before and After

The creation of the 'Plank' is being compared with the available haptic device that is currently in the market. The Phantom haptic device has been chosen in order to make the comparison between the 'Plank' and the Phantom itself. The main idea for this comparison work is to identify and explore the value of the force-feedback. The main discovery that has been found from the comparison work is the simple spring-mass simulations, which are uncontrollable without force-feedback, and it shows that this type of simulations can be controlled simply by having or letting the vibrating system transfer energy to the human (Verplank, Gurevich and Mathews, 2002). Besides from the discovery that has been found, there is other several syntheses that has been developed as the result from the comparison work. The other scanned synthesis that has been found is (Verplank, Gurevich, and Mathews, 2002):-

- A dynamic wave shape at human-hand frequencies will be directly manipulated while scanning the wave shape out of radio frequencies.
- The length of the wave and the scan rate will be observed for determining the pitch.
- The wave shape which is being continuously controlled by the performer will be taken for determining the timbre.

There are number of illusions that need to be acquired by the designing and creation of the 'Plank'. The design work of the 'Plank' is to take an advantage of

several illusions (particularly in haptic illusions) that will allow the user to reduce the complexity of the device while the heptics fidelity shall be maintained (Verplank, Gurevich and Mathews, 2002). The key feature of the 'Plank' is on the surface that will give an interaction between the user and the haptic device.
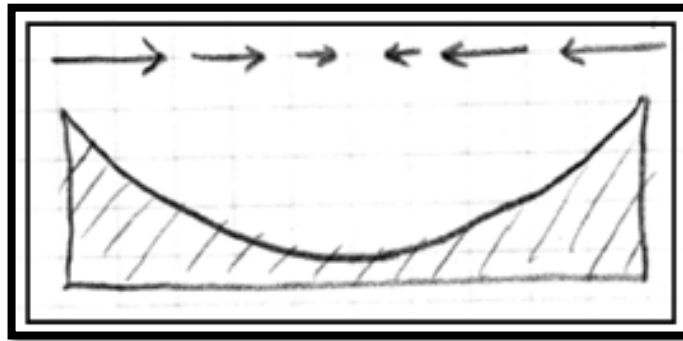
Figure 5: The 'Plank'. Slope Illusion

The slope illusion is also play a very crucial part in designing the 'Plank'. When the user of the haptic device (the 'Plank') presses down on a surface of the device, it will pushes back towards the user, in which will come with a 'surface normal' perpendicular to the space. The device will generate the force-feedback in which will give the illusion of slopes of a surface, thus the small variations in force as the user of the device moves along the surface will be felt as bumps (Verplank, Gurevich and Mathews, 2002).
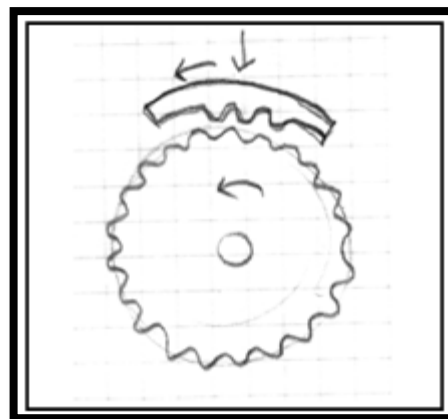
Figure 6: The 'Plank'. The Haptic Clutch

A variety of dynamic systems can be stimulated by having an engagement by the applying forces from the user on the device. The main function of the haptic clutch can be generated when the user engages with a stimulated moving object by

pressing on the 'Plank'. Verplank, Gurevich and Matthews (2002) state that this kind of technique will only compensates for the limited travel of the 'Plank' itself and will allow the illusion of wide reach.

2.3.2 The 'Plank' and Music

The haptic device can be used in order to help the musician to perform their musical presentation in a better way. In addition, the haptic device can also be manipulated and utilized by the musician or performer in order to improve the quality of the musical performance. The usage of haptic (particularly force-feedback) for controlling the music controller has been explored by the expert for more than fifteen years of time (Verplank, and Georg, 2011). With the increasing awareness about the importance of haptic in human life has encouraged most of the experts on making a research about the performance of the haptic. The advantages of using haptic in a human life will certainly bring amount of beneficial aspects towards the user, particularly in helping user towards the musical learning activities. The active force-feedback will be used by the haptic interface and it is widely been used for emulating the current existing instruments and also for making the conventional music (Verplank, and Georg, 2011).

The 'Plank' will not only can be utilized and used by the normal human being, but it also can bring lots of beneficial aspects towards other type of human being, such as dyslexic people. The value of the 'Plank', which is the force-feedback, will certainly give lots of advantages towards the user, focusing on the user to remember better towards their working and learning. The importance of haptic will certainly be helpful and useful towards the human being activities, as it can accommodate people who are kinesthetic and tactile learners, as the presence of haptic will make the people to understand better and remember more when education involves movement and touch (Sulaiman, Wan Ahmad, Awang Rambli, Hasbullah and Goh).

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is important towards the author for carrying out the research on the creation of a low-cost haptic device in supporting working and learning activities for the user. Therefore, each process that will be carried out by the author needs to be well taken care. An author will give explanations for each step or process in order to derive the answers and results of a research paper. Besides from that, in the methodology section also, the author needs to explore any options that are available in order to complete the creation of a low-cost haptic device. The option that will be found by the author needs to be ensured that it will be reasonable and suitable for the completion of the research paper. It is important for the author to maintain the step and process that will be taken for the completion of the project.

The process of designing and creating a low-cost haptic device needs to be conducted in six steps or processes that are important towards the completion of a low-cost haptic device. The main important function for the creation of a low-cost haptic device is mainly focusing on the value proposition that can be brought by the introduction of a low-cost haptic device towards the user. Therefore, the characteristics of the haptic device that will be created need to be able to be used by the user towards giving a support for working and learning activities. This is important to ensure that the low-cost haptic device can be fully utilized by the user to fulfill the potential that can be raised in working and learning activities.

Besides from explaining each step or process that needs to be carried out, the author also needs to give details about tools, equipments, materials and parts that will be used for the completion of a low-cost haptic device. The information about the necessary tols, equipments, materials and parts are as important as step or process that needs to be carried. The list of tools, equipments, materials and parts that are necessary needs to be listed for the further improvement, if there is a need to do so. In addition, the selection of tool, equipments, materials and parts that will be used

for completing the research paper is based on the requirements and standards that need to be achieved by the author for creating the low-cost haptic device.

There will be six important steps that are selected by the author in completing the research paper. Each step or process that will be briefly discussed is selected based on its own suitable manner. Thus, each step or process that is selected will be based on the understanding, ability and capability of the author on the respective subject. The six steps that need to be carefully examined by the author towards the completion of a low-cost haptic device are listed below:-
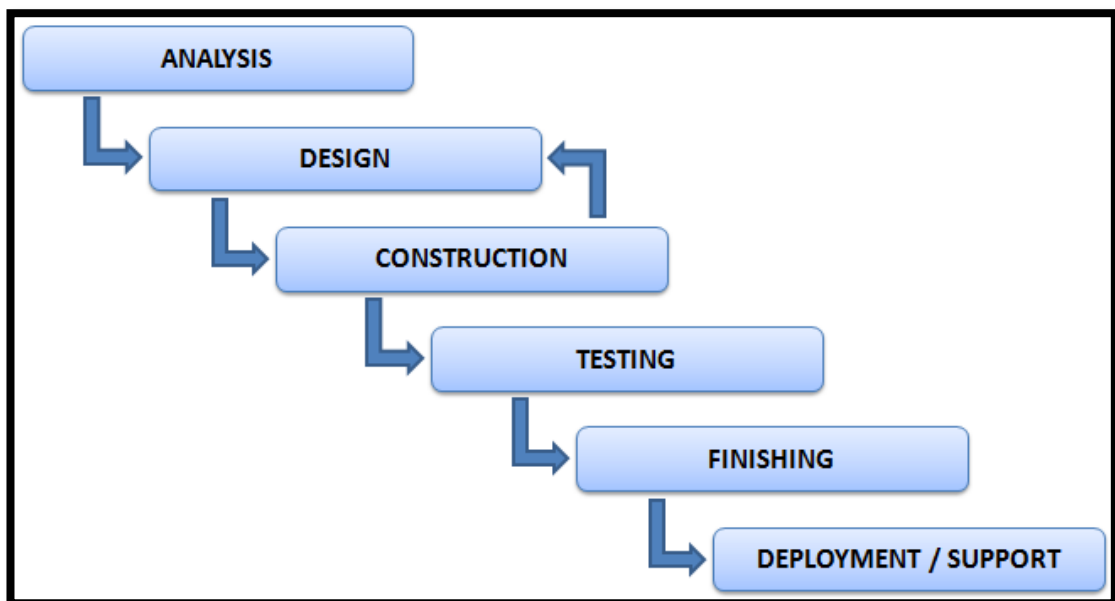
Figure 7: Steps for the Creation of a Low-Cost Haptic Device

Based from the figure that is shown above, the entire six steps that need to be undertaken by the author should be followed in a sequence. It is important for the author to understand each steps or processes that need to be taken in a well manner. This is to ensure that the low-cost haptic device that will be built can be completed according to the expected result that has been agreed. Each steps or processes that will be completed will produce the results that are necessary towards the author in order to gain valuable information for the completion of the low-cost haptic device. Thus, a low-cost haptic device that will be built can meet requirements that are needed by the user towards working and learning activities. The main idea for the creation (which include the design and construction work) of a low-cost haptic device is to give a support towards the user to establish the potential of a low-cost haptic device. Therefore, the characteristic of a low-cost haptic device needs to be

built based on the requirements and specifications that are suitable for the user in conducting working and learning activities.

In addition, each steps or processes that will be gone through by the author should be maintained in a correct manner. Any adjustments that will be made during the production period of a low-cost haptic device will affect the completion of the research paper. The evaluation of each step or process needs to be carried out by the author for acquiring the best result. The result that will be produced needs to be documented for further investigation and experimentation.

3.2 Analysis

The first step that needs to be taken by the author before the design step can be taken into action is the analysis work. The analysis work needs to be done and completed by the author in order to collect the useful information and requirements that are needed for the creation of a low-cost haptic device. This is important as the information that will be collected will based on the research (journal, other research from local and international researchers), and also by having a discussion with other personnel that are involved. The communication that will be made between the authors will be focusing on acquiring the knowledge and skills that are needed for the creation of the low-cost haptic device. Besides from having a communication with the respective personnel, the author also will have to make a research work, based on the research journals that have been produced by the experts in the respective field of study.

The information that will be gathered are useful towards the author to ensure that these information can be used as the requirements that are needed for a low-cost haptic device. Throughout the analysis process, the author needs to be able to find any obstacles that will bring any effects towards the completion of the low-cost haptic device that needs to be built. This is important towards the author in order to find any available options that can support the completion work of a low-cost haptic device. In addition, by having an analysis work, the author can develop a strong understanding towards the creation of the haptic device. This can be done by having an interaction and communicating with the experienced person. However, the author

needs to ensure that the knowledge and information that will be gathered are relevant towards the creation of a low-cost haptic device.

3.3 Design

The design work that needs to be performed by the author will be based on the characteristics of the user (the understanding of the user's behavior through the observation work), and also will be based on the findings (information and requirements) that are collected from the analysis work. In the design work, the author needs to act as the designer, where the fundamental of design work needs to be well understood. The fundamental of design is to improvise the previous design that has been made earlier. For the completion of this project, the author needs to be able to come out with the design that will bring benefits towards the user in the future. Besides from that, it is important towards the author to create a design of a low-cost haptic device that can meet the characteristics of the user itself. Therefore, the characteristics and important features of a low-cost haptic device that is built need to be understood by the user towards giving a support in working and learning activities.

The completion of the design work will be achieved by having a communication with the creator of 'the plank' (simple haptic controller), Bill Verplank. The communication and relationship that will be built with Bill Verplank is important towards having a good understanding on the circuit design and working system of the haptic device. Therefore, any ideas regarding towards the changes that will be made for the author to build the haptic device will be based on the advice that will be given by Bill Verplank and from the consultation session with the personnel who has the knowledge on the electric and electronic study. In addition, the author should be able to find the tools, equipments, materials and parts that are needed in constructing a low-cost haptic device. The author should be able to come out with the list tools, equipments, materials and parts that are essential for the completion of the haptic device. Therefore, the necessary knowledge should be acquired by the expert and experienced personnel in assisting the author in finalizing the design work of the haptic device. These kinds of assistance are essential for the author to maintain the

progression of work with the schedule that has been projected due to the time constrain that the author has throughout the completion of the haptic device.

3.4 Construction

After the approval has been received by the supervisor, the construction work of a low-cost haptic device will get started. The approval from the design work is essential towards the author as the design work that has been produced and completed will be used as a reference towards the creation of a low-cost haptic device. In the construction work, there are several tools that need to be used by the author. Besides from that, the author also needs to ensure that the parts and materials that will be used for the creation of a low-cost haptic device are suitable for the user (focusing on the usability of the user). In addition, it is important for the author to finalize the specifications that are necessary for the completion of the low-cost haptic device. The specifications of a low-cost haptic device are important as the author should come out with a low-cost haptic device that is suitable for the usage of the user in working and learning activities. The specifications of a low-cost haptic device will be constructed based on the design work that has been performed earlier.

Throughout the construction process of the low-cost haptic device, the author needs to be able to find out any possible solutions that can help improving the construction work in the future. Any future additional knowledge and information that are necessary need to be stated by the author. For the construction process of the creation of a low-cost haptic device, the collaboration needs to be made between the author and the technicians. The collaboration that will be made between the author and the individuals that involved (experts and practitioners) will play the important part towards the creation of a low-cost haptic device. Additional helps and guidance are important towards the author for adding its own current knowledge and skills for this project.

3.5 Testing

The testing work will be performed by the author after the construction work of a low-cost haptic device has been completed. During the testing work activity, the author needs to come out with the testing work that will be focusing on the characteristics and value propositions of a low-cost haptic device that will be built, based on the requirements that have been collected earlier. This is important towards the user itself, as the low-cost haptic device that will be built needs to be in a suitable manner. A low-cost haptic device must suits with the needs that will be made by the user, particularly in supporting the user towards working and learning activities. Besides from that, the author also needs to make a comparison work (based on the research study that has been conducted) with other haptic devices that are available in the market.

For the purpose of the testing work, there will be two types of testing work that shall be done by the author. The first testing will be the integration testing, followed by the user testing. These types of testing work are important towards the author in order for a low-cost haptic device that will be built can be used by the user in a safely manner. The results and discussions, mainly focusing on the low-cost haptic device will be made in order to support the value propositions that can be acquired by the user in the future by using the low-cost haptic device in their learning activities. The inspection work also shall be done by the author in order to test the low-cost haptic device reliability towards giving a support towards working and learning activities that will be conducted by the user in the future.

3.5.1 Preparation for the Testing Work

In the preparation for testing work, the author needs to be able to think very carefully about the characteristics of a low-cost haptic device that needs to be tested. This is important towards the author in finding the correct information towards the completion of a low-cost haptic device. Besides from that the author also needs to minimize the variability in performance of the low-cost haptic device itself, in which it could be caused by factors other than the objective of the testing work that need to be done. The important point that needs to be tested is to ensure whether the low-cost haptic device that will be built can be useful and suitable towards providing a good support for the user

It is important for the author to understand the benefits that will be produced by the low-cost haptic device. Therefore, the author needs to understand the results that will be brought by the creation of a low-cost haptic device. Besides from that, the author also needs to identify the suitable method that can be assisted by the presence of a low-cost haptic device towards the working and learning activities of the user. The working and learning activities that will be performed by the user should be supported by the introduction and implementation of a low-cost haptic device.

3.5.2 During the Testing Work

Throughout the whole duration during the testing work, the author needs to be able to identify any additional information that can be used in order to improve the effectiveness and efficiency of a low-cost haptic device that will be built. Any findings are important towards the author for having a good understanding of the characteristics of a low-cost haptic device that will be offered towards the user's working and learning activities. In addition, the observation work also should be managed and well taken care of by the author, as during the testing work, the author may find any default or error of a low-cost haptic device that is being tested. The error that may arises during the testing work needs to be addressed by the author before any further action can be made for the completion of a low-cost haptic device that will be built.

3.5.3 After the Testing Work

The completion of the testing work happens when a low-cost haptic device is said to be compatible and can be used by the user. After the testing work has been completed, the author needs to come with the analyzing work, focusing on the results that will be projected during the testing work. The additional analyzing work is important towards the author in finding any useful information that can be used in order to improve the characteristics of a low-cost haptic device that will be built. Besides from that, from the analyzing work also, the author will be able to use any useful information for making an improvement towards a low-cost haptic device. In addition, any suggestions that will be made by the author from the analyzing work also are important towards making any changes for improvement in the future.

