

**THE ROLE OF HAPTICS FEEDBACK IN SUPPORTING THE
LEARNING PROCESS FOR DYSLEXIC CHILDREN**

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CERTIFICATION OF APPROVAL

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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.

Rohashnur Hazwan Nur Ashriel

ABSTRACT

This report discusses the research and project done on the chosen topic, which is **The Role of Haptics Feedback in Supporting the Learning Process for Dyslexic Children**. This project shows that haptics feedback and interaction can be used to support Dyslexic children in their education. The general objective of this project is to expose the Dyslexic children to the technology that can assist them in their learning process and to include the element of kinesthetic in the learning process of Dyslexic children by using haptic interaction/feedback technology. The literature review component discusses about all the research that the author had done prior to the pre-development and post-development of the project. It consists of all the information required in both building the software interface and understanding the hardware to be used. All the related elements such as the nature of Dyslexia, its symptoms and treatment, the methods used to teach Dyslexic children, haptic introduction and technologies are further discussed in detail. In the methodology section, the author discussed about the software development methodology applied in developing the project. The project phases are also being discussed in detail. Other than that, the author has also included a Gantt Chart as a development phase reference to ensure that the project is progressing perfectly according to plan. In the results and discussions section, the prototype development process and results together with the testing results will be discussed in detail. All the justifications are made clearly. In the recommendations section, the author lists some of the things that can be done to improve this project in the future. These things include to add more interactivity to the current prototype such as making games out of it or include sounds. Lastly, the conclusion section will discuss about the role of haptics feedback in supporting the learning process of Dyslexic children in overall, based on the results of the current project.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
GUI	Graphical User Interface
VAK	Visual, Auditory & Kinesthetic
VB	Visual Basic

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Dyslexia is a type of disorder whereby the person will have a hard time to read and understand written letters, words or phrases. In some extreme cases, the person with Dyslexia may have difficulties in writing and understanding spoken words too. Dyslexia is commonly found among children and if it is not treated early, the child might have difficulties in his or her studies when they grow up. Dyslexic children have special way of learning and their teachers are properly trained to teach them, as they require special mode of education in order to help them in their studies.

Haptics refers to the sense of touch and how human understand their physical environment by having the feel (touch) of the objects. Human being learns and understands things around them by using all of their senses. Apart from visual and auditory, the touch sense (kinesthetic) is also important as it is one of the most fundamental feel that gives human the sensation of the objects around them. As for Dyslexic children, kinesthetic element is really important as it helps them remember better when they can touch and feel what they have learned.

1.2 Problem Statements

The problem statements of this project are:

- The current methods of teaching Dyslexic children using technology do not include the kinesthetic element. This creates a gap in improving the learning experience for Dyslexic children.
- The current methods of teaching and learning for Dyslexic children do not give them the opportunity to use the latest technology. These children are not able to benefit from the current technology.

1.3 Objectives and Scope of Study

The objectives of this project are;

- To examine the current technology that could assist the Dyslexic children in their learning process
- To include the element of kinesthetic in a haptics prototype for Dyslexic children
- To test the usefulness of the prototype in terms of supporting the learning process

The scopes of study for this project are haptic interface, haptic interactions (feedback) and its abilities that can be used to help Dyslexic children. The nature of these children (their disorder, characteristics and how they can learn effectively) will be studied in order to come out with a suitable program/interface to help them. The kinesthetic element which helps a lot in Dyslexic children's learning will also be studied and it will be integrated with the haptic interface and haptic device. In this project, the haptic device that will be used will be the Phantom, which is developed by SensAble Technologies Inc. The programming for this device will be studied thoroughly and it will be more focused on C++ programming language.

CHAPTER 2

LITERATURE REVIEW

2.1 Dyslexia

2.1.1 What is Dyslexia

Dyslexia is a learning disorder characterized by an obvious difficulty in recognizing written words accurately and/or fluently, as if there were a significant loss in the ability to decipher or spell them out (A. Benítez-Burraco, 2010). People who are normally having this disorder have difficult time in reading books or any written texts. These people are not technically illiterate, because they actually have the knowledge of these written words but it is just that they have a tough time in identifying them due to this brain disorder. Dyslexia is common among children and if it is not detected at the early stage, it may persist until the child has grown older. These children are not only having difficulties in reading, but also the overall learning process. They have adequate level of intelligence but due to the failure of the brain in translating the images received from the eyes into understandable languages, their learning process is disrupted. If the signs of Dyslexia are undetected at the early stage, the child might become demotivated to learn and he/she might dislike school/learning.

2.1.2 Causes of Dyslexia

There are several causes related to Dyslexia. It has been said that Dyslexia could originate from a cerebellar dysfunction (A. Benítez-Burraco, 2010). Apart from motor control, the cerebellum also controls part of the verbal working memory that stores linguistically relevant information. Due to the phonetic properties of this part of the brain, it acts like a ‘silent speech’ (when we read something) and then it refreshes the phonological representations of the phrases. When the verbal memory load is overloaded, the ‘silent speech’ mechanism will no longer work, thus the cerebellum will

compare the acoustic phonological representation with the articulation of the ‘silent speech’ instead, resulting in reading difficulties.

Other than the cerebellum, another part of the brain that causes Dyslexia when it dysfunctions is the magnocellular pathway (A. Benítez-Burraco, 2010). Magnocellular pathway’s function is to activate and redirect attention mechanisms in the higher level cortical areas (in the brain). When this part dysfunctions, it may cause other sensorial deficits to take place also, including cerebellar dysfunction.

Other than those two main causes, there is another cause of Dyslexia that was discussed by A. Benítez-Burraco in his article. According to A. Benítez-Burraco, Dyslexia can also be caused by the inability to process (and discriminate) extremely rapid acoustic-type sensorial impulses (linguistic and non-linguistic). When the brain is not able to process these sensorial impulses, the person will experience the symptoms of Dyslexia which is the difficulty in reading and understanding words.

From these factors, we can conclude that the main causes of Dyslexia are primarily focused on the brain, due to the dysfunction of areas that control linguistic and senses mechanisms.