3.6 Finishing

The quality control and quality assurance of a low-cost haptic device that will be built needs to be done and carefully inspected by the author. A low-cost haptic device that will be built by the author needs to be maintained in a safe manner, as this device will be used by user towards working and learning activities. By having the quality control and quality assurance, the features and the characteristics of the low-cost haptic device can be assured. Thus, it will increase the level of confidence of the user of this low-cost haptic device in the future. In addition, it is important for the author to conduct the quality control and assurance in a very carefully manner, as a low-cost haptic device that will be built should be maintained in a high quality, and it is important to acknowledge that the creation of a low-cost haptic device that will be built will not be only used by the user, but also for future students that will make an additional research and improvements of a low-cost haptic device in the future.

3.7 Deployment and Support

The last stage or the process of the creation of the low-cost haptic to support the user's working and learning activities is on the deployment and support. In this stage, the author should be able to come out with any additional knowledge and information that can be useful towards the future of a low-cost haptic device that will be built. Any additional information and knowledge that will be generated by the author is important for having its own pattern in the future. Besides from that, by having its own pattern, the author can make a modification on the low-cost haptic device that will be built, as the pattern that will be generated should be able to increase the quality and characteristics of a low-cost haptic device that will be offered towards the user in the future. This is important, as the author feels the importance of potential benefits that can be offered by the introduction and implementation of a haptic device in the future. Therefore, the beneficial aspects that can be brought by the introduction and implementation of the haptic device shall be appreciated and acknowledged.

CHAPTER 4
RESULTS AND DISCUSSIONS

Recorded in this section is on the expected outcome and result made by the author towards the completion of the design and development of a low-cost haptic device. This section consists on the finding results from the research work that has been done by the author, the analysis and design work of a low-cost haptic device and also on the challenges that have been faced by the author towards finding the necessary information for the creation of a low-cost haptic device. The entire information and knowledge that have been gained are clearly described and explained by the author in this section. Thus, it will be useful towards the future works, mainly focusing on the enhancement and improvement activities that will be conducted. Therefore, the continuity of this project is expected by the author towards the implementation of a low-cost haptic device in the future.

In order to enhance the understanding of the concept of haptic and the creation of a low-cost haptic device, the author also has received the consultation from the experts in the respective field. The communication has been made with the Bill Verplank, the creator of the 'The Plank'. It is important for the author to have a strong foundation regarding towards the creation of a low-cost haptic device that will be built. In addition, the author also has received the support and consultation from the respective personnel regarding towards the understanding on the design work of the electric and electronic diagram (circuit diagram), as the design of circuit diagram is one of the vital parts of a low-cost haptic device that will be built. In order to produce the circuit diagram for a low-cost haptic device, the author needs to acquire the necessary knowledge in electric and electronic study. This is important towards the author for having ideas on the design work of the circuit diagram. In addition, the circuit diagram that will be designed will determine the results that will be produced. Therefore, the results of the working mechanism for a low-cost haptic device shall be achieved and in accordance with the expected results that have been agreed, based on the requirements that have been set.

4.1 Finding on the Literature Review Research

The Phantom haptic device is one of the devices that have been introduced towards supporting the working and learning activities of the user. Besides from that, the haptic technology has been regarded as the important aspect that needs to be appreciated. The haptic device can be useful towards many kind of applications, in respective industries. With the implementation of Phantom haptic device towards the working and learning activities of the user, the user will be offered with the beneficial aspects that can be acquired, in which the user will be able to have feelings on the shape of the objects that have been touched. The interactions that will be occurred from the purpose of perception and manipulation of the object can only be achieved by the presence of haptic.

Based on the research that has been conducted by the author, the results of findings that have been acquired by the author towards having a good understanding for the completion of this report (design and development of a low-cost haptic device) are listed below:-

- Haptic is referring to the sense of human touch that human being have. It is on the mechanism for understanding the physical environment by having the physical contact with the object.
- The kinesthetic element that can be developed by the presence of haptic is important towards the user, where it can enhance the memory of the user by helping them to remember objects that have been touched by them in working and learning activities.
- The haptic device that is currently available in the market will become the main reference towards the author in the development of a low-cost haptic device. The characteristics and features of a haptic device that is currently available is being studied by the author in acquiring the ideas and information that are useful towards the development of a low-cost haptic device.

4.2 A Low-Cost Haptic Device

The author believes that a low-cost haptic device that will be built is feasible enough to be constructed from the scratch, rather than buying it (due to the expensive price for purchasing Phantom Haptic Device). The creation of a low-cost haptic device will bring lots of beneficial aspects towards the progression and positive results that can be brought through the working and learning activities for the user of a low-cost haptic device. Besides from that, the cost that is needed for acquiring a haptic device that will be built also is considered as competitive and reasonable. This can be done as a low-cost haptic device that will be built is a simple haptic controller, and the materials that will be used for the creation of a low-cost haptic device come from the recyclable and reusable materials. Apart from that, the materials and parts that are needed in designing and constructing a low-cost haptic device can be acquired easily, as they are all readily available in the market. A low-cost haptic device that will be built also can be used not only for the normal user but it also can be introduced and enjoyed by the dyslexic users towards their learning activities. By having a support from the low-cost haptic device, the progression of the dyslexic children can be more meaningful and can be enjoyed by the dyslexic children in the future.

4.3 Analysis

The analyzing work that will be conducted by the author will be focusing on having a good understanding about the characteristics of the creation that is made by Bill Verplank, which is called as The 'Plank'. The information that will be gathered is important towards the author for the creation of a haptic device that will be used for giving supports towards working and learning activities for the user. Besides from that, it is important for the author to create and develop the haptic device that will be useful towards the user as kind of assistance towards having a good result from working and learning activities that will be conducted.

The author also needs to have a good understanding on the concept of haptic itself. By having a good understanding on the concept of the haptic, it will be useful towards the author for having a correct decision that will be implemented in a low-

cost haptic device that will be de developed. The development of a low-cost haptic device should include the important elements of haptic. In addition, the author feels that the concept of haptic should be regarded as the main important study for the completion of this project. The information and knowledge that can be acquired by performing a study on the concept of haptic are useful towards the author.

The creation of Bill Verplank, which is called The 'Plank' has become the main reference towards the author for the design and development of a low-cost haptic device. Therefore, the author needs to have a set of mind as a designer in order to understand and have feelings towards the creation of a low-cost haptic device. In order to have that kind of manner, the communication that will be made between the author and Bill Verplank needs to be built and maintained. The communication that will be made is important towards the author in seeking the additional information and knowledge about the haptic and kinesthetic elements. The comparison of study on the concept of haptic and kinesthetic elements has also been conducted by the author.

In addition, the study on the working mechanism of The 'Plank' also has been performed by the author. The results of this study are being used by the author in making any consideration that is needed towards the design and development of a low-cost haptic device. Apart from that, any available option that is found from the study that has been conducted by the author is useful towards the creation and completion of a low-cost haptic device.
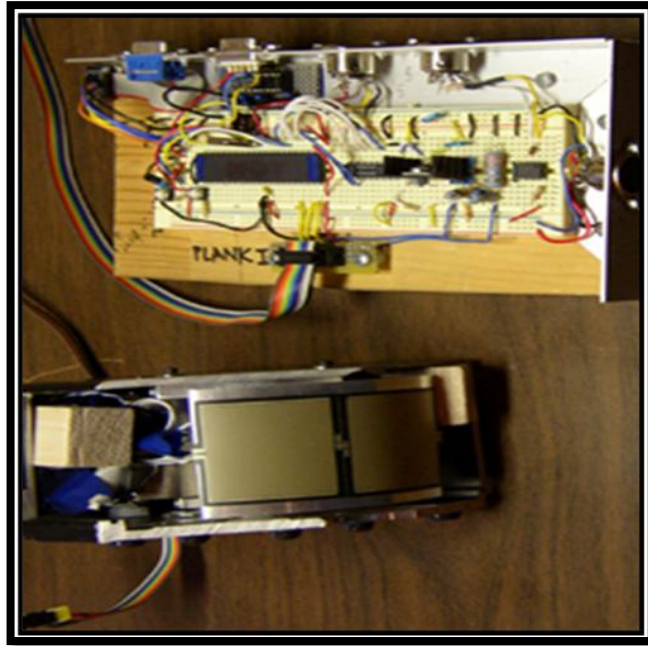
Figure 8: The 'Plank'

4.4 Design

4.4.1 Hardware Requirements

For the completion of a low-cost haptic device, the author needs to find the solution towards hardware requirements. The entire hardware that will be used to assemble a low-cost haptic device needs to be ensured in a precise manner. This is important as the selection of hardware parts will be helpful towards the completion of a low-cost haptic device that will be built. For the completion of hardware requirements, the author has worked closely with the creator of 'the plank', Bill Verplank. With the assistance that has been given by Bill Verplank, the author has managed to find the suitable materials for the hardware part. In addition, the views and opinions that have been made by other skilled personnel also have given lots of contribution in completing the hardware part.

The list of materials that are used for the completion of a low-cost haptic device (for hardware requirement) is listed below:-

i.   Arduino Uno Starter Kit
ii. Hard disk drive
iii. Electronic Breadboard

iv.   Quadruple Half-H Driver (L293NE)

v.   DC Motor (3V to 12V)

vi.   9V Battery Clip

vii.   T Hall Effect Sensor, UNIPLR, 3SPI

viii.   Magnet Suited Sensor

ix.   2 Way Switch (On and Off)

x.   Jumper Wire (single core wire)

xi.   Light-emitting Diode (LED)

xii.   Resistor

xiii.   Variable Resistor

4.4.2 Software Requirement

The programming language that is used for the completion of a low-cost haptic device is C++ language. C++ language has become the main preference for the author to come out with the solution for meeting the software requirement. The main reason for the author in selecting C++ language is due to its own characteristics. C++ language is also known as 'Human Readable Code' where the author can manipulate the program that will be coded into the Arduino microcontroller board.

Figure 9: Arduino Splash Screen

Arduino is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. The Arduino programming language is an implementation of wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment. Most Arduino supplied libraries are written in C++ and any sketch using these libraries is using C++ constructs. Some of the libraries are built around object-oriented programming: for instance Wire and some of the Liquid Crystal Displays (LCD) libraries. The hardware Serial interface also has its library written in C++.
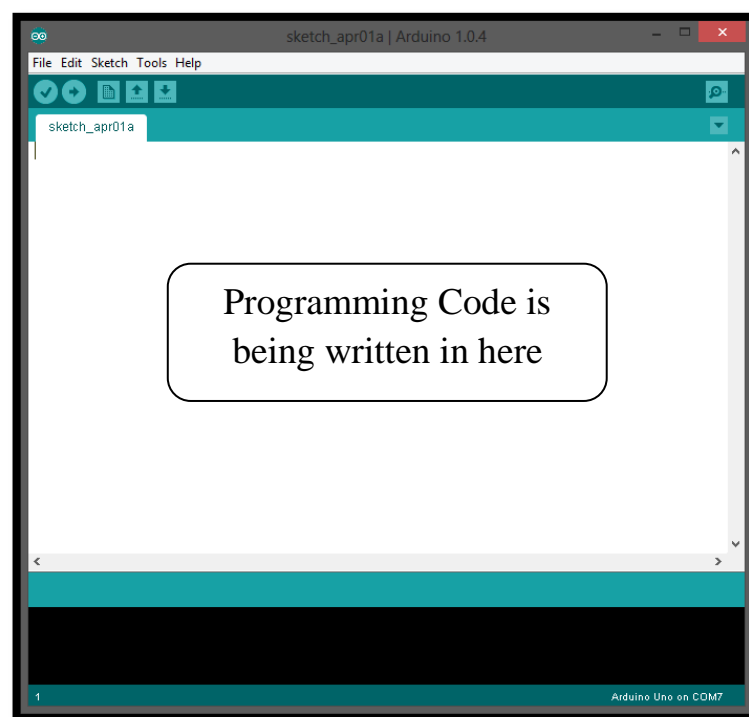
Figure 10: Arduino Programmer

4.4.3 The Arduino Module

The core part of the low-cost haptic device is Arduino module itself. The Arduino module will act as the brain for the low-cost haptic device that will be built. For the completion of this project, the author has made a research about the benefits that will be offered by the selection of Arduino module in fulfilling the hardware part. Based form the research that has been made, it can be said that the Arduino module is a simplified microcontroller board. The original design of the Arduino module will include the electronic parts that are necessary in powering and

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communicating with the microcontroller regulator, USB-to-serial interface, and SPI (Serial Peripheral Interface) programming interface. In fact, the Arduino board is more than a piece of hardware. The Arduino board that will be used by the author also will allow the author to program and have a communication with it, in which will make more interactive way in working with the Arduino module, and make the project to be more useful.

Figure 11: Front and Back View of Arduino Uno Starter Kit

The decision on selecting the Arduino module to become the core part for the completion of a low-cost haptic device is based on the benefits that are offered by Arduino. The benefits that are offered towards the author by selecting the Arduino module are listed below:-

- It is an open-source project, in which the software and hardware requirement is extremely accessible and it is very flexible to be customized and extended for future works
- The flexibility that is offered is useful for a variety of digital and analog input, Serial Peripheral Interface (SPI), digital and Pulse-Width Modulation (PWM) outputs.
- It is very easy to be used, by connecting the Arduino to computer via USB. Besides from that, the communication can be made by using standard serial protocol, which it runs in standalone mode and as interface connected to PC computers.
- The price of purchasing the Arduino is reasonable, around RM150 and below for a complete Arduino set per board along with free authoring software (depending on the products that will be purchased).

- The Arduino is backed up by growing online community, where the knowledge and information will be shared among the community.

4.4.4 Design of Circuit Diagram

The design of circuit diagram shall be done after the hardware and software requirement has been completed. The design of circuit diagram will ensure the success of the working system that is necessary for the completion of a low-cost haptic device. At this stage, the author needs to work closely with Bill Verplank (the creator of 'The Plank'), and also with the skilled personnel who has a good knowledge on the electric and electronic study.

The main important consideration that needs to be achieved by the author is on the design work for controlling the DC Motor and hard disk drive. The main objective for controlling the DC motor and hard disk drive is to acquire the vibration that will be produced by both the DC motor and hard disk drive when it is in the working mode. The vibration that will be produced will bring the great benefits towards the multi-sensory sense of the user in their working and learning activities. Therefore, the design of the circuit diagram that will be able for controlling the DC Motor and hard disk drive is important towards the completion of a low-cost haptic device. The circuit diagram that will become the main reference towards the author is shown below:-
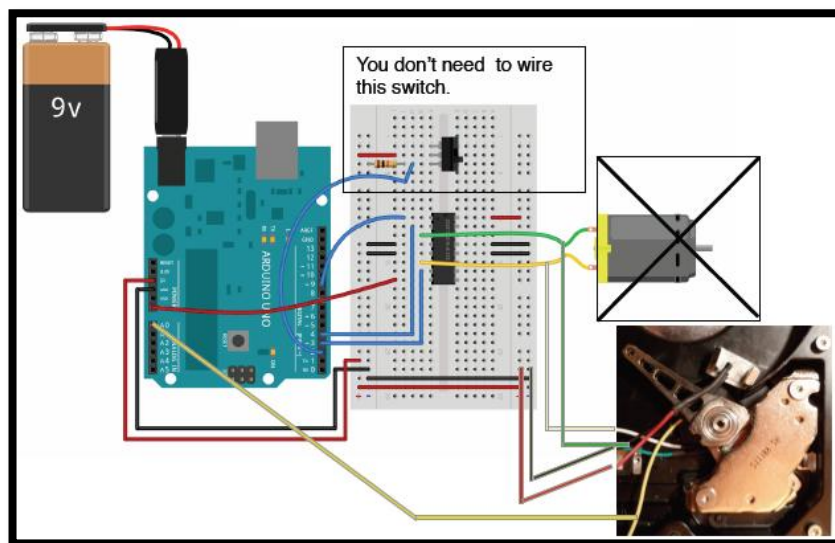

Figure 12: Circuit Diagram for a Low-Cost Haptic Device

Based on the circuit diagram that is shown above, the DC motor will be replaced by the hard disk drive, due to the high power of vibration (produced by the hard disk drive). However, for the completion of this report, the author will come out with two prototypes of a low-cost haptic device, both using DC motor and hard disk drive. This is important towards the author for making a comparison work, focussing on the application or usage that can be offered by both low-cost haptic devices. For the completion of this report, the author needs to complete two prototypes of a low-cost haptic device. Two prototypes that need to be designed and constructed by the author are listed below:-

- Basic Haptic Device (using DC motor)
- Advance Haptic Device (using hard disk drive)

Apart from that, the communication that will be made between the Arduino board and hard disk drive will be done by the presence of an H-Bridge. In addition, it is important to understand that the H-bridge can be controlled by the Arduino itself. Thus, the working system of a low-cost haptic device can be ensured. It is important to acknowledge the importance of having a good understanding about the Half-H drivers itself.
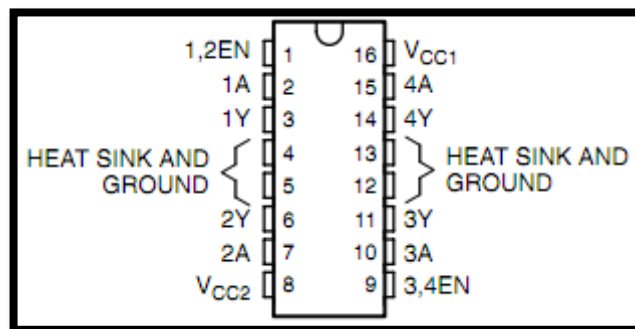
Figure 13: L293 (N or NE Package) and L293D (NE Package)

The completion of designing work for the Quadruple Half-H Drivers is completed with the assistance from Bill Verplank through the communication that the author had made. The four Half-H drivers should be understood in the clear manner, as each of the drivers can drive a DC motor in one direction. For this kind of work, the author has made several try and error concept in order to get the meaning and working mechanism of the Quadruple Half-H Drivers. The result of the input and output of the usage of Half-H drivers is listed below:-

- **1,2 EN**, connect to power to enable motor, connect to ground to disabled motor
- **1A**, motor logic pin 1
- **1Y**, motor terminal 1
- **2Y**, motor terminal 2
- **2A**, motor logic pin 2
- **V$_{CC2}$**, motor power supply
- **V$_{CC1}$**, IC power, +5V

4.5 Construction

Based on the design work of the low-cost haptic device that has been achieved, the author needs to ensure that the requirements that have been agreed on the design work to be implemented. The entire software and hardware requirements shall be utilized in the construction work. Any improvement that will be made during the construction work should be referred back to the design work that has been completed. It is important for the author to take notes on any mistake regarding towards the information or requirements that have been agreed before if there is a failure. The specifications of a low-cost haptic device need to be followed according to the requirements that have been specified in the design work.