2.1.3 Symptoms of Dyslexia

Davis (one of the authors of *The Gift of Dyslexia*) who was a dyslexic in his early age argued that the symptoms associated with dyslexia arise from disorientation that results from the confusion over language symbols (Siti Huzaimah Sahari, Aiza Johari, 2012). This can be observed in most dyslexic children, as they are always confused with the way the word is spelled or they way that the letters of the word is being arranged. For example, the reversal of the word ‘dim’ into ‘mid’ as seen by a dyslexic child. In most cases, the child may also have difficulties in identifying certain letters such as ‘p’, ‘q’, ‘b’, and ‘d’. For example, in the word ‘bed’, the dyslexic child might see it as ‘deb’ or ‘beb’ or ‘ded’ (a condition where the letter ‘b’ and ‘d’ seems to be inverted).

A child with dyslexia will also have trouble in making the connection between the sound and the letter that makes the sound, and at times, he or she will have difficulty blending those sounds to form words (Siti Huzaimah Sahari, Aiza Johari, 2012). This causes the child to take a long time to utter and identify the word. If this gets too long, the child would have serious difficulties in reading the sentences and digesting its meaning. The overall process of reading and understanding will be disrupted. In some cases, the child cannot differentiate the sounds from the letter 'p' and 'b' because they are almost similar.

A child with dyslexia may forget the word and its meaning in the larger context of the sentences or paragraph (Siti Huzaimah Sahari, Aiza Johari, 2012). Due to this, some words that they have learned might be forgotten easily and they could hardly recall the word that they have learnt previously when they came across with that particular word/phrase in the future. It is hard for them to progress in the learning curve as this condition would cause them to repeat the learning of basic words numerous times before they could advance to the next level.

2.1.4 Treatment for Dyslexia

The main treatment for Dyslexia is actually having the overall education process and environment of the Dyslexic children under appropriate supervision. It should also be integrated with intensive alphabet knowledge learning and phonological awareness. According to Anne O'Hare, randomized controlled trials of phonological awareness training and of intensive small group interventions for reading have been shown to be effective. Phonological awareness training teaches the children how to recognize the phonemes (sounds) in spoken words. For example, this training helps the children to recognize that the word 'bed' is actually made up of three different letters with different sounds which are 'b', 'e' and 'd'. In terms of reading, the children will be taught on how to sound out the printed words. They will be guided on how to link the written letters to its corresponding sounds/spoken phenomes. The children will also be taught

how to understand what they are reading, add it up to their vocabulary and also they will be taught how to read with good level of fluency, accuracy and speed.

Dyslexic children need proper teachers/tutors who understand their disorder, their capabilities and their needs. This is to ensure that the support provided by the teacher/tutor is effective and will lead towards the improvement of the Dyslexic child's learning capabilities especially in reading and understanding sentences, as learning all of those things alone will be hard for them. Schools for Dyslexic children should hire good teachers in order to execute the special learning programmes designed for Dyslexic children and assist them in their learning.

According to Anne O'Hare, sometimes it is appropriate to consider adding to these approaches in school by home-based programmes which build up the child's capacity in phonological awareness. This means that assisting in Dyslexic children's learning process should not only be done in school but also at home to. Parents should be aware of this and they need to take appropriate actions. They need to take their own initiative by hiring a private tutor or learning how to assist/teach Dyslexic children by themselves so that they can teach their child by their own.

2.1.5 Method of teaching Dyslexic children

Other than the normal treatment steps that has been discussed previously (which focuses more on reading and understanding sentences), there are several other unique methods of teaching specially designed to help Dyslexic children in their studies. One of them is by using different colour chalks for each line if there is a lot of written information on the board, or underline every second line with a different coloured chalk (Hodge, P.L., 2000). Most Dyslexic children have short-term memory with regards to words or phrases and this colourful approach in the classroom may capture the child's attention and make him/her remember better. By underlining the main points or writing it using a different coloured chalk, it makes the child notice the word's uniqueness and thus by understanding the key words, it is easier for them to understand the whole phrase or sentence better.

Previous approach by Hodge P. L. was only focusing on the visual and cognitive elements. On the other hand, John Bradford in his article discusses about using multi-sensory teaching methods to teach Dyslexic children. According to John Bradford, using a multisensory teaching approach means helping a child to learn through more than one of the senses. In the normal school learning process, most of the students use their vision and their sense of hearing. But Dyslexic children may have problems in those two senses. They may have poor sight of the words as the words may be blurry, fuzzy or moving around (creating confusions) and as for sense of hearing they might have a weak auditory memory. According to John Bradford, multisensory methods are also known as VAK modalities, which stands for visual (what you see), auditory (what you hear) and kinesthetic (what you physically do). John Bradford stated that the process of learning for Dyslexic children is best done by combining all the three senses which are visual, auditory and (focusing more on) kinesthetic, as it gives the child's brain kinesthetic memory to hang on to, as well as the visual and auditory ones. Therefore, teachers who practice this approach use a lot of physical movement in teaching the children how to read or spell rather than using conventional techniques. Some teachers ask their Dyslexic students to write the letters on a box of sand so that they can feel the movement of the sand on their finger while they are writing the letter/word slowly. Others use sandpaper to create words/letters so that their students can feel the sandy surface of the letters.

Teachers who are even more creative use colourful plasticine, play-dough or clay for their Dyslexic students. The children will be asked to form the letters/words that they had just learned by using the clay/plasticine/play-dough so that they remember the feeling and the shape of the words physically. This will help them to memorise and understand better.

Technology has also become one of the supporting elements in the learning process of Dyslexic children. An example of it would be the Jollymate. Jollymate is a self-learning device for Dyslexic children. Designed in a form of a school notebook, it enables the child to practice how to write letters and numbers correctly using Jolly phonics, a system specifically designed to teach letter sounds and letter formation of the

English language to children with this learning difference (Khakhar, J., Madhvanath, S., 2010). This phonics program contains six 'letter sound' groups (six distinct letters that produces different sounds) and this group has already been designed to help the Dyslexic children. An example of the sets of groups are the letters s, a, t, i, p, n. Each of them produces different sounds and according to Khakhar, the letters are introduced not just visually but also through their sound and also actions. For example, the letter 's'. In Jollymate the letter 's' is introduced through a story featuring a snake. The sound 'sssssss...' is played when the snake is introduced, and the letter 's' animated and wave it's body just like a snake. When the elements of action, visual and auditory are present, the Dyslexic child can remember the words/letters better.

From the figure below we can see that in Jollymate the child can practice writing the letter/word on the right-hand-side workspace. If the letter is written correctly, a star will be displayed and the applause sound will be played. If the letter is not written correctly, the Jollymate recognizes the mistake and will give out an auditory feedback to instruct the child to retry.



Figure 1: Jollymate

2.2 Haptics

2.2.1 What is Haptics

Haptics refers to manual interactions with environments, such as exploration for extraction of information about the environment or the manipulation for modifying the environment and these interactions may be accomplished by human or machine hands and the environments can be real or virtual (Mandayam A. Srinivasan, 1997). Most of the current virtual environments are equipped with display devices, haptics devices such as gloves and also sound devices. This is because all of these equipments are needed in order to simulate or give the actual environment experience to the user in the virtual environment. Haptics display with force or tactile feedback can add more to the user experience of interacting with the virtual environment. The feelings/experience of touching and physically manipulating objects in the virtual environment (aside from seeing and hearing) provides a better representation for the real world to the user. According to Mandayam, some of the most popular application of haptics and virtual reality are:

- 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 haptics 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 haptics 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 interaction between human users and haptic interfaces are shown in detail in the figure below (Mandayam A. Srinivasan, 1997):

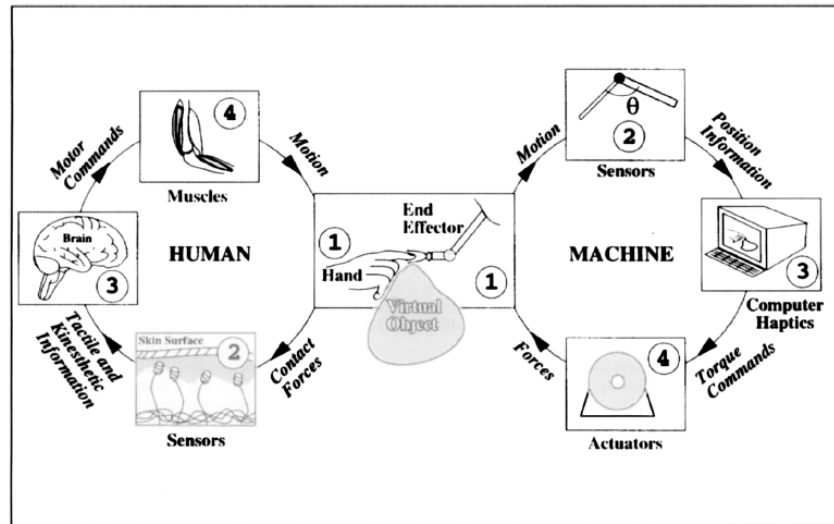


Figure 2: Human users & haptic interfaces interactions

- 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.

2.2.2 Haptics Interfaces

In interacting with virtual environments using a 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 his or her tactile and kinesthetic sensory systems (Mandayam A. Srinivasan, 1997). Simple haptic devices include keyboard, mouse and trackballs while more complex haptic devices include gloves, exoskeleton that tracks the body movement and suits. These examples cannot convey the touch and feel of objects to its users, because these characteristics could only be conveyed by tactile or force feedback.

According to Mandayam, there are basically two types of distinction among haptic interfaces. The first way to differentiate them is to determine 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 is much 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 way to differentiate haptic interfaces is whether the interface is ground-based or body-based. Ground-based haptic interfaces like force reflecting joysticks are interfaces that resides on the ground while the user is using/interacting with it whereas body-based haptic interfaces like the exoskeleton resides on the user's body while he or she is using or interacting with it.

Mandayam stated that currently the best performance by haptic interfaces is achieved by ground-based force-reflecting devices such as the PHANToM (SensAble Technologies, Inc.) and The Impulse Engine (Immersion Corp.). The performance of haptic devices lies on the human (users) abilities and limitations. The most preferable interface would be the one which can simulate the virtual environment closest to the real environment, accurate and approximate. According to Mandayam, the desirable features of force-reflecting haptic interfaces are as follows:

- Low back-drive inertia and friction, and no constraints on motion imposed by the device kinematics so that free motion feels free.
- The range, resolution and bandwidth both in terms of position sensing and force reflection, should match those of the human for the tasks for which the haptic interface is employed. The user (a) should not be able to go through rigid objects by exceeding the force range of the interface, (b) should not be able to feel unintended vibrations such as due to quantization of position or low servo rate, and (c) should not feel stiff objects as soft due to low structural and servo stiffness.
- Ergonomics and comfort: making the human user comfortable when wearing or manipulating a haptic interface.

2.2.3 Phantom Haptics Device

In the early stage, haptic rendering method only focused on displaying simple, rigid and frictionless objects. Massie and Salisbury developed the Phantom haptic interface device and proposed a point-based method for rendering primitive objects such as cube, cylinder and sphere (Mandayam A. Srinivasan, 1997).



Figure 3: The Phantom Haptics device

The Phantom haptic device is a device that lets you literally feel virtual objects with your hands (Salisbury, J.K.; Srinivasan, M.A., 1997). It looks like a miniature desk lamp. It allows the user to interact with it just like as if the user is holding a pen, using it to touch objects and shapes. The user will be able to feel the shape of the object (tactile display) by moving the pen around, as if the pen is really touching the object.

Touch or haptic interaction is one of the basic ways for human being to interact with their world. This is because human understand things with their senses, and touch feedback is one of the most important senses for a human being's understanding of the physical world. The creation of Phantom haptic device is another effort to integrate human's understanding/interaction to physical world into virtual/simulated world.