4.5.1 Working with the DC Motor

The working system of a low-cost haptic device has become the main priority towards the author for the testing work of a low-cost haptic device. The working system is important as it shows whether the design work that has been completed is in a correct manner or not. Therefore, the author needs to ensure that the design work (circuit diagram) shall be followed in the construction work. In order to ensure whether the circuit diagram that has been designed works, a DC motor has been used instead of hard disk drive. This is due to the cost of the hard disk drive in which it is more expensive than the DC motor. However, it is important to acknowledge that both DC motor and hard disk drive will be used for the completion of a low-cost haptic device.
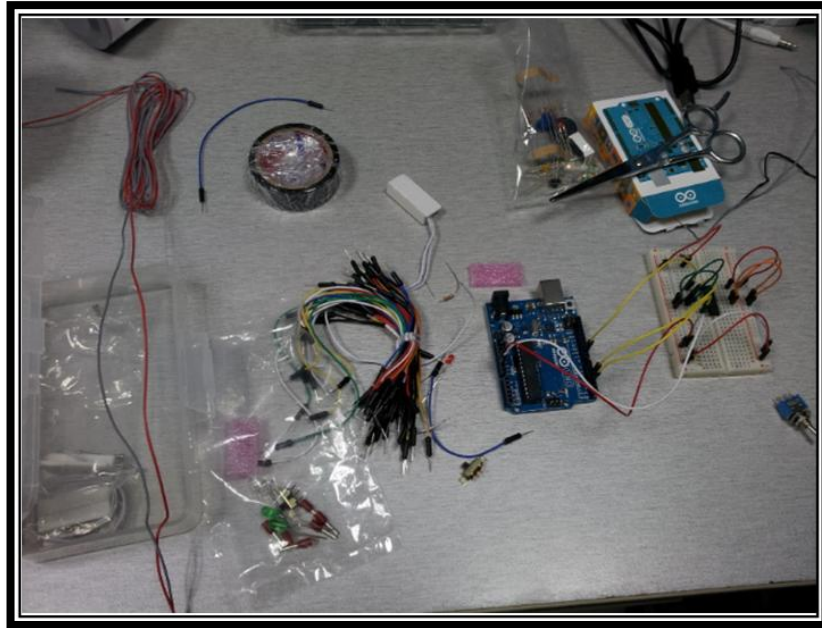
Figure 14: Assembling Parts Work

After the entire pin (input and output) has been located at their own position, the programming work can get started. As been mentioned earlier, the author has to perform this work by using C++ programming language. The main objective for this work is to ensure that the working system of a low-cost haptic device can be achieved in a successful manner. In addition, the author needs to focus on the working mode of the DC motor (can run in a clockwise and anti-clockwise mode). This is important towards the real implementation to the low-cost haptic device, in which the manipulation for the vibration force of the DC motor can be achieved.

```
constintswitchPin = 2;   // switch input
constint motor1Pin = 3;   // H-bridge leg 1 (pin 2, 1A)
constint motor2Pin = 4;   // H-bridge leg 2 (pin 7, 2A)
constintenablePin = 9;   // H-bridge enable pin
void setup()
 {
   // set switch as an input:
pinMode(switchPin, INPUT);
   // set other pins as outputs:
pinMode(motor1Pin, OUTPUT);
pinMode(motor2Pin, OUTPUT);
pinMode(enablePin, OUTPUT);
   // pinMode(ledPin, OUTPUT);
   // set enablePin high to turn on the motor:
digitalWrite(enablePin, HIGH);
 }
```

Figure 15: The Programming Work (To Connect the Entire Pin)

The basic programming work for the working system of a low-cost haptic device is shown above. It is important for the author to ensure that the entire pins that are located on the Arduino Board can be connected. The programming work is done by the author using the Arduino Code. In addition, the author also needs to identify the suitable code to ensure the DC Motor can run into dual mode, clockwise and anti-clockwise. The programming work for the purpose of running DC Motor into both modes (clockwise and anti-clockwise) is shown below:-

```
void loop()
 {
   // if the switch is high, the motor will turn on one direction:
if (digitalRead(switchPin) == HIGH)
   {
digitalWrite(motor1Pin, LOW);  // set leg 1 of the H-bridge low
digitalWrite(motor2Pin, HIGH);  // set leg 2 of the H-bridge high
   }
   // if the switch is low, motor will turn in the other direction:
else {
digitalWrite(motor1Pin, HIGH);  // set leg 1 of the H-bridge high
digitalWrite(motor2Pin, LOW);  // set leg 2 of the H-bridge low
   }
 }
```

Figure 16: Code for Running Clockwise and Anti-Clockwise Mode

Once the programming work has been completed, the author needs to do checking work. This is to ensure that the entire completion of work follow the specifications that have been made in the design work. From the figure that is shown below, it can be seen that the working system of a low-cost haptic device can be working in a good manner (the DC motor can run in two mode, clockwise and anti-clockwise), based on the expectation and specification that needs to be followed by the author in the design work.
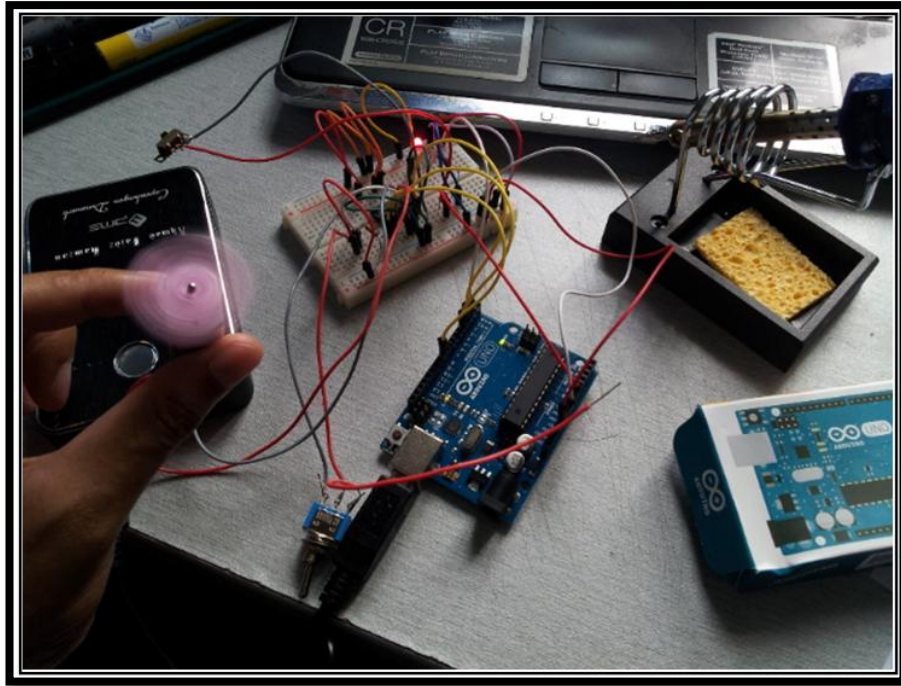
Figure 17: The Working System of a Low-Cost Haptic Device

After the completion of the determination for the working system using DC motor, the author needs to assemble the complete design of a low-cost haptic device that uses DC motor as a medium for having a vibration effect towards the application that will be used and enjoyed by the user for working and learning activities.
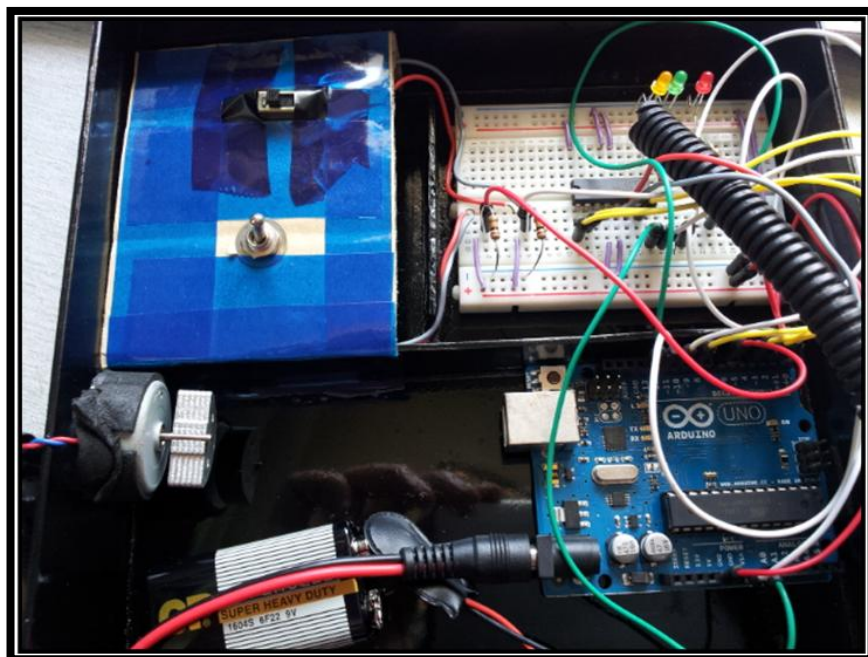
Figure 18: Assembling Work for a Low-Cost Haptic Device (DC Motor)

4.5.2 Working with the Hard Disk Drive

After the working system of a low-cost haptic device has been successfully accomplished, the author needs to come out with the creation of a low-cost haptic by using the hard disk drive. This is important for the author, as a low-cost haptic device that will be completed needs to be in accordance with the 'Plank' that has been designed and built by Bill Verplank. The main important aspect that needs to be acknowledged by the author for using the hard disk drive is to ensure that the arm pivot can be manipulated. For this kind of work, the author has to ensure the arm pivot of the hard disk drive can rotate freely, as the pivot needs to be minimized while the arm swings in its full rotation.

Figure 19: Re-Assembling the Hard Disk Drive (Before and After)

The main objective of using the hard disk drive in the creation of a low-cost haptic device is to acquire the different kind of vibration that will be produced by the hard disk drive. The different set of vibration will be determined by utilizing the arm pivot that is installed inside the hard disk drive itself. The author has to ensure that the arm pivot can swing according to the specification that has been agreed earlier. This is important as the arm pivot that is equipped in the hard disk drive will provide the vibration effect towards the completion of the project.
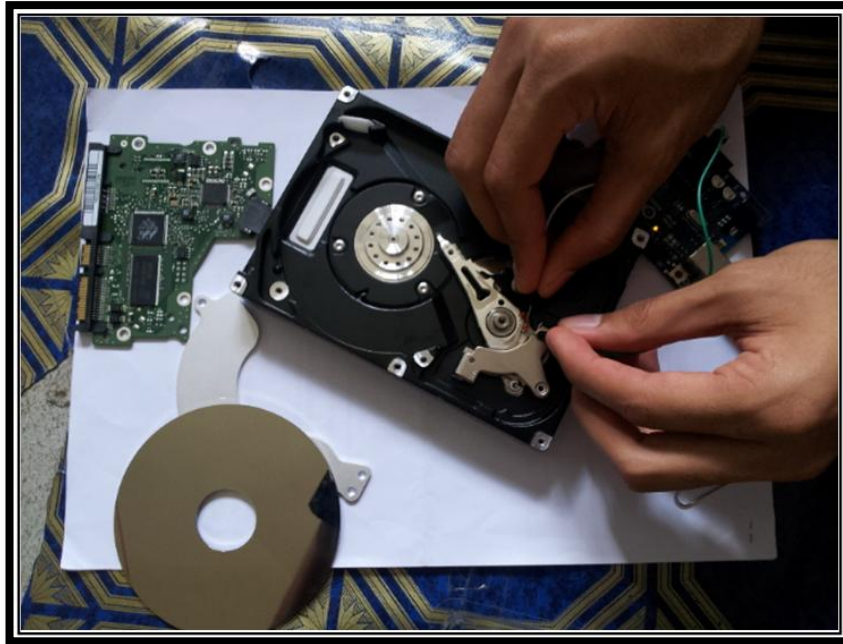
Figure 20: Testing the Arm Pivot
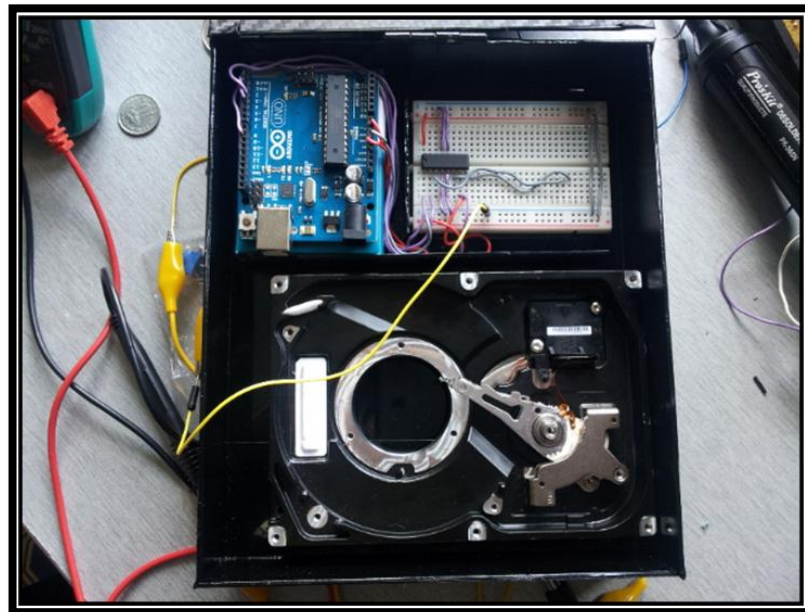
Figure 21: Assembling Work for a Low-Cost Haptic Device (Hard Disk Drive)

The completion of this work will be completed by having a programming code that will control the performance of the hard disk drive. The implementation of the Arduino in the creation of a low-cost haptic device is useful towards the author as the Arduino itself will be programmed for controlling the vibration force that will be acquired by the hard disk. This can be done as te Arduino itself has the ability to utilize the micro processor controller, in which it is the combination of hardware and

software. The different kind of vibration that will be utilized and manipulated will be useful towards having better and useful a low-cost haptic device. This is important, as the user can make an adjustment of the vibration effect that will be used for their working and learning activities.

```
constint motor1Pin = 3;    // H-bridge leg 1 (pin 2, 1A)
constint motor2Pin = 4;    // H-bridge leg 2 (pin 7, 2A)
constintenablePin = 9;    // H-bridge enable pin
intval = 0; //
void setup() {
pinMode(motor1Pin, OUTPUT);
pinMode(motor2Pin, OUTPUT);
pinMode(enablePin, OUTPUT);
digitalWrite(enablePin, HIGH);
 }
```

Figure 22: Signal for the Entire Pin

The programming work that is shown above consists of the selection of variable mode. Therefore, the Arduino module will determine the instruction that will be sent towards the entire pin that has been installed on the circuit board.

```
 }
void loop() {
val = analogRead(5); //Read analog pin 5 (potentiometer)
digitalWrite(3, LOW);//Send signal to H-bridge leg 2
analogWrite(4, 255);//
delay(val);        //Delay
digitalWrite(3, HIGH);//Send signal to H-bridge leg 1
analogWrite(4, 255);//
delay(val);
}
```