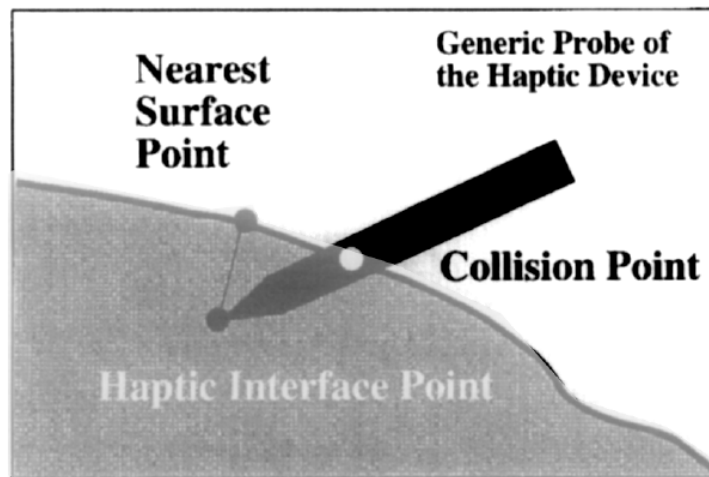


Figure 4: The Haptic Interface Point

In Phantom, the important figure/value is the distance between the Haptic Interface Point and the nearest surface point. It involves the calculation to determine the force vector and dividing the objects into sub-spaces associated with particular portions of the object's surface. Superposition of surface normals will be used to calculate the resultant force vector once the Haptic Interface Point enters the region shared by multiple sub-spaces. From this, a virtual scene can be constructed.

But according to Mandayam, there are problems related to this haptic approach, which are (1) it is hard to divide objects into sub-spaces or to construct a virtual environment from primitive objects and (2) the superposition of force vectors breaks down for thin or complex shaped objects.

The simplest analogy to explain how the Phantom haptic device works is by imagining that you holding a pencil/pen and probing objects (touching the objects) with the pen and having your eyes closed at the same time. To mimic these point contact interactions, the Phantom interface allows and measures motion along six degrees of freedom and can exert controllable forces on the user along three of those freedoms (Salisbury, J.K.; Srinivasan, M.A., 1997). This device does not constrain motions within its workspace. The inertia and friction are also low, therefore free motion feels free and comfortable, thus the users will not feel distracted while using this device. The Phantom provides convincing display of object impact, rigidity and close realistic sensation to its users due to its relatively large dynamic rang in force output (ratio of the largest to the smallest displayable force) and a compatible match with human resolution and bandwidth.

According to Salisbury in his journal, in order to evoke the sensation of touching objects, we must first model the geometric, material, kinematic, and dynamic properties of the world that we wish to represent. After that, the computational methods (haptics rendering) can be set to determine how much force that we want as a result of the interaction between the Phantom and the user. The resulting force must be considered carefully in order to achieve closest representation of the virtual object to the real object. Too much force or too low will cause the virtual object to be unrealistic and the user might interpret the object wrongly.

As for Dyslexic children, this device will have a great impact in their study especially in terms of interactivity. The Phantom provides a good and convincing physical feel to the object, thus this will allow the Dyslexic child to remember better or understand better as kinesthetic helps a lot in their learning process a lot apart from visual and auditory input.

CHAPTER 3

METHODOLOGY

3.1 Introduction

There are numerous types of software development methodologies. As for this project, the combination of linear sequential (waterfall) and iterative methodology is used. Sometimes called the “classic life cycle” or the “waterfall model”, the linear sequential model suggests a systematic, sequential approach to software development that begins at the system level and progresses through analysis, design, coding, testing and support (Roger S. Pressman). On the other hand, iterative methodology is a software development model with a basic principle of releasing bigger and bigger portions of the complete project to discover problems early and make necessary adjustments when the requirements cannot be adequately defined by users (Sachin (2009)).

This project shall be developed with the linear sequential methodology and if in the middle of coding phase or testing phase new requirements are found or some requirements need to be changed, that’s where the iterative methodology comes in. If such situation happens, the development process would have to go back to the analysis stage, redefine the new requirements changes and proceed with design, coding and testing phases again.

The purpose of the combination between linear sequential model and iterative model is because an iterative model allows re-definition of the existing system/user requirements, a feature which is not available in the linear sequential model. When a new requirement comes in or when there are current requirements that require changes, a new iteration is created as the developer goes back to the analysis phase. The iteration that had just ended will consist of complete development of the system up until the moment before the new requirement was added. In other words, the developer is

actually building up a separate component with the new iteration due to the newly defined/changed requirements. This component will be joined with the system once its development has completed (testing phase).

The software development model is further explained in Figure 5:

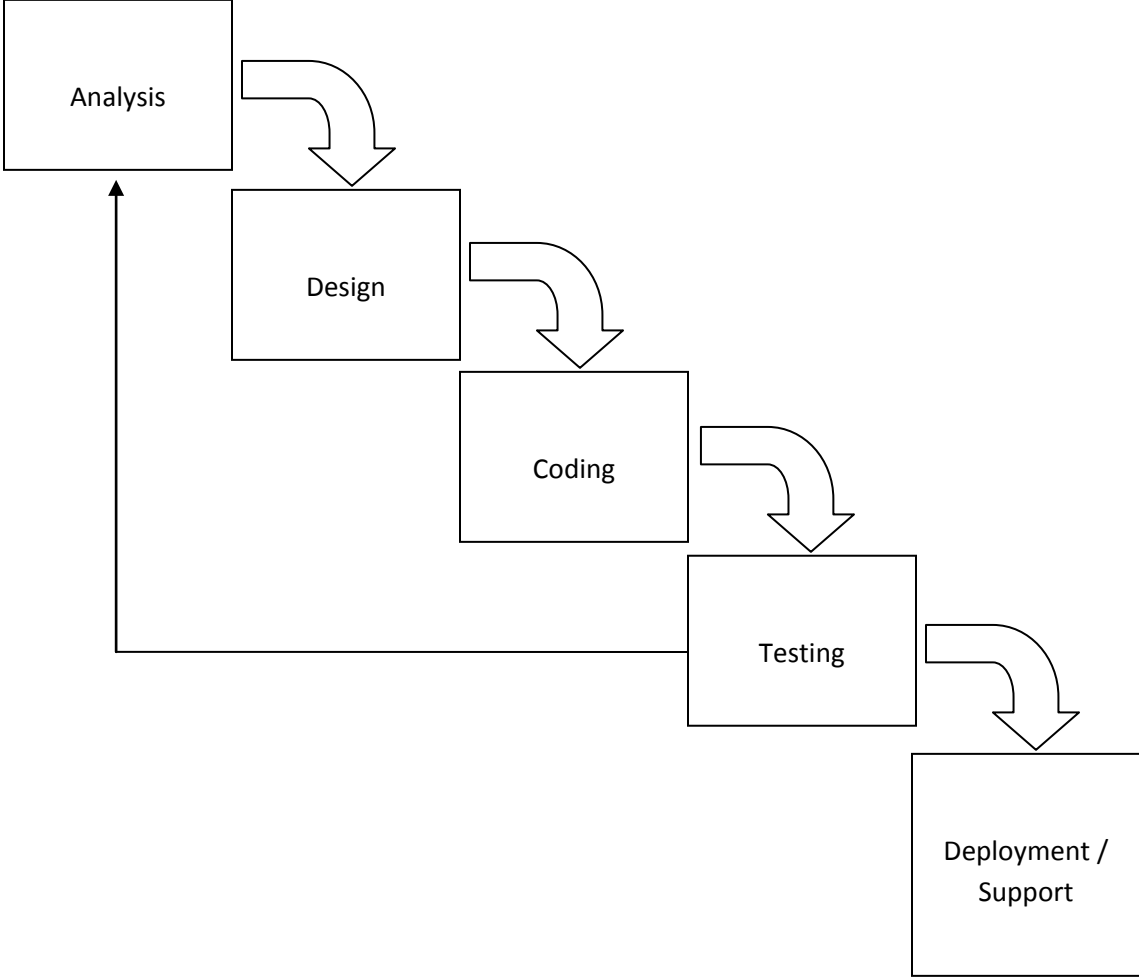


Figure 5: The Combination of Waterfall & Iterative Methodology

3.2 Project Phases

3.2.1 *Default Iterative:*

i. Analysis

- Identify problem statements, objectives, scope of work
- Create a Gantt Chart for project planning and scheduling
- Conduct literature review/preliminary research upon the topic/project title
- Identify the right programming language (C++) for the haptic interface and haptic device (PHANToM) programming
- Identify the suitable tools to be used for the interface development (Microsoft Visual Studio)
- Study on sample codes, guidelines and tutorials in developing haptic interfaces

ii. Design

- Create system flowchart and pseudocode
- Design the programming structure for the application
- Design the system GUI

iii. Coding

- Write the codes for the application software (programming)

iv. Testing

- Conduct testing and debugging
- Should there be any new requirements discovered or any current requirements that require changes, proceed with additional iterative (next page)

3.2.2 *Additional Iterative:*

i. Analysis

- Identify the new system/user requirements (what changes are to be made to the current system)
- Modify the gantt chart (update)
- Conduct literature review/preliminary research upon the new requirements

ii. Design

- Update the system flowchart and pseudocode (where possible)
- Design the programming structure

iii. Coding

- Write the codes (programming)

iv. Testing

- Conduct testing and debugging
- Should there be any new requirements discovered or any current requirements that require changes, proceed with a new additional iterative

3.3 Gantt Chart

Tasks	Weeks													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Select project title	█													
Writing project proposal		█												
Project title approval			█											
Perform preliminary research (literature review)				█	█	█								
Select project methodology					█									
Define project overall flow & Gantt Chart						█								
Analysis:														
Perform research on possible program design							█	█						
Perform research on tools required (programming language / sample codes) for program development									█	█				
Perform research on the hardware to be used (configurations / driver installations)											█	█		
Perform research on user requirements													█	█

Table 1: Gantt Chart Part 1

Tasks	Weeks													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Design:														
Design the program (storyboard)	█	█	█											
Coding:														
Program the software prototype				█	█	█	█	█	█					
Testing:														
Prototype testing & Error debugging										█	█	█		
Submission of Dissertation & Project finalized prototype													█	█

Table 2: Gantt Chart Part 2

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Discussion on System Flowchart

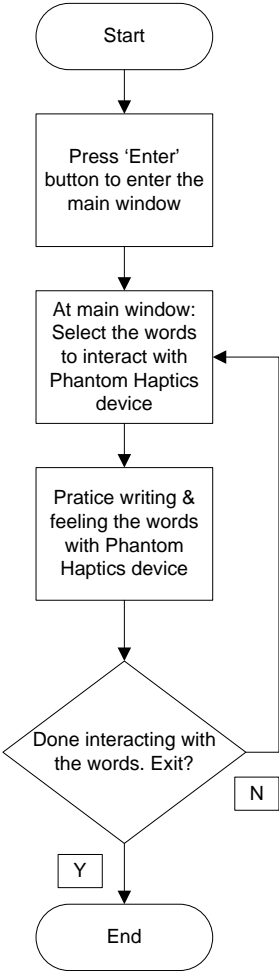


Figure 6: System Flowchart

In order to interact with the prototype system, the users first need to enter the main window. After that, the users may choose the words to be interacted with (feeling & writing with the Phantom Haptics device). Once the users are done interacting with the words, the users may choose either to exit the program or to go back to the main window and interact with a different word.

4.2 System Use-Case

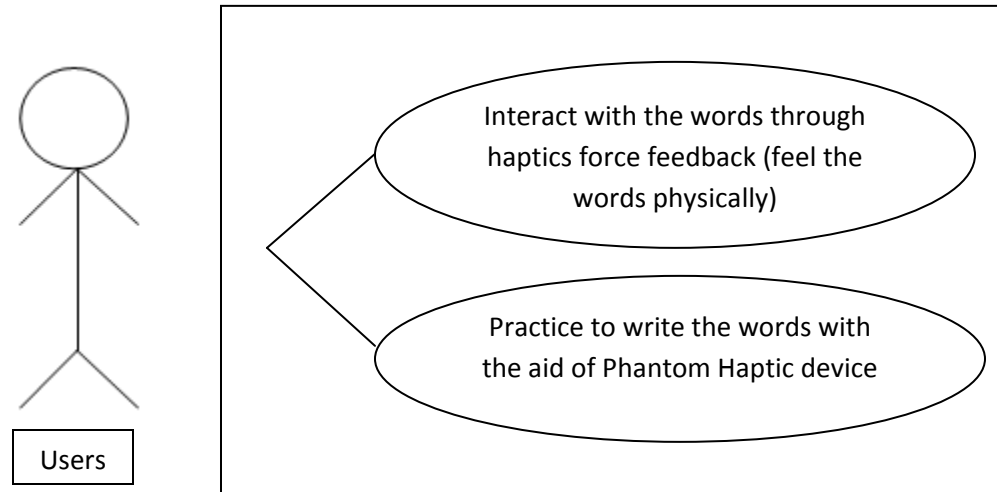


Figure 7: System Use-Case

In this prototype system, the idea is to allow the users (Dyslexic children) to interact with the words. The users can feel as if the words are physically real with the help of the Phantom Haptics Device. The users also can practice or learn how to write by following the feel of the shapes of the words via haptics force feedback.