Figure 23: Controlling Direction and Speed for the Arm Pivot

Once the programming work has been completed, the author needs to perform checking work. This is to ensure that the entire completion of work follow the specifications that have been made in the design work. From the figure that is

shown below, it can be seen that the working system of a low-cost haptic device can work accordingly based on the specification that has been specified in the Arduino module. Thus the speed and direction of arm pivot can be controlled using the variable resistor. The result of the working mechanism that has been achieved (using the hard disk drive) is the same result that has been shown by using the DC motor.
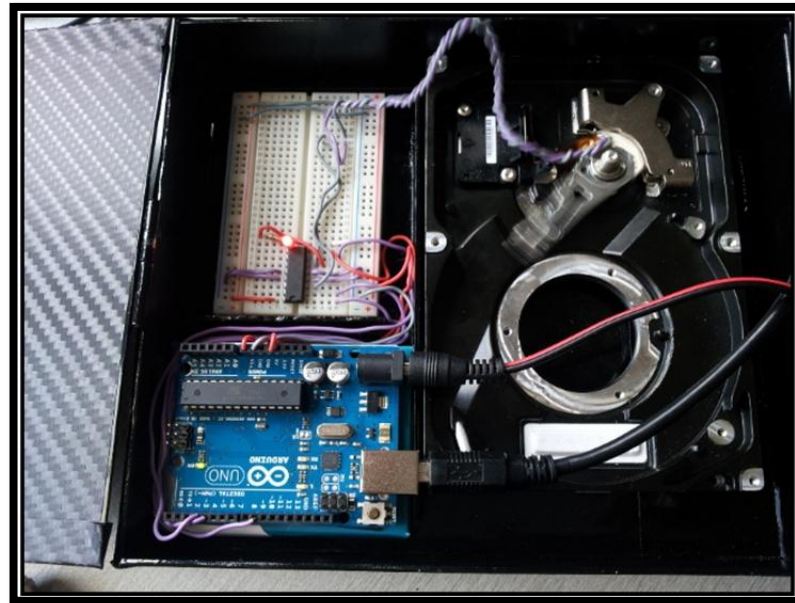
Figure 24: Working System for the Hard Disk Drive

4.6 Testing

There will be three processes that need to be completed by the author for the testing work. These three processes need to be conducted by the author in a good manner. It is important for the author to acquire additional knowledge and information that are useful in the future. Any additional knowledge and information that will be gathered during the testing work shall be recorded for the benefits of the future. Three processes that are mentioned earlier are:-

    i.   Preparation for the testing work
   ii.   During the testing work
  iii.   After the testing work
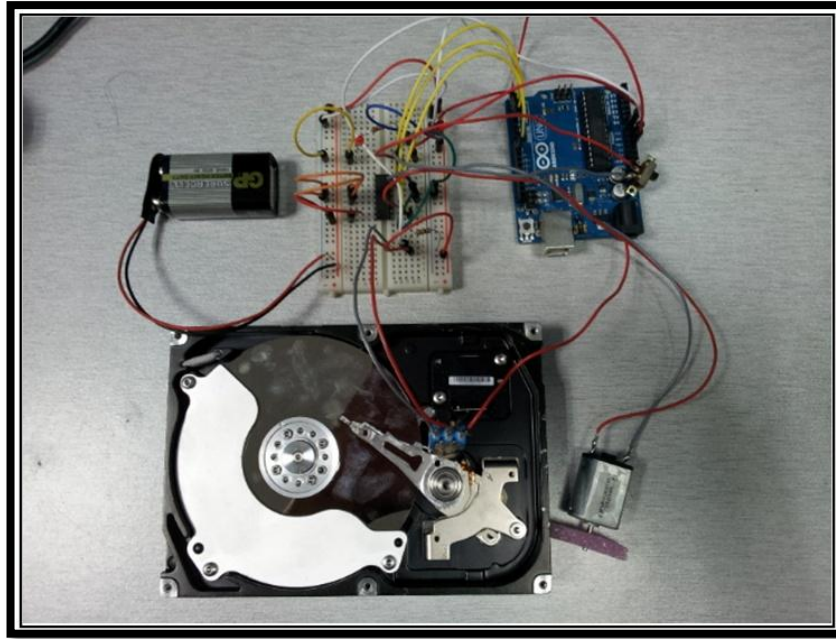
Figure 25: Testing Work for a Low-Cost Haptic Device

4.6.1 Preparation for the Testing Work

The author needs to determine the characteristics that will be provided by the creation of a low-cost haptic device. The correct finding and information are very essential towards the author as this information will become more valuable towards the author. Apart from that, the information that will be gathered also will be useful towards the enhancement and improvement that will be brought into the creation of a low-cost haptic device in the future. For the testing work that will be conducted by the author, the author needs to use the multi meter in which the author need to perform the inspection work towards the entire connection of a low-cost haptic device. Thus, the current and power that is necessary for the working mechanism of a low-cost haptic device can be recorded.
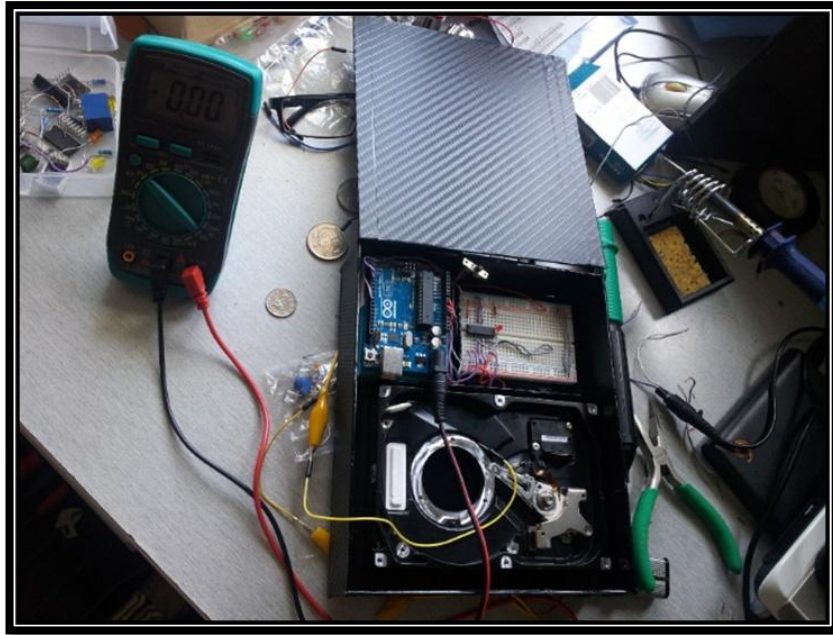
Figure 26: Preparation for the Testing Work

4.6.2 During the Testing Work

The entire information that will be gathered from the results of the testing work needs to be recorded by the author. The entire duration of the testing work will be important towards the author in the completion of a low-cost haptic device. These kinds of information are important towards the author for having a good understanding of the characteristics of a low-cost haptic device that will be offered towards the user's working and learning activities. In addition, the observation work also should be managed and well taken care of by the author, as during the testing work, the author may find any default or error of a low-cost haptic device that is being tested.
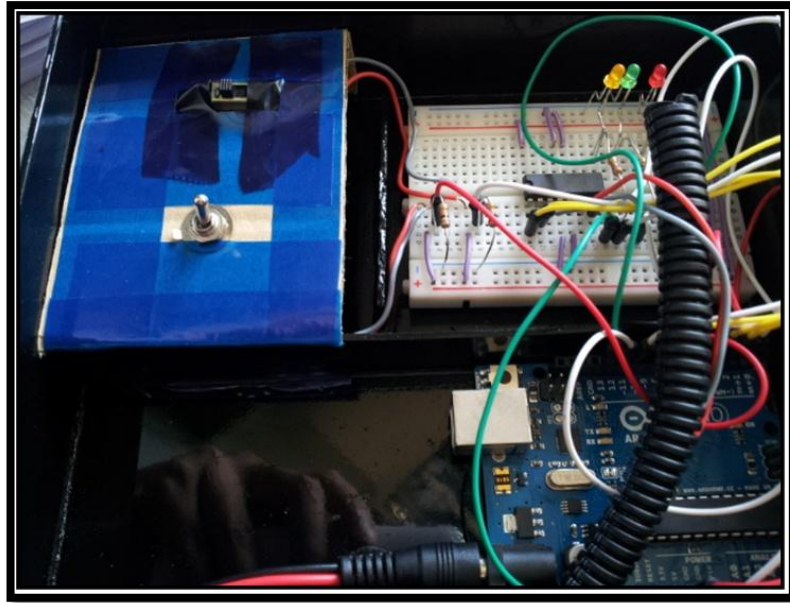
Figure 27: Testing Work for the DC Motor
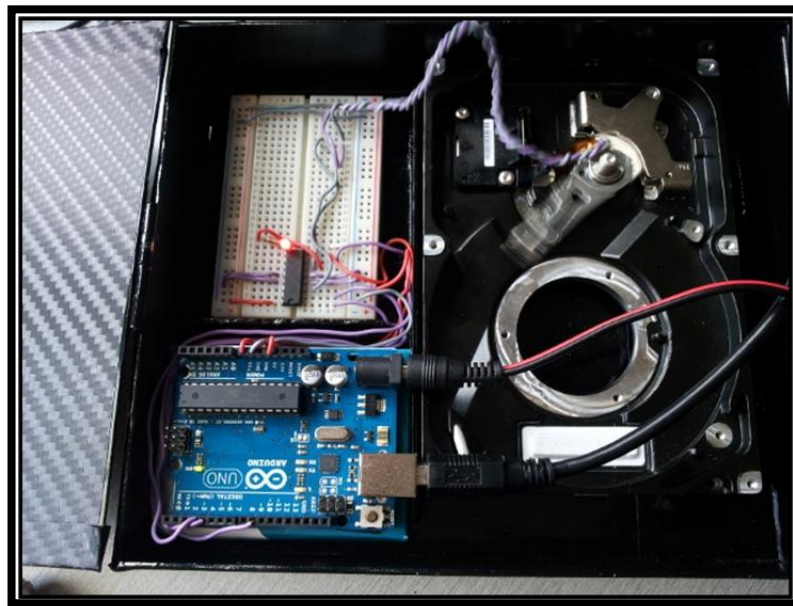
Figure 28: Testing Work for the Hard Disk Drive

4.6.3 After the Testing Work

The completion of the testing work is said to be when a low-cost haptic device is said to be compatible and can be used by the user. After the testing work has been completed, the author needs to come with the analyzing work, focusing on the results that will be projected during the testing work. The additional analyzing work is important towards the author in finding any useful information that can be

used in order to improve the characteristics of a low-cost haptic device that will be built.

For the purpose of testing work, there will be two types of testing work that shall be conducted by the author. The first testing will be the integration testing, followed by the user testing. These types of testing work are important towards the author in order for a low-cost haptic device that will be built can be used by the user in a safe manner. The value proposition of a low-cost haptic device also needs to be determined by the author. This is essential as a low-cost haptic device will be used for assisting the user towards working and learning activities in the future. The inspection work also shall be done by the author in order to test low-cost haptic device's reliability and durability for giving a support towards the user's working and learning activities.

4.7 Finishing

The quality of a low-cost haptic device that will be built needs to be ensured by the author before it can be introduced and be used by the user for working and learning activities. It is important for the author to ensure that a low-cost haptic device that will be built shall be maintained in a safe manner. This is important towards the author as a low-cost haptic device will be used by the user in the future, particularly for working and learning activities. The features and characteristics of the low-cost haptic device need to be assured. In addition, the author also needs to give protection towards the low-cost haptic device that will be built.
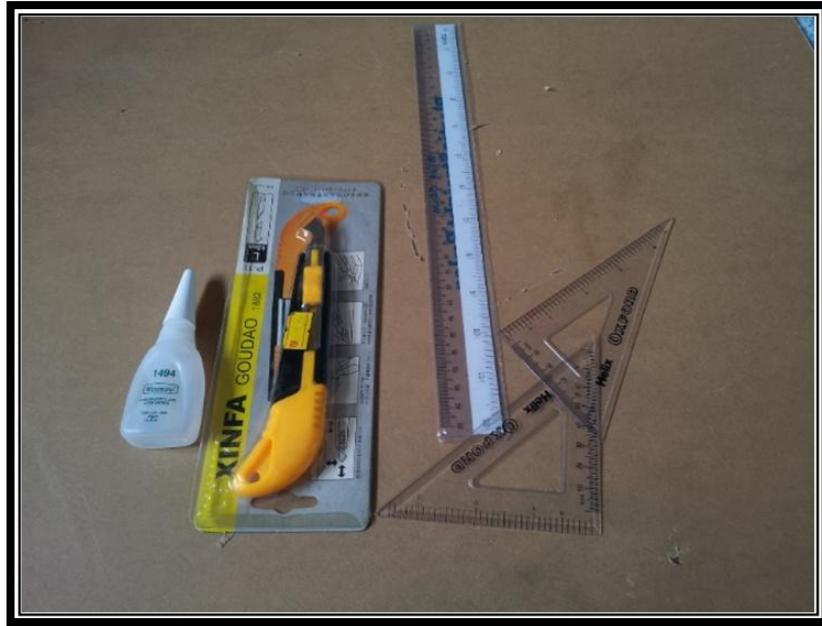
Figure 29: Preparation for Casing Work

In order to give protection towards a low-cost haptic device, the author has made a preparation for designing and constructing the casing for a low-cost haptic device. The casing will act as the holder in order to keep a low-cost haptic device in a safe manner. The main intention for the author to come out with the casing for a low-cost haptic device is to keep the main parts in a safe manner.

Figure 30: Casing for a Low-Cost Haptic Device

In addition, it is important for the author to conduct the quality control and assurance in a very carefully manner, as the low-cost haptic device that will be built should be maintained in a high quality. In addition, a low-cost haptic device that will be built will not be only used by the normal user, but it also can be used by others (such as dyslexic children) for any suitable applications. Thus, the completion of finishing will be achieved once a low-cost haptic device has been fitted into a casing.

Figure 31: Finishing Work for the Casing

4.8 Deployment and Support

Any additional knowledge and information that will be gathered by the author for making any improvement also should be taken into consideration, as a low-cost haptic device can be fully utilized by other applications, instead of focusing on the working and learning activities for the user. Any additional information and knowledge that will be generated by the author is important for having its own pattern in the future.
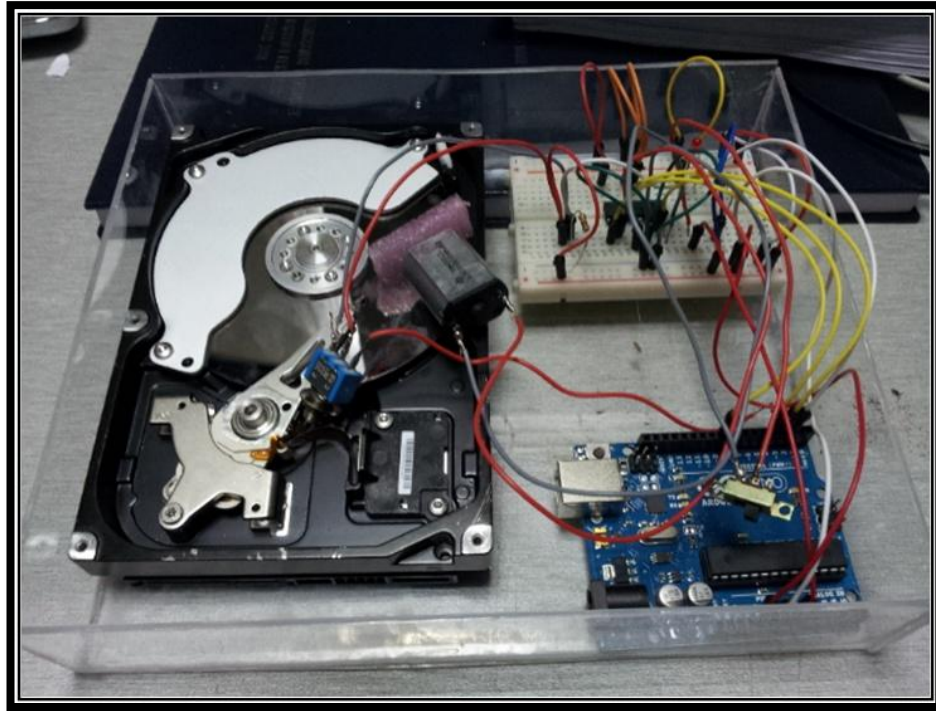
Figure 32: A Low-Cost Haptic Device
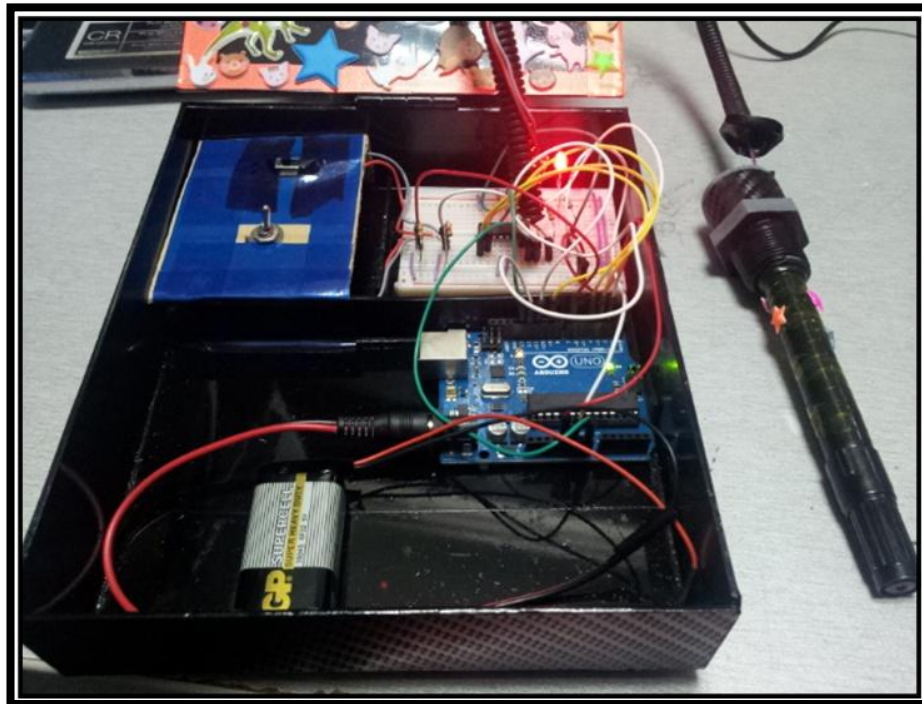
Figure 33: A Low-Cost Haptic Device (DC Motor)