4.3 Discussion on prototype development

The idea for this project is to produce a prototype program that can integrate the element of haptics into a learning software or interface for Dyslexic children. The primary focus for the prototype is to get the feeling of haptics force feedback working in order to let the users feel the virtual words physically via Phantom Haptics device.

The System Architecture for the prototype is displayed below:

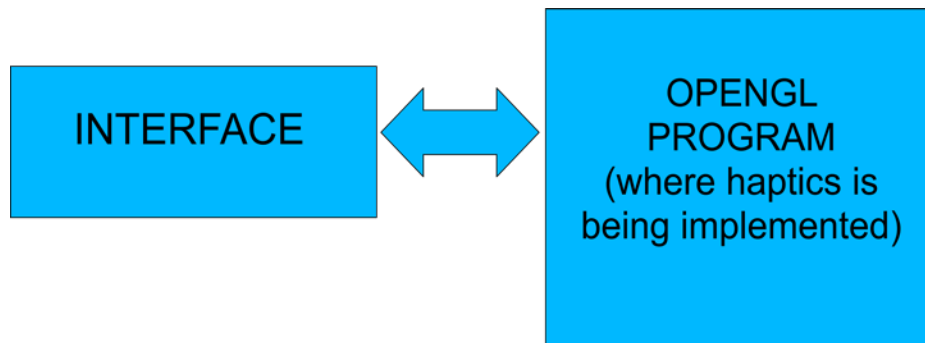


Figure 8: System Architecture

As displayed in the figure above, the prototype consists of two components which are the interface and the OpenGL program. The Interface mainly focuses of user interface, which is developed through Visual Basic programming. It aims to guide the user throughout the prototype with pictures, colourful fonts, buttons and etc. On the other hand, the haptics force feedback is being implemented in the OpenGL program. This program is responsible for the haptics / touch element of the whole prototype. It communicates directly with the Phantom Haptics device, working together with it in order to provide the physical feeling of the virtual words in the program. In a nutshell, the users will use the interface to navigate through the words to be interacted with. Once the particular word has been selected, the OpenGL program will be started and the users may start to interact and feel the words via the Phantom Haptics device.

4.3.1 User Interface development

The interface was developed through Visual Basic (VB) programming language. This component's development was kept as simple as possible because the priority was given on the OpenGL Haptics program development, due to its complexity.

The interface was developed based on a simple storyboard, which was designed beforehand. The initial concept was to build a software for Dyslexic children aged 5-10 and therefore a lot of pictures and colourful words will be included in the interface (suitability for Dyslexic kids). Below are the interface's windows screenshots:

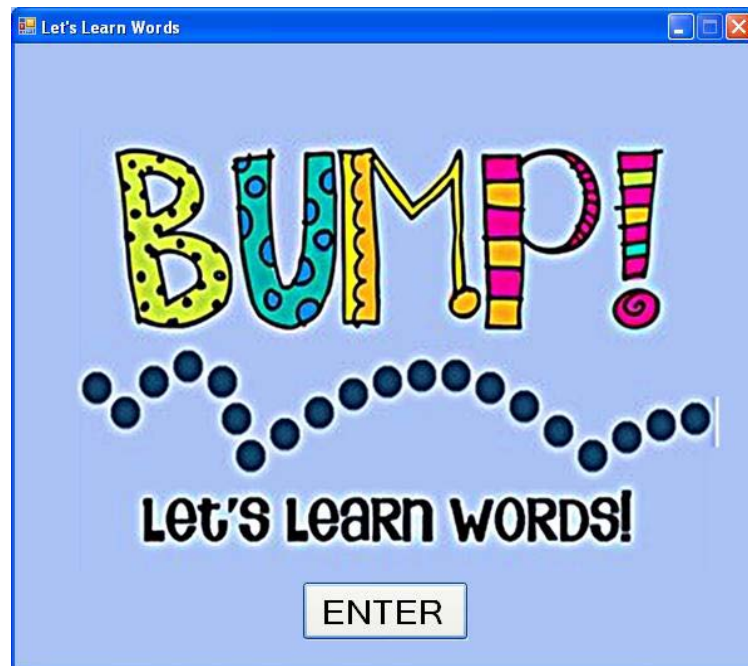


Figure 9: The first window

From the first window (as shown in Figure 9) the users will be guided to the main window of the prototype through the 'enter' button. The colourful words / phrases was designed to suit children's interest and attention to colours. In this window the VB codes are simple, straight forward and do not involve complicated functions. It involves the drag and drop design-process in VB and also some simple code modifications on the 'enter' button in order to link this window to the main window (via hide and show function).

The code snippet for the first window (Form1) is as follows (Figure 10):

```
Public Class Form1
    Private Sub Form1_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Form2.Show()
        Me.Hide()
    End Sub
End Class
```

Figure 10: The first window's code snippet

The main window of the prototype contains the word samples that the users can choose to feel / interact with the Phantom Haptics device, as shown in Figure 11:

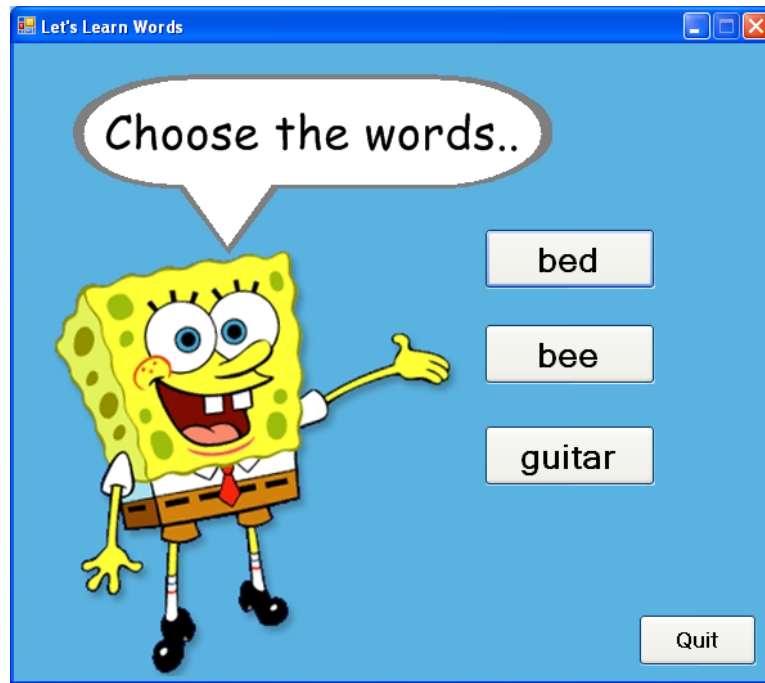


Figure 11: The main window

In the main window, the Spongebob Squarepants character is being used to attract children's attention while reading the instructions in the dialog box. A list of word samples can be selected by the users and by clicking the sample words' buttons, it

will lead the users to another window (via the show and hide functions in VB), which is the OpenGL program interface window. The ‘quit’ button is being coded to terminate the prototype’s main run or in other words, to exit / quit the program via close function in VB. Below is the code snippet for the main window (Figure 12):

```
Public Class Form2
    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button3.Click
        Me.Close()
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Form3.Show()
        Me.Hide()
    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button2.Click
        Form4.Show()
        Me.Hide()
    End Sub

    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button4.Click
        Form5.Show()
        Me.Hide()
    End Sub
End Class
```

Figure 12: The main window’s code snippet

In the OpenGL program interface window, there are two main buttons. One is the ‘back’ button and another one is the ‘write’ button. The ‘back’ button will lead the user back to the main window, and the ‘write’ button will run the OpenGL program via the Process.start function in VB. When the OpenGL program is being run, a black console window will appear on the screen (on the right side of the interface program) displaying the corresponding word on the OpenGL program interface window. The users can now hold the Phantom Haptics device and start to interact / feel the words in the black console window. The blue cursor will move according to the hands movement of the Phantom Haptics device, and the users can move the cursor towards the words in the black console window in order to be able to feel the words physically through the device.

Figure 13 below shows the OpenGL haptics program interface window together with the black console window on the right side (OpenGL Haptics program):

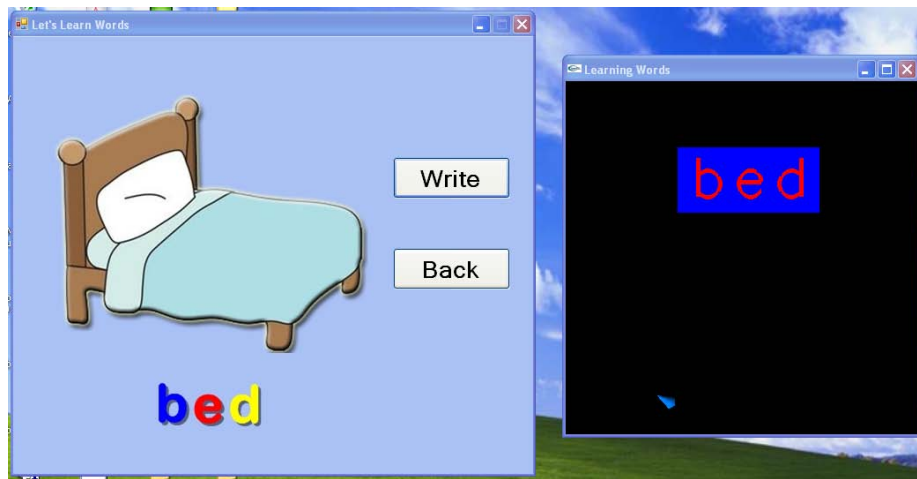


Figure 13: The OpenGL haptics program interface window

In the OpenGL program interface window, pictures were used according to the sample word that has been selected by the user. If the user selects the word ‘bed’, therefore it will display a window with a bed picture with colourful fonts. This is being implemented in order to help the children to understand the words better via pictures and the children’s imagination. Figure 14 shows the code snippet for this OpenGL haptics program interface window, together with the Process.start function and error handling (if the OpenGL program cannot be found):

```
Public Class Form3
    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button2.Click
        Form2.Show()
        Me.Hide()
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Dim Res
        Dim Filename
        Filename = "C:\Ash_FYP\bed.exe"
        If Dir(Filename) = "" Then
            MsgBox(Filename & " not found. Please specify the path correctly.", vbInformation)
        Else
            Res = Process.Start("C:\Ash_FYP\bed.exe")
        End If
    End Sub
End Class
```

Figure 14: The OpenGL haptics program interface window’s code snippet

The codes in the 'write' button are using the Process.start function and the MsgBox function. The Process.start function will run the OpenGL program in the specific directory. But first, the interface program will search for the OpenGL program in that directory, and if it fails to find the OpenGL program, MsgBox function will be called to display the error message to the user.

4.3.2 OpenGL Haptics program development

This is the second component of the whole prototype software. Due to its complexity, this component has been developed with more focus and priority. This component is actually a C++ program, combined with OpenGL and haptics programming. In this program the haptics force feedback shall be implemented in order to let the users feel the words through their hands via the Phantom Haptics device. There are several subcomponents to be discussed, namely:

1. window creation
2. the words' width and colour
3. the words' positioning & font
4. the strength of the forces on the words (stiffness)
5. the plane positioning
6. the strength of the forces on the plane (stiffness)
7. the blue cursor
8. Phantom Haptics device error handling

The OpenGL haptics program black console window is shown as below (Figure 15):

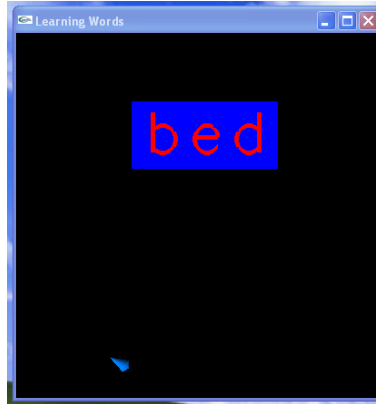


Figure 15: The OpenGL haptics program black console window

The first subcomponent to be discussed is the window creation. The OpenGL haptics program is coded to pop out on the right side of the interface program as shown in Figure 16 below.