The creation of a low-cost haptic device that comes with the implementation of the DC motor is completed by making a pen holder along with the casing of the DC motor. Therefore, the user will have the opportunity or platform to enjoy the

benefits that will be produced by the DC motor (producing vibration effect). In addition, the speed of the DC motor can be regulated by the user, based on the suitability and needs of the user itself. This kind of advantage will certainly give benefits towards the user in manipulating the introduction of a low-cost haptic device. This is important as the author needs to identify the benefits that will be produced by a low-cost haptic device in giving supports towards working and learning activities (particularly in writing works).
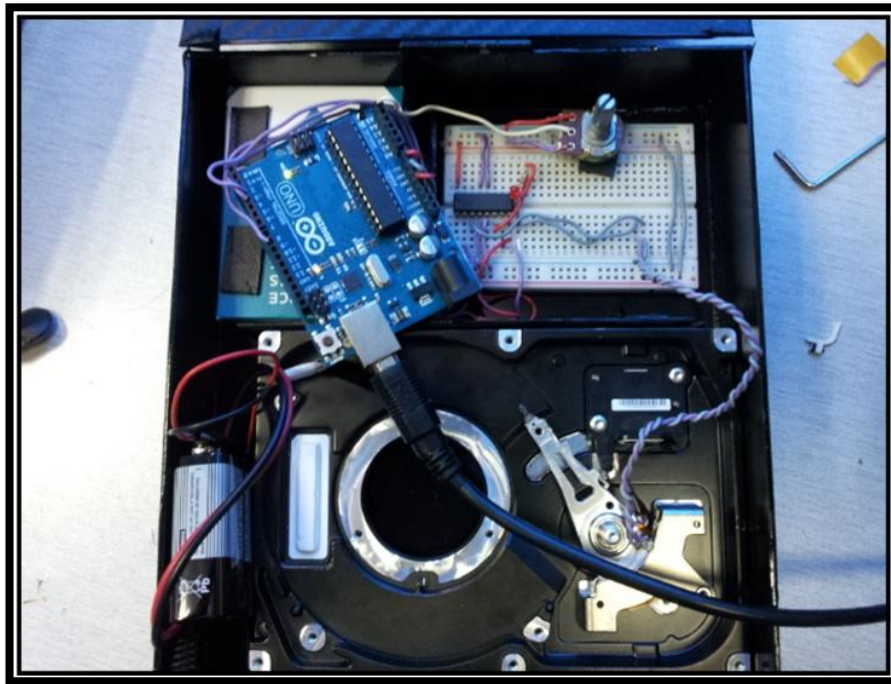
Figure 34: A Low-Cost Haptic Device (Hard Disk Drive)

For the completion of a low-cost haptic device that comes with the hard disk drive, the variable resistor has been used by the author for manipulating different kinds of vibration and movement of the swing arm pivot. Thus, the study on the movement and vibration that will be produced by the arm pivot needs to be carried in order to find new ideas that can be implemented into a low-cost haptic device in the future.

Besides from that, by having its own pattern, the author can make a modification on a low-cost haptic device that will be built, as the pattern that will be generated should be able to increase the quality and characteristics of the low-cost haptic device that will be offered towards the dyslexic children and other individuals in the future. This can be done as a low-cost haptic device can be used by other

applications because of the vibration that will be produced by the haptic device (the result of kinesthetic factor).In addition, additional research and improvements of a low-cost haptic device can be also be performed by the future student.

4.9 Potential Usage of the Development for a Low-Cost Haptic Device

The author believes a low-cost haptic device that has been built can be enhanced and improved in the future. The continuation of this project will bring lots of beneficial aspects and values towards reaching the potential in the market. Therefore, additional research and development work needs to be conducted in the future. The applications of a low-cost haptic device that has been built should be broaden. This is important as a low-cost haptic device that has been built will provide many opportunities that can be enjoyed by the user in the future. For the time being, the author feels that a low-cost haptic device that has been built can serve the user towards giving a support in working and learning activities. However, it is important to acknowledge the potential usage that can be acquired by the introduction and implementation of a low-cost haptic device towards the user in the future.

The entire information and knowledge that have been gathered throughout the completion of this project will become the valuable assets in the future. These lists of information and knowledge can be used by potential individual who is interested with the enhancement and improvement that can be made towards the creation of a low-cost haptic device. Thus, the author believes that a low-cost haptic device that has been completed has a potential value in the future market. However, it is important to acknowledge the importance of further study that will be made towards the creation of a low-cost haptic device. Apart from that, the research work also should be conducted in the future towards having an excellent understanding on the potential and benefits that will be brought by the impact of haptic and kinaesthetic elements.

4.9.1 Music

The fact that musicians have different brains is well regarded and known for a long time. The idea on how brains could respond and become modified by the things that are experienced in the daily life is one of the studies in the science of neural

(brain) plasticity. There is evidence that can be seen clearly as brains will continuously adapting to the environment and scenario in the world and also will be engaged towards the demands that will be made by the human in every single day of human's life. Therefore, it makes sense that brains of the musicians would adapt better than non musicians as they have been exposure and engaged with the presence of the music. The cognitive neuroscience is the beneficial effects of musical education, as it is presented for finding highlights the positive effects of musical lessons (Magne, Schon, and Besson, 2006).

Apart from that, the individual that are trained to have musical lessons as part of their learning activities also are regarded as intelligent person. It is said that musical lessons will bring several different intellectual abilities such as verbal and mathematical. Therefore, musician certainly has advantages on their abilities to perform significantly number of cognitive tasks such as math ability, reading skills, and verbal memory when compared to non musician. Magne, Schon and Besson (2006) find that the IQ of the children can be significantly improved by having a year of musical training, in which could be the reasons for why musician children can outperform non musician children.

Therefore, the introduction of a low-cost haptic device wills certainly bring great impacts towards the user who would like to implement a low-cost haptic device into the musical learning activities. The manipulation and utilization of a low-cost haptic device will be helpful towards the individual for having an enhancement of skills that are required for musical learning activities. Apart from that, the introduction of a low-cost haptic device in the musical learning activities also will provide good values towards the user as a low-cost haptic device can provide an assistance towards the user (musician) in its own musical performance. The advantage that can be acquired by the implementation of a low-cost haptic device towards the musical learning activities is on the accuracy of the rapid timing, which involves musical timing skills.

4.9.2 Dyslexic Learning

It is important for people to have a common understanding that dyslexia actually is not a disease. Therefore, it is not necessarily to have a discussion on finding the cure for the dyslexia. However, it is vital to understand that dyslexia is a

lifelong conditions, whereby each dyslexic children need to bear and live with the dyslexia. The dyslexia cannot be cured in a total manner, but the effects of dyslexia can be alleviated by the support and help from the skilled specialist in their learning activities in education (as an example: writing and drawing activities). Although it is a lifelong condition, results show that most of the dyslexic person (as an example: dyslexic children) has the ability to learn read and write besides from having difficulties on the disruption of the learning process.

The phonological awareness training alone is not the only method that needs to be implemented in assisting dyslexic children's learning activities. The phonological training alone is not enough to support the dyslexic children. Besides from having the support from the phonological traning, the dyslexic treatment programs also requires the support from the planned reading instruction that needs to be designed in a careful manner (Snowling, 1996). The selection of using the resources for supporting the dyslexic children must suits the unique needs of dyslexic children itself, as there is a different kind of needs, depending on the dyslexic children itself.

Another approach that can be used in order to support the dyslexic children's learning activities is by using the multi-sensory teaching methods. Bradford (2008) says that the usage of multi-sensory teaching approach will help the dyslexic children to have learning activities by using more than one of the senses. Most of the normal students will use their sense of vision and hearing throughout the whole period of their learning process in the school. However, most of the dyslexic children may have problems with those two senses. There are several difficulties that may be imposed by the dyslexic children with those two senses as they may have poor sight of the words (words that are written may be blurry, fuzzy or jumbling up in the eyes of dyslexic children) and also poor hearing sense that could lead into a weak auditory memory.

Multi-sensory methods that can be applied towards the learning process for dyslexic children are also referred to as VAK modalities. Bradford (2008) states that VAK modalities stand for visual (what you see), auditory (what you hear) and kinesthetic (what you physically do). By combing these three senses, the dyslexic children may receive advantages towards their learning activities. The process of

learning activities that are imposed by the dyslexic children could be best done by having the combination of all three senses (visual, auditory and more on kinesthetic), as it will benefits the dyslexic children's brain kinesthetic memory to hang on to, as well as the visual and auditory aspects (Bradford, 2008).

In the world of technology nowadays, it is understood that technology has become one of the supporting elements that is useful towards the learning process for dyslexic children. However, the selection of using the technology in the learning process should be well carefully studied, as it should be based on the needs of an individual for the dyslexic children. It is important to ensure that the outcome or results that will be gained from using methods that are available for supporting dyslexic children's learning activities will bring beneficial aspects towards their development process for the future. Therefore, the introduction and implementation of a low-cost haptic device in the learning activities for the dyslexic children should be acknowledged and recommended. The impact that can be brought by using a low-cost haptic device in dyslexic's children learning activities will bring benefits towards their own career development and maintaining their own self-esteem (having a confidence level when interact with others).

5.0 Challenges

The main challenge that is faced by the author throughout the process of the creation of a low-cost haptic device is on the finding suitable materials (hadware tools) that are needed for the design work. The main part of a low-cost haptic device that will be built is the hard disk drive itself. However, the design of the disk drive that has been used by the creator of 'The Plank', a simple haptic controller, Bill Verplank is difficult to be found. The hard disk drive that has been used which is called MFM-5 inch is not readily available in the market, as it is the disk drive that has been used in the old computer. However, throughout the whole process of th design work, the author has been able to find another solution, which is replacing the old version of the hard disk drive that has been used for 'The Plank' with the updated version of disk drive that is readily available in the market.

Another challenge that is faced by the author is on finding the available parts that are important towards the completion of the haptic device. Most of the important parts that need to be brought into the construction of a low-cost haptic device are not readily available in the local market. Therefore, the author needs to find these parts through online purchase, as these parts are only available in the international market (in United States of America). The parts that need to be acquired by the author are important towards the completion of a low-cost haptic device. This is essential, as the design work (designing the electric and electronic diagram and selection of materials) shall be followed by the author. The list of parts that need to be acquired (by online purchasing order) by the author is listed below:-

i.   Arduino Uno Starter Kit

ii.   T Hall Effect Sensor, UNIPLR, 3SPI

The brain of the haptic device that will be built by the author is the Arduino Uno Starter Kit itself. It is important to acknowledge the importance of Arduino Uno Starter Kit towards the completion of a low-cost haptic device that will be built by the author. Since it will act as the brain of a low-cost haptic device that will be built, the author has to come out with the solution regarding towards the programming language that is necessary in order to make the Arduino Uno Starter Kit works. The author needs to understand the application of the Arduino Code since Arduino Uno Starter Kit can only be programmed by using Arduino Code. The programming language that needs to be used in Arduino Code is C++ language. The time constrain is the main challenge towards the author in learning and understanding C++ language that needs to be applied in Arduino Code.

Another challenge that needs to be overcome by the author in completing a low-cost haptic device is to find the suitable method that will be used in manipulating the vibration that will be acquired by the hard disk drive. For the completion of this work, the author needs to identify the correct command (by working on the programming part) that will be created in the Arduino itself (input and output command). By having the right command, the usage of the hard disk drive can be utilized by the author in manipulating the vibration from the hard disk drive. Therefore, the author has to find another way in determining the right command that will be programmed in the Arduino itself. The completion of this

activity is done by doing a research from the Arduino forum, and having discussion with the skilled personnel.

The knowledge and study about the usage of T Hall Effect Sensor also has played a big challenge towards the author for the completion of a low-cost haptic device. The implementation of T Hall Effect Sensor is mainly for the usage of the hard disk drive that will be installed on the low-cost haptic device. Due to this matter, the author has to make a research study on the working mechanism of the T Hall Effect Sensor. Therefore, there were several testing work that has been conducted by the author in developing and understanding the working mechanism of the T Hall Effect Sensor. However, due to the lack of knowledge and experience in dealing with T Hall Effect Sensor, the author has decided not to implement the role that will be played by T Hall Effect Sensor in the creation of a low-cost haptic device that uses the hard disk drive.

Besides from having difficulty in finding main parts of the creation of a low-cost haptic device, the author has met challenges in terms of the limitation of knowledge and skills in electric and electronic study. The knowledge that has been acquired by the author is important towards having a good understanding on the design of the circuit diagram. Without the knowledge that has been acquired, the completion of the circuit diagram could not be achieved. Thus, it will lead into the failure for the whole work. Therefore, the author needs to meet with several respective personnel, in order to have a good understanding and knowledge in the study of electric and electronic. Although the knowledge that needs to be acquired by the author will not be equivalent with the knowledge of the student who is studying on the electric and electronic study, the author will have a basic understanding on how the haptic device works. The other important part of a low-cost haptic device that needs to be understood by the author is on the circuit diagram of a low-cost haptic device itself.

CHAPTER 5

FUTURE WORKS

The design activity or work takes longer time compared to the other activity or work that need to be done by the author throughout the whole process for the completion of a low-cost haptic device that will be built. The time consumption that needs to be taken by the author in the design activity is longer than any other related and continuous activities due to the complexity and challenges that are faced by the author in having a good understanding and finding the suitable materials on the creation of a low-cost haptic device. The characteristics of a low-cost haptic device is the main concern towards the author, as the author needs to ensure that a low-cost haptic device that will be built is suitable and can meet the needs of the user in order to support working and learning activities. The author needs to ensure that the user can have an interaction with the low-cost haptic device, and also to understand the working mechanism of the low-cost haptic device when conducting working and learning activities. These are the important aspects that need to be taken into consideration by the author for the completion of a low-cost haptic device.

The work that needs to be completed by the author in completing a low-cost haptic device will be resumed after the design work has been completed. The final decision on the design work that will be performed by the author will be used as a guideline for the completion of a low-cost haptic device in the future. By completing the whole cycle of the process, the analyzing work shall be done by the author in determining the reliability of a low-cost haptic device. In addition, the author also needs to find the value propositions of a low-cost haptic device that will be built to support working and learning activities for the user. The continuation of a design work for the low-cost haptic device should be made in order to produce great impacts and more beneficial aspects for the creation of a low-cost haptic device. In the future, the needs and demands that will be made by the user will become greater. Thus, it is important for a low-cost haptic device to keep up with the demands of the user.