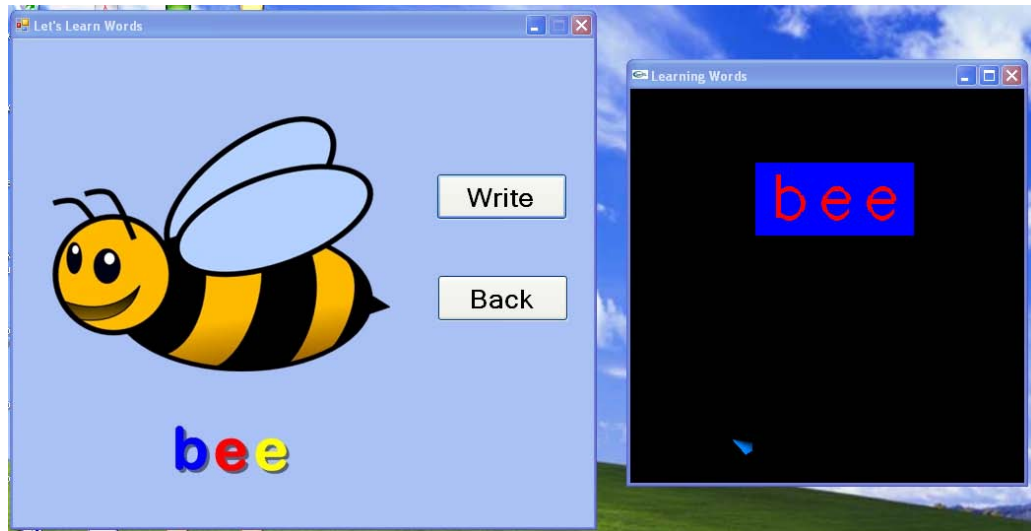


Figure 16: The position of the OpenGL haptics program black console window

This is done that way so that the OpenGL haptics program console window will not overlap with the interface program while the users are interacting with the prototype. Other than that, it was programmed this way so that the pictures and the words in the interface program will not be overlapped by the OpenGL haptics program console window. The window's size was fixed to 400 pixel x 400 pixel and the

window's position was set to a certain pixel coordinate on the screen, so that it will always pop up on the right side of the interface window. Figure 17 shows the code snippet for window creation and initialization:

```
int main(int argc, char *argv[])
{
    glutInit(&argc, argv);

    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);

    glutInitWindowSize(400, 400);
    glutInitWindowPosition(650, 100); //set window position
    glutCreateWindow("Learning Words");
}
```

Figure 17: The position of the OpenGL haptics program window code snippet

The next subcomponent to be discussed is about the words' width and colour. The colour was fixed to red because it needs to be contrasted with the plane, which is blue in colour. The text colour can be changed via the `glColor3f()` function and the width of the text can be adjusted via `glLineWidth()` function. The text will be generated via `drawstring()` function. Figure 18 shows the code snippet for the words' width and colour:

```
void drawHapticsString()
{
    static GLuint displayList = 0;

    if (displayList)
    {
        glCallList(displayList);
    }
    else
    {
        displayList = glGenLists(1);
        glNewList(displayList, GL_COMPILE_AND_EXECUTE);
        glPushAttrib(GL_ENABLE_BIT | GL_LIGHTING_BIT);
        glDisable(GL_LIGHTING);
        glColor3f(1.0,0,0);
        glLineWidth(5.0);
        glPushMatrix();
        glScalef(0.003,0.003,0.003);
        drawString("guitar");
        glPopMatrix();
        glPopAttrib();
        glEndList();
    }
}
```

Figure 18: The text's width and colour code snippet

The words' letter generation is being handled by `glutStrokeCharacter()` function. The font is a predefined font in OpenGL which is `GLUT_STROKE_MONO_ROMAN`. There are other several fonts available but this font is the most suitable one to be used. The positioning of the text on the other hand, is being handled by the `glTranslatef()` function, whereby the coordinate inputs in the functions can be edited depending on where the programmer wants to put the text in the OpenGL window.

Figure 19 shows the code snippet for the text's position handling and font:

```
void drawString(const char* string)
{
    //glTranslatef(130, -10, 0);//this is to adjust the positioning of the text for bed & bee
    glTranslatef(-20, -10, 0);//this is to adjust the positioning of the text for guitar

    for (;*string != '\0';++string)
    {
        glutStrokeCharacter(GLUT_STROKE_MONO_ROMAN, *string);
        // glutBitmapCharacter(GLUT_BITMAP_TIMES_ROMAN_24,*string);
    }
}
```

Figure 19: The text's position and font handling code snippet

The strength of the haptics feedback force (stiffness) on the words can be adjusted via modifying the `hlMaterialf()` function. The bigger the number or value supplied to this function, the harder the haptics feedback force of the words and then the haptics force feedback is stronger on the words, the stronger (more stiff) the physical feeling of the words. The stiffness of the text should be adjusted accordingly in order to give the users the best physical feeling of the text via the Phantom Haptics device.

Figure 20 below shows the code snippet for this purpose:

```
// String shape.
hlBeginShape(HL_SHAPE_FEEDBACK_BUFFER, gHapticsStringShapeId);
hlTouchModel(HL_CONSTRAINT);
hlTouchModelf(HL_SNAP_DISTANCE, gHapticsStringShapeSnapDistance);
hlMaterialf(HL_FRONT, HL_STIFFNESS, 5.5);
hlMaterialf(HL_FRONT, HL_STATIC_FRICTION, 0);
hlMaterialf(HL_FRONT, HL_DYNAMIC_FRICTION, 0);
drawHapticsString();
hlEndShape();
```

Figure 20: Text's stiffness adjustment code snippet

A plane was put together with the text / words on the OpenGL haptics program. The plane has the haptics force feedback element too, which allows the user to feel it just like the text / words does. This is done in order to guide the blue cursor towards the text while the user interacts with this program. The width of the text is quite small and therefore the plane is designed to guide the cursor to the text without missing it. This is to allow better interactions experience for the hyperactive Dyslexic children or first time users (who will normally have difficulties to feel the haptics feedback of the text). The plane is drawn via the drawPlane() function and the coordinates of the plane's vertices is defined by the glVertex3f() function