It is recommended by the author in the future, that a low-cost haptic device should be enhanced and improved in order to make it becomes more reliable towards

the user. The enhancement and improvement that will be made should be focusing on the working mechanism of a low-cost haptic device itself. Thus, the additional features of a low-cost haptic device can bring more beneficial aspects towards user in having a support for working and learning activities. The author believes that the creation of a low-cost haptic device can be enhanced in the future. Thus, the selection of parts that will be installed into a low-cost haptic device in the future shall be made based on the good consideration. It is important as the author believes that a low-cost haptic device can be designed and built in a compact manner. As an example, the usage of DC motor can be replaced by the usage of sensor and motor from the hand phone (reusable materials). The usage of sensor and motor from the hand phone will bring the same effect as DC motor. Apart from that, a low-cost haptic device that will be enhanced also can be built based on the wireless connection. This kind of advancement will bring more beneficial aspects towards development of a low-cost haptic device.

The study on the usage of T Hall Effect Sensor also needs to be made in the future, as it is useful for the creation of a low-cost haptic device using the hard disk drive. For the completion of this report, the author could not complete the implementation of T Hall Effect Sensor in a low-cost haptic device. This is due to the lack of knowledge that the author had on the application of T Hall Effect Sensor. Thus, the implementation of T Hall Effect Sensor has not been successfully achieved. A good value from the implementation of T Hall Effect Sensor into a low-cost haptic device will become more valuable due to the advantage that will be brought by T Hall Effect Sensor. It is mainly due to the important aspect that can be offered by the arm pivot from the hard disk drive (the characteristics of the arm pivot that will be connected with the T Hall Effect Sensor will be useful towards having a good data and information for making a further study on the application that can be used in the future).

In the future, the author believes that the creation of a low-cost haptic device will be useful by others who are in need, not particularly focusing on the dyslexic children. The power and benefits that will be produced by a haptic device should be recognized and be appreciated about. However, the author believes that there is still a room for improvement that can be made for a low-cost haptic device that will be made. The development of a low-cost haptic device should be enhanced in order to

meet the desire from the individual who is in needed in the future. Apart from that, the author also believes that a low-cost haptic device that will be built can be used for other applications as well. The author believes that the introduction and implementation of a low-cost of haptic device can be enjoyed by other individual with many applications (working and learning activities).
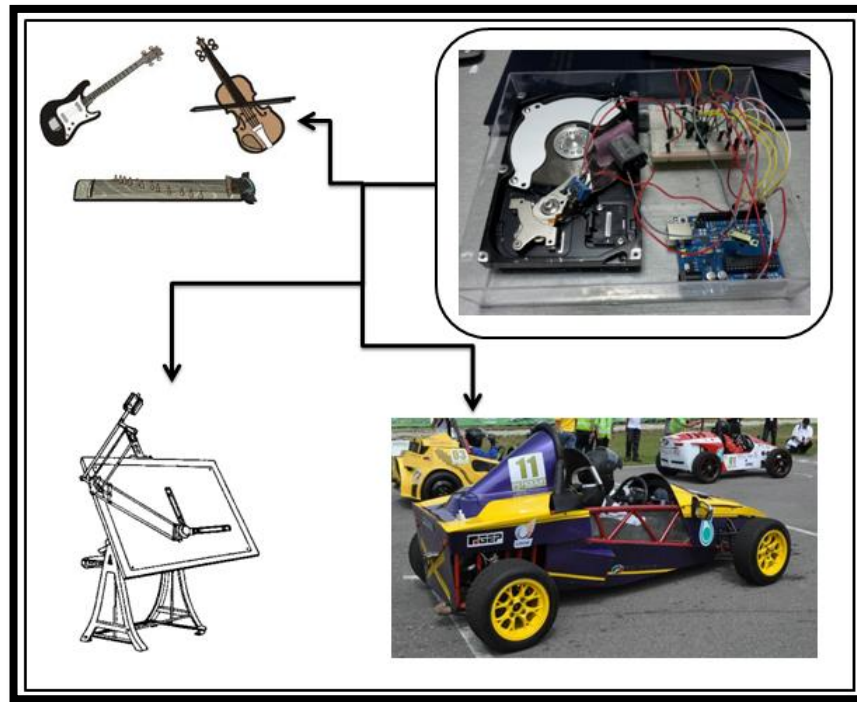
Figure 35: Future Applications of a Low-Cost Haptic Device

However, in order for the low-cost haptic device to be implemented with other applications, there should be coordination between skilled personnel which have their own related knowledge and skills. It is important to have collaboration with different kind of skilled personnel which have different kind of knowledge in order to bring lot of beneficial aspects towards a low-cost haptic device that has been built in the future. The author believes that the value of team work can be achieved from the collaboration that will be made between different skilled personnel. The different kind of knowledge and ideas will be gathered and acquired from the different personnel that are involved in the future. Thus, it will provide extra features and advantages towards the creation of a low-cost haptic device.

CHAPTER 6

CONCLUSION

The introduction of haptic feedback and haptic device has been regarded as one of the important factors that can be enjoyed by the people who are in need, especially towards the user who would like to improve the results from working and learning activities. The presence of haptic in the user's working and learning activities will bring lots of beneficial aspects towards the results that will be achieved and projected. The concept of the haptic itself will bring great values towards the user of a low-cost haptic device in which the user will be allowed to use the sense of touch for having an interaction with the objects that will be touched. Besides from that, the presence of sense of touch towards the user's working and learning activities also will be useful towards enhancing the memory of the user by remembering the objects that have been touched.

The creation of a low-cost haptic device will act as another alternative towards giving a support for the user's working and learning activities. By providing a simple haptic controller that comes with a competitive and affordable price, a low-cost haptic device can help the user to acquire the device that can give the support towards the completion of working and learning activites. The positive results of work from working and learning activities also can be acquired with the introduction and implementation of a low-cost haptic device in the future. This kind of positive result can be achieved due to the value propositions that will be offered towards the user in the market.

Apart from that, the author believes that further study on the haptic device and kinesthetic elements should be conducted. This is important towards making an improvement for a low-cost haptic device that has been built. The positive impact that can be brought by the haptic device should be regarded as one of the benefits that should be enjoyed by the users. In addition, the knowledge and information of haptic and kinesthetic elements that will be acquired in the future will bring positive impacts towards the current low-cost haptic device that has been completed by the author.

As for the conclusion, the creation of a low-cost haptic device is mainly to act as an alternative towards the user that would like to experience the implementation of a low-cost haptic device in working and learning activities. The current technology that is available in the market comes with a high price. Therefore, the introduction of a low-cost haptic device will provide an option towards the user in the market. The completion of a low-cost haptic device involves the hardware and software requirements that are needed. The information on the selection of hardware and software requirements is the most important part for the creation of a low-cost haptic device. The positive results that have been acquired by the introduction of a low-cost haptic device will become the main aspect towards the enhancement and improvement of a low-cost haptic device in the future.

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Appendices

1.   Gant Chart of Project Work for a Low-Cost Haptic Device

2.   Cost of a Low-Cost Haptic Device (Basic)

3.   Cost of a Low-Cost Haptic Device (Advance)

4.   'The Plank', The Original Design Using MFM-5 inch Hard Disk Drive

5.   Circuit Diagram for DC Motor Control Using an H-Bridge

6.   Block Diagram of Half-H Drivers

7.   Casing for a Low-Cost Haptic Device

8.   Tools used for a Low-Cost Haptic Device (Multi-Meter, Electric & Electronic Tools and Soldering Kit)

9.   A Low-Cost Haptic Device (DC Motor)

10.   A Low-Cost Haptic Device (Hard Disk Drive)

11.   Circuit Diagram and Circuit Schematic for a Low-Cost Haptic Device

12.   Pen Holder (Cap)

13.   Motor (for Vibration Effect)

14.   T-Hall Effect Sensor

15.   Technical Paper (Design and Development of a Low-Cost Haptic Device)

Task	Final Year Project 1	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	Final Year Project 2	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28
Select Project Title & Supervisor		■																												
Preliminary Research			■																											
Submit Project Proposal				■																										
Approval of the Project Proposal				■																										
Requirement Plan				■	■																									
Objective Setting					■																									
Perform Research (Literature Review)						■	■	■																						
Perform Research (Hardware&Software)						■	■	■																						
Perform Research (Tools)						■	■																							
Set Up Methodology							■																							
Management Plan									■	■																				
Perform "Analysis" Activity								■	■	■	■	■	■	■			■													
Perform "Design" Activity											■	■	■	■	■		■	■	■	■										
Interim Report															■															
Perform "Construction" Activity																		■	■	■	■	■	■	■	■					
Perform (Testing) Activity - Integration																				■	■	■	■	■						
Perform (Testing) Activity - User Acceptance																						■	■	■	■	■				
Perfrom "Finishing" Activity																									■	■	■	■		
Deployment & Support																											■	■	■	

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Basic Haptic Device (Using DC Motor)

Item Identification	Usage	Equipment	Available At	Market Price RM	Type of Measurement	Quantity	Item Cost
HC01	The part that will be used for having a vibration. Testing the working system.	DC Motor 3 – 12V	Lian Hup Electronics and Electric Sdn. Bhd	RM 8.00	Per Unit	1	RM 7.50
HC02	Act as the brain of the low-cost haptic device	Arduino Uno Starter Kit	Cytron Technologies Sdn. Bhd.	RM 150.00 and below	Per Unit	1	RM 135.00
HC03	To locate the entire pins (output and input)	Circuit Board	Lian Hup Electronics and Electric Sdn. Bhd	RM 15.00	Per Unit	1	RM 13.50
HC04	Drive the motor in both (clockwise and anti-clockwise direction)	Quadruple L293D	Lian Hup Electronics and Electric Sdn. Bhd	RM 10.00	Per Unit	1	RM 9.50
HC05	Act as the switch for the low-cost haptic device	On / Off Switch	Lian Hup Electronics and Electric Sdn. Bhd	RM 3.00	Per Unit	1	RM 2.50
HC06	Connection for the battery	9V Battery Clip	Lian Hup Electronics and Electric Sdn. Bhd	RM 1.00	Per Unit	1	RM 0.50
HC07	Limits or regulates the flow of electrical current in an electronic circuit	Resistor	Lian Hup Electronics and Electric Sdn. Bhd	RM 1.00	Per Unit	5	RM 5.00
HC08	Electrically connect two or more positions within a connector.	Jumper Wire (single core)	Lian Hup Electronics and Electric Sdn. Bhd	RM 0.50 per half meter	Per Unit	4	RM 2.00
HC09	To give a signal on the power that will be distributed	Light-emitting Diode	Lian Hup Electronics and Electric Sdn. Bhd	RM 0.30	Per Unit	3	RM 0.90

Item Identification	Usage	Equipment	Available At	Market Price RM	Type of Measurement	Quantity	Item Cost
HC10	To connect the battery with the plug on the Arduino	DC Plug with Wire	States Electronic Sdn. Bhd.	RM 1.50	Per Unit	1	RM 1.50
HC11	Casing for the low-cost haptic device	Perspex	Eng Huat Hardware Trading	RM 50 Per Square Feet	Per Unit	2	RM 100.00
LC01	The Programming Work of Arduino (Working System of the Low-Cost Haptic Device)	Knowledge of Arduino Programming (C++ Programming Language)	-	RM 1000 – RM1500 per complete program	Individual	1	RM 500.00

The total cost for a basic low-cost haptic device, equipped with the DC motor is **RM 777.90**

The amount of money that needs to be spent for the personnel who would like to acquire the benefits that will be produced by a low-cost haptic towards giving a support for dyslexic children's learning activities is reasonable and affordable. The objective of producing a low-cost haptic device has been achieved as the amount of the total cost that is needed for the completion of a low-cost haptic device is below RM 1000.

Any additional hardware or materials that are necessary towards the enhancement of a low-cost haptic device will be specified later (depends on the requirements that will be set by the user).
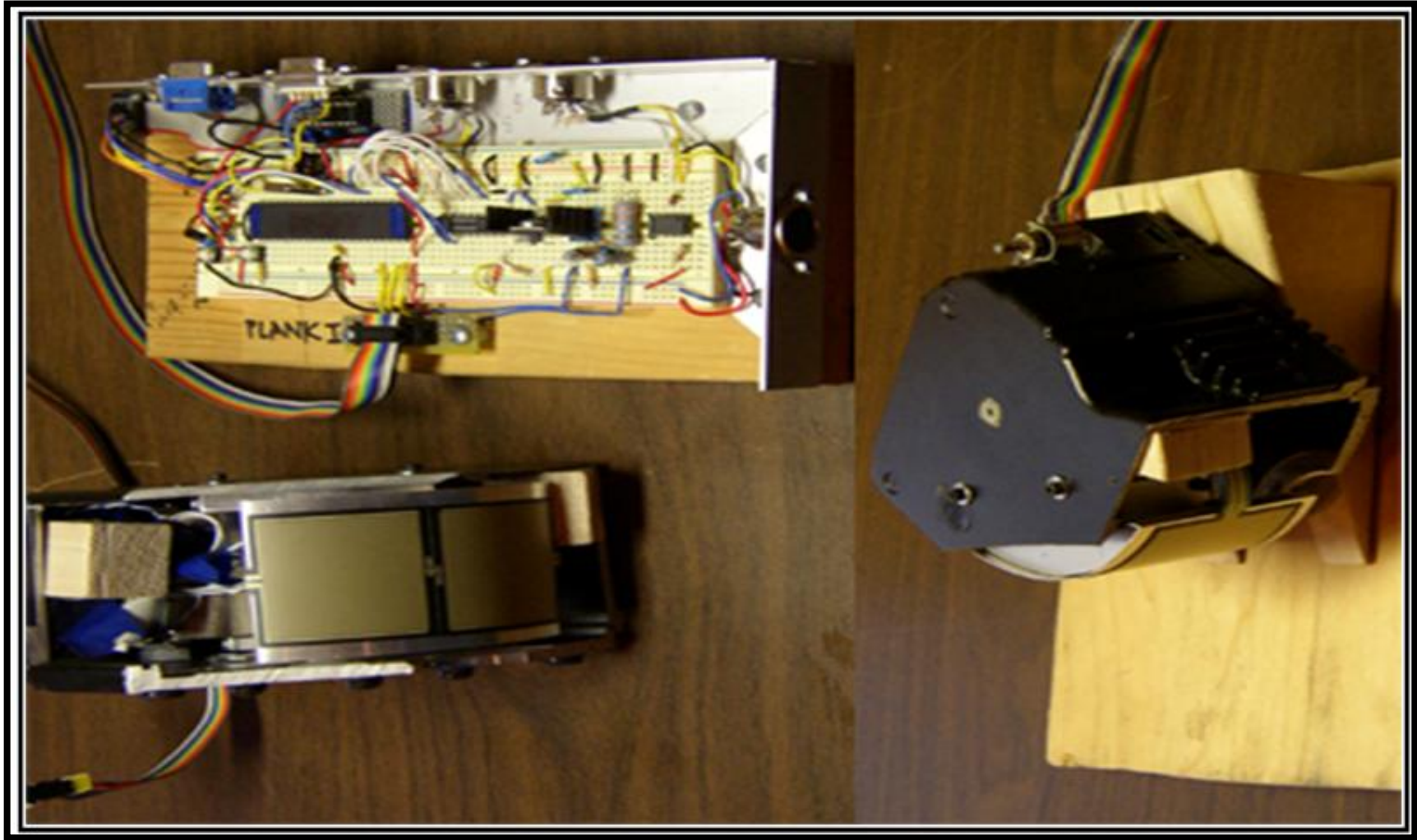
Advance Haptic Device (Using Hard Disk Drive)

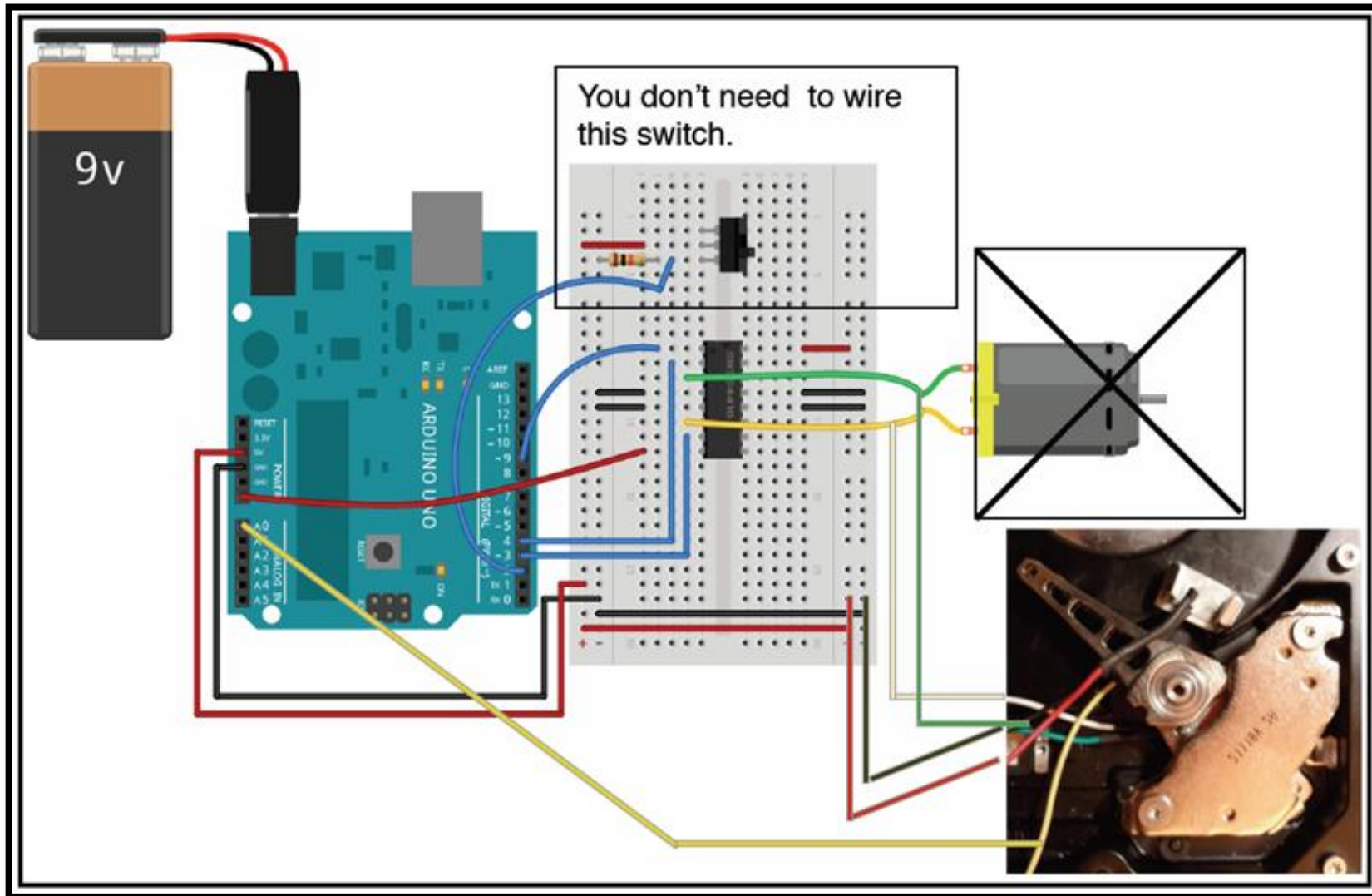| Item Identification	Usage	Equipment	Available At	Market Price RM	Type of Measurement	Quantity	Item Cost
HC01	The part that will be used for having a vibration	Disk Drive (preferable the new one)	Wawasan Computer Sales & Services, Serdang	RM 220.00	Per Unit	1	RM 220.00
HC02	Act as the brain of the low-cost haptic device	Arduino Uno Starter Kit	Cytron Technologies Sdn. Bhd.	RM 150.00 and below	Per Unit	1	RM 135.00
HC03	Minimize the travel where the arm swings is full	T-Hall Effect Sensor, UNIPLR, 3SPI	Element 14	RM 7.00	Per Unit	1	RM 7.00
HC04	To locate the entire pins (output and input)	Circuit Board	Lian Hup Electronics and Electric Sdn. Bhd	RM 15.00	Per Unit	1	RM 13.50
HC05	Drive the motor in both (clockwise and anti-clockwise direction)	Quadruple L293D	Lian Hup Electronics and Electric Sdn. Bhd	RM 10.00	Per Unit	1	RM 9.50
HC07	Connection for the battery	9V Battery Clip	Lian Hup Electronics and Electric Sdn. Bhd	RM 1.00	Per Unit	1	RM 0.50
HC08	Limits or regulates the flow of electrical current in an electronic circuit	Variable Resistor	Lian Hup Electronics and Electric Sdn. Bhd	RM 10.00	Per Unit	1	RM 10.00
HC09	Electrically connect two or more positions within a connector.	Jumper Wire (single core)	Lian Hup Electronics and Electric Sdn. Bhd	RM 0.50 per half meter	Per Unit	4	RM 2.00
HC10	Limits or regulates the flow of electrical current in an electronic circuit	Resistor	Lian Hup Electronics and Electric Sdn. Bhd	RM 1.00	Per Unit	1	RM 1.00

Item Identification	Usage	Equipment	Available At	Market Price RM	Type of Measurement	Quantity	Item Cost
HC11	To connect the battery with the plug on the Arduino	DC Plug with Wire	States Electronic Sdn. Bhd.	RM 1.50	Per Unit	1	RM 1.50
HC12	To give a signal on the power that will be distributed	Light-emitting Diode	Lian Hup Electronics and Electric Sdn. Bhd	RM 0.30	Per Unit	2	RM 0.60
HC13	Casing for the low-cost haptic device	Perspex	Eng Huat Hardware Trading	RM 50 Per Square Feet	Per Unit	2	RM 100.00
LC01	The Programming Work of Arduino (Working System of the Low-Cost Haptic Device)	Knowledge of Arduino Programming (C++ Programming Language)	-	RM 1000 – RM1500 per complete program	Individual	1	RM 500.00

The total cost for an advance low-cost haptic device, equipped with the hard disk drive is **RM 999.60**

The amount of money that needs to be spent for the personnel who would like to acquire the benefits that will be produced by a low-cost haptic towards giving a support for dyslexic children's learning activities is reasonable. The cost of the advance haptic device is quite high compared to the basic haptic device due to the necessary part that need to be installed into the completion of a low-cost haptic device. however, it is important to acknowledge that the advance haptic device that is built can be used for many applications in the future.
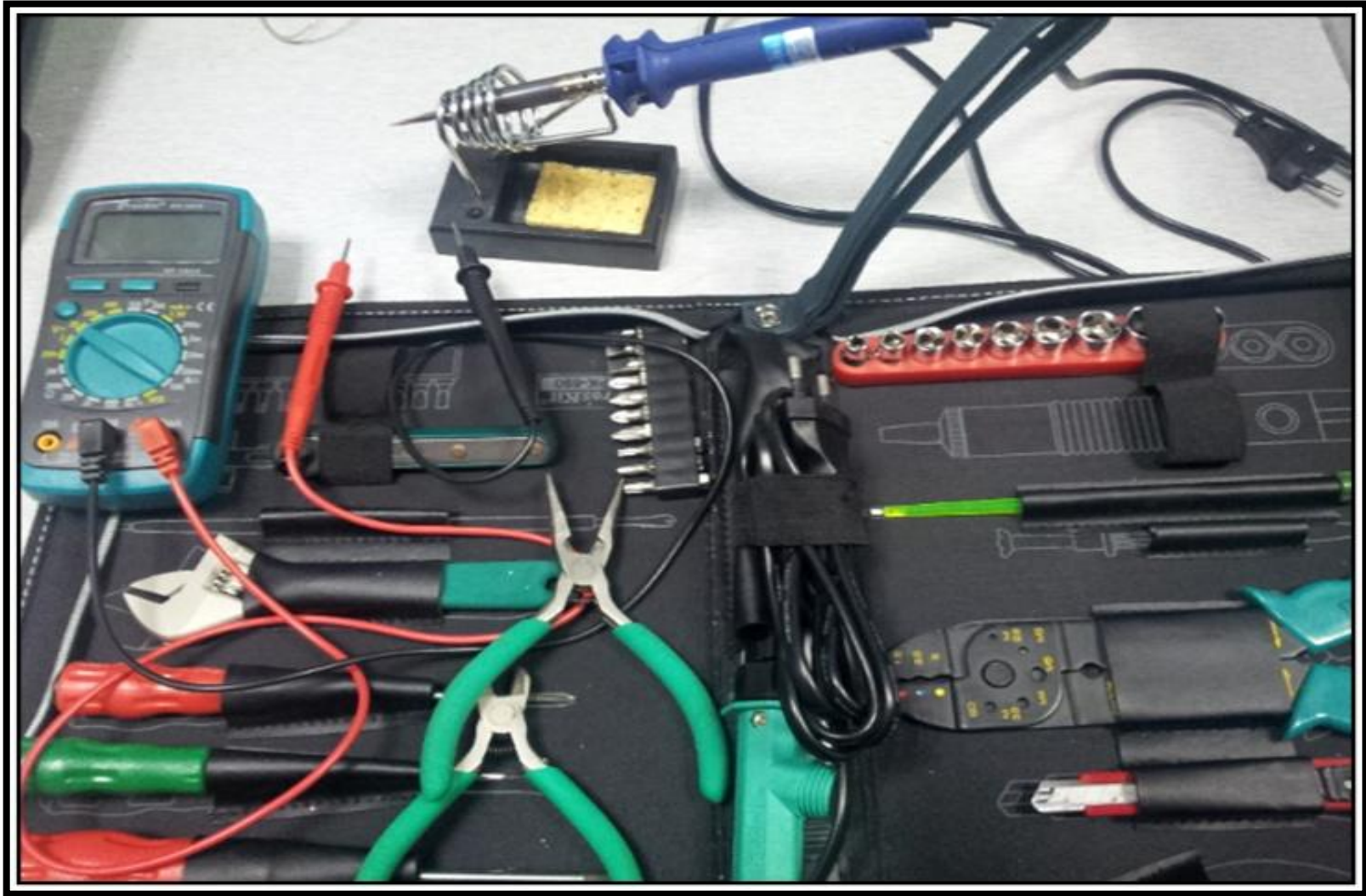
Any additional hardware or materials that are necessary towards the enhancement of a low-cost haptic device will be specified later (depends on the requirements that will be set by the user).
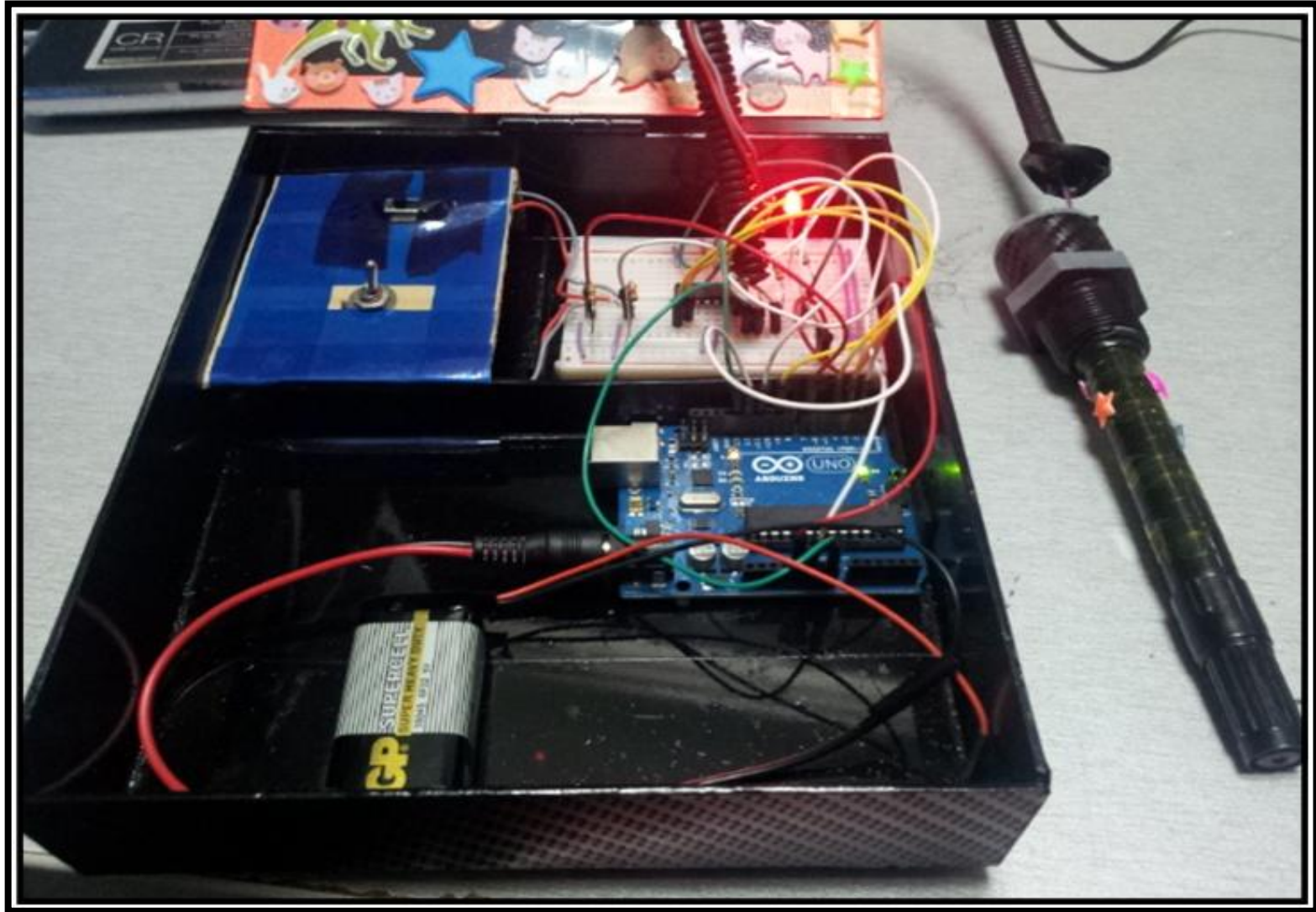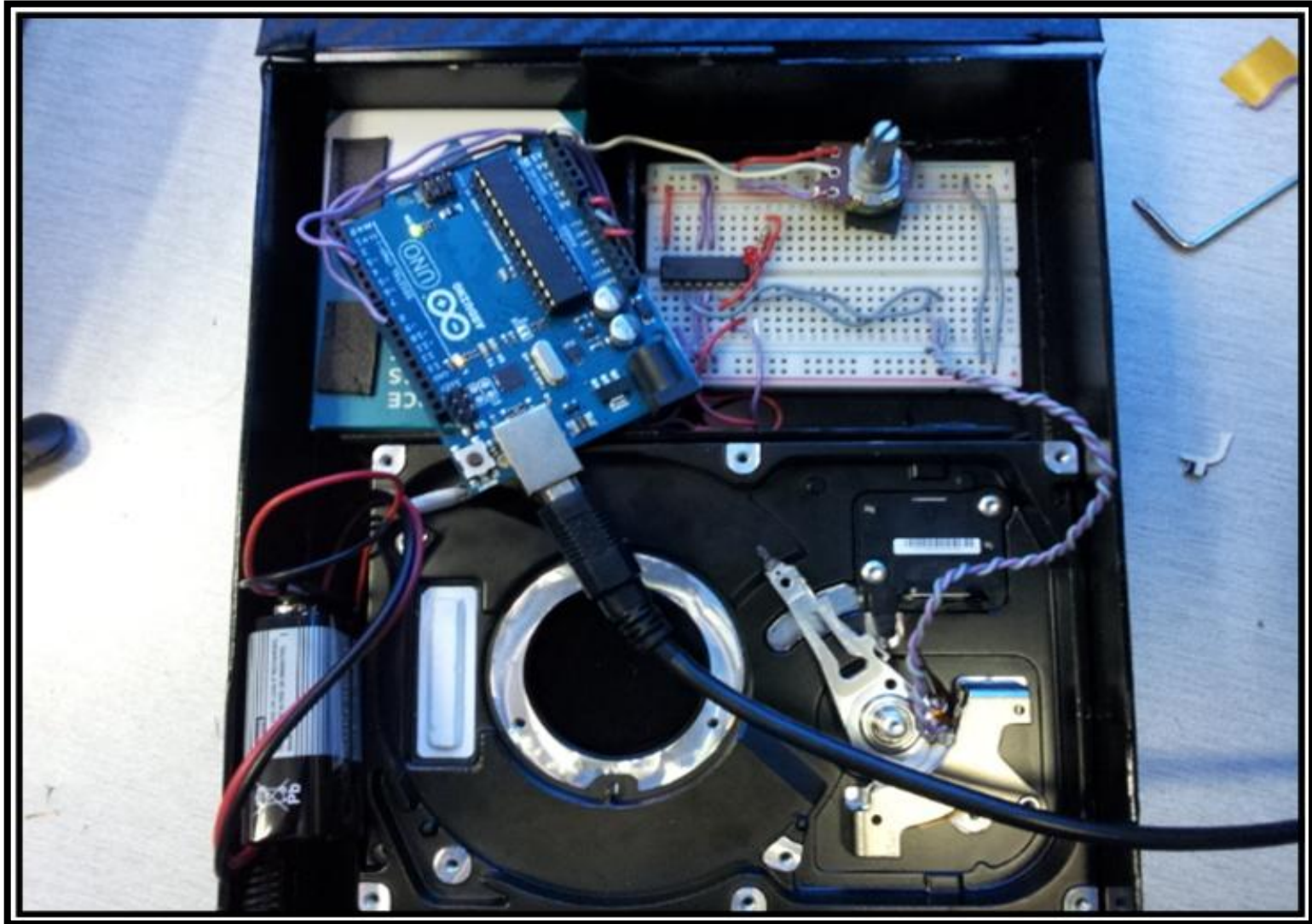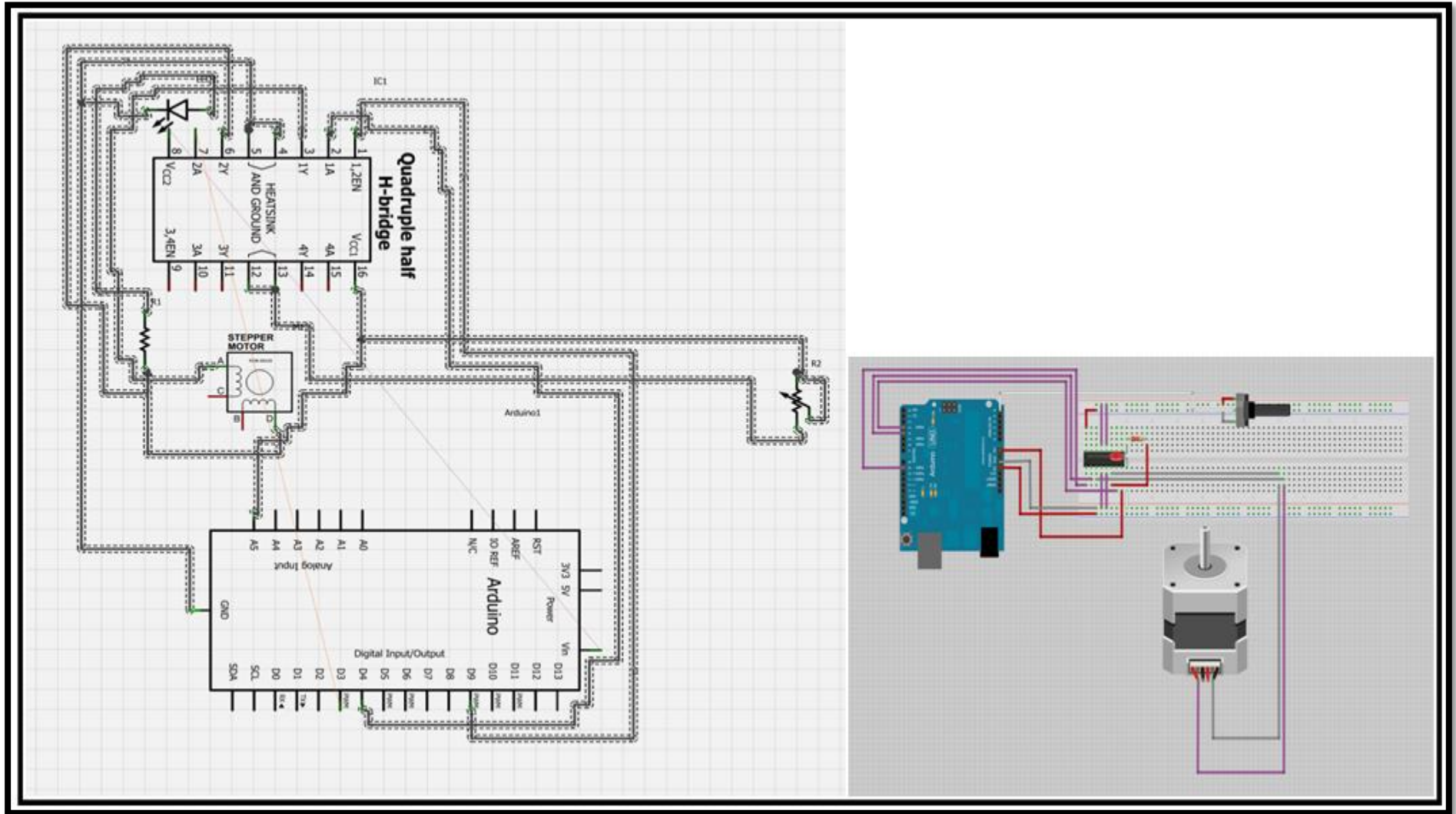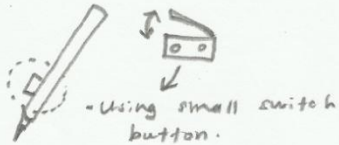
You don't need to wire this switch.

Owner:	Title:
[University Teknologi Petronas logo] UNIVERSITI TEKNOLOGI PETRONAS	**A LOW COST HAPTIC DEVICE TO SUPPORT DYSLEXIC CHILDREN'S LEARNING ACTIVITIES**
	Reference: Casing for the Low-Cost Haptic Device
	Supervisor: Dr. Suziah Sulaiman
	Designer: Ahmad Faidz Hamzan
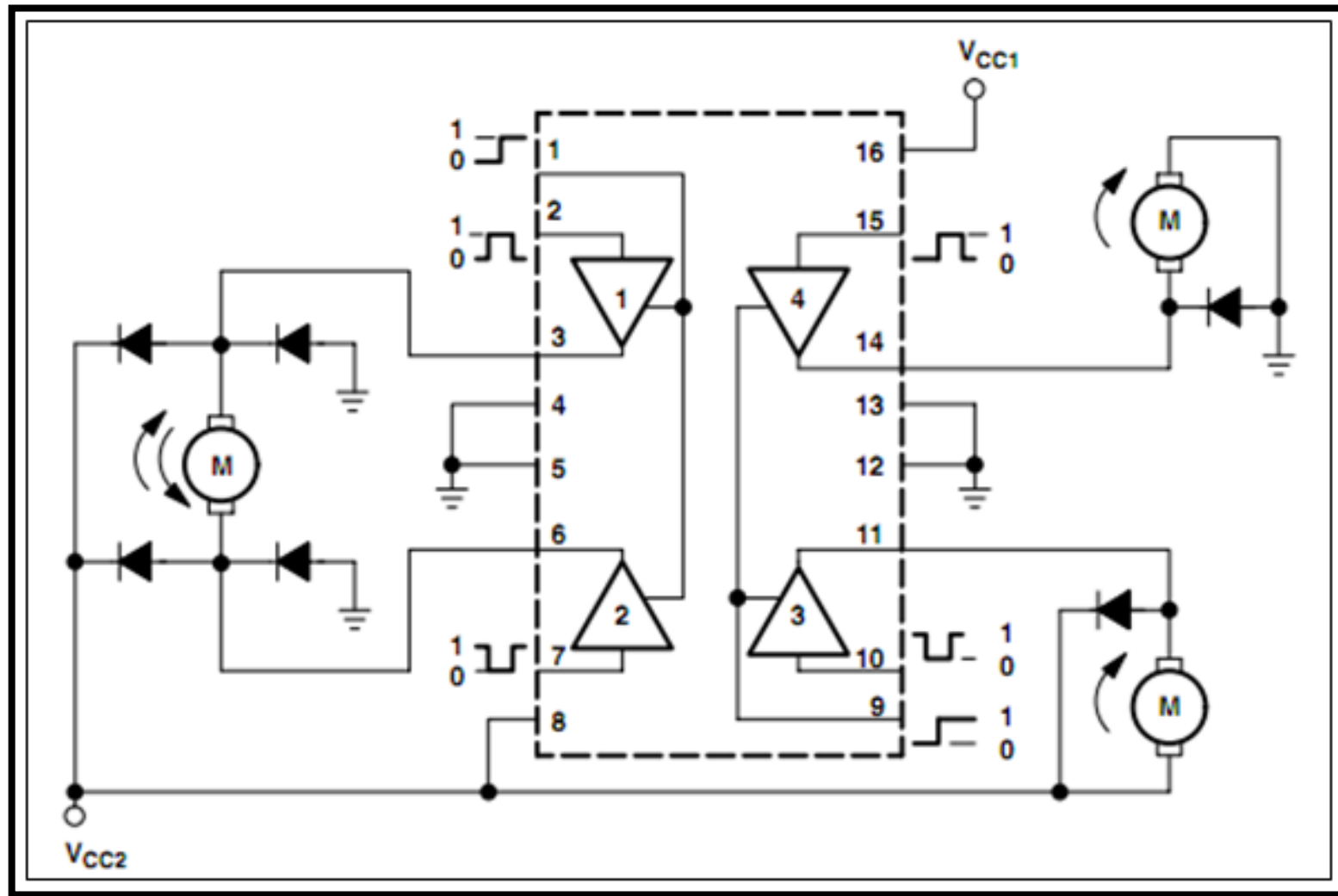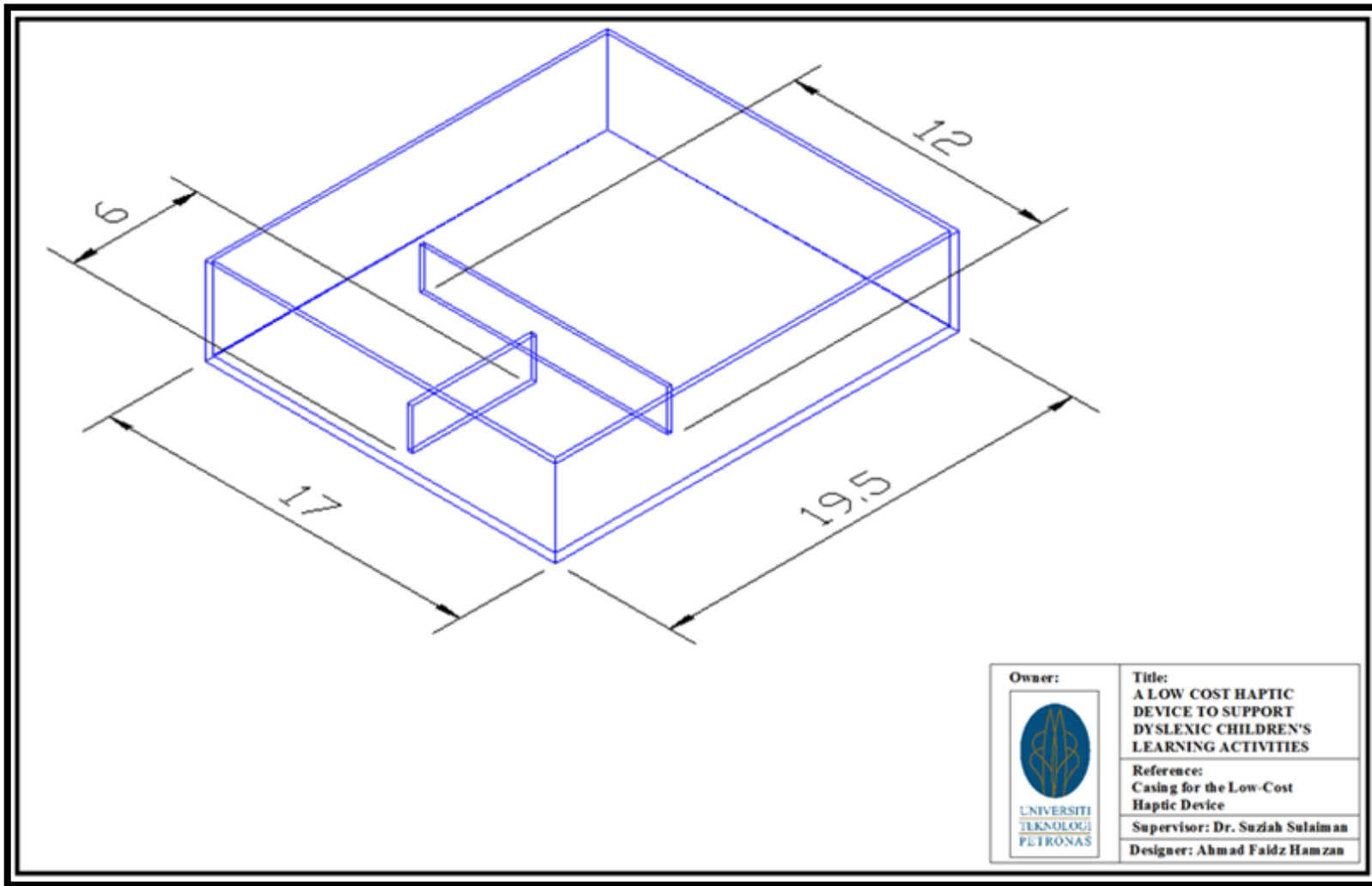
PEN (TOOLS FOR WRITING).

① Magnetic sensor
   - Attached to the pen.

   - Using small switch button.

} Reason:
Idle mode : when the user doesn't touch the pin. the pen will not vibrate. even though the haptic device is on.

Working mechanism.

i - ON

   - Switch on button mode.
   → the vibration will be produced.

ii - OFF

   - Switch OFF button mode.
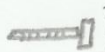   → there will be no vibration be produced.

② CAP → Holder for writing tools.

① Producing the Cap for the tools.

   Reasons :.
   i - Allow different size of pen to be fitted in.
   ii - Make it adjustable.

A.

② Screw.

   Reasons.
   i. Make it adjustable.
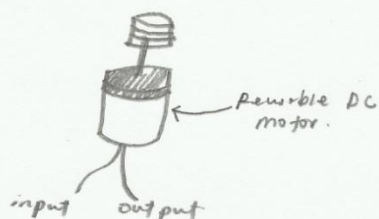   ii - to strengthen the position of the pen (holder).

* Make a study on reusable items that can be used for producing the holder.

* Determine the input and output of the switch button.

parrone.

MOTOR (FOR VIBRATION).
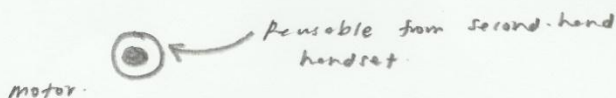
Current

Reurble DC motor.

input   output

- Connect with the arduino.
- Measurement Value (speed)
  - 0 - 255
  - 10 - low speed rotation.
  - 255 - High speed rotation.

Working Mechanism.

① Clockwise → High speed rotation.
     - Produce high vibration.

② Anti-clockwise → Low speed rotation.
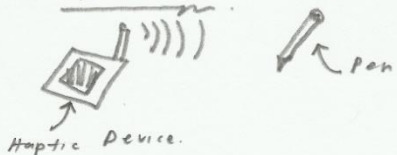   - Produce low vibration.

Future

motor.

Reusable from second-hand handset

Working Mechanism.

① High speed vibration.   } Question
② Low speed vibration.   - Determine the measurement speed of the sensor (motor).

          ＊ Reasons
     i - Make it more compact.
     ii - producing different kind of vibration.
     iii - Produce phonological awareness. (sounds)

Make it wireless.

Haptic Device.

- Longer position.

Pen.

Additional Parts

＊ Arduino Wi-fi shield.
     - study on the additional parts
       'Arduino wifi shield' is recommended.
     - Come out with the additional
       circuit board.

7 HALL-EFFECT SENSOR.

Package UA

3 UNIPLR, SP1

Usage:-
i - to determine the direction from the arm pivot.
ii - Ensure the direction of rotation and vibration from the arm pivot.
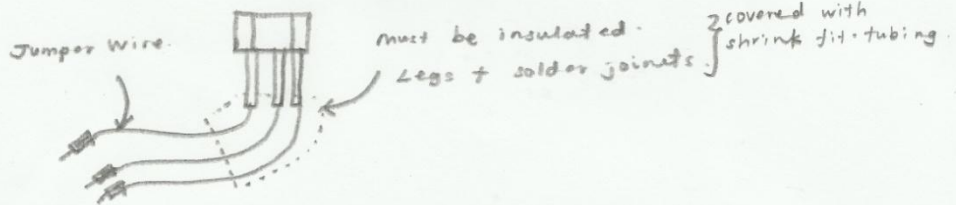iii - the direction will be measured and be used for the programming work.

Package	Symbol	Description
1	VCC	- connects power to supply chip.
2	V OUT	- output from circuit.
3	GND	- Ground.

Jumper Wire.

must be insulated.
Legs + solder joints } covered with shrink fit tubing.

∴ Working Mechanism.

i - Working mode

Arm Pivot

'ON'
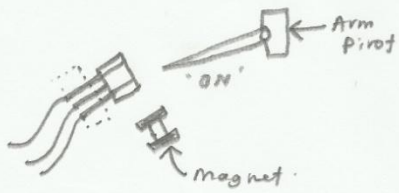
Magnet.

@- Arm pivot needs to be as closed as possible with the 7 Hall effect sensor and magnet

'OFF'
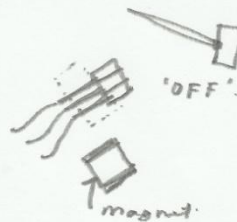
magnet.

Recommendations
- suitable magnet.
- reusable magnet is not recommended.
- Shrink fit tubing instead of wire type.
- Determine the position of the magnet and the arm pivot.
- Position the magnets and sensor as close as possible, to minimise the travel while the arm swings its full

Ramone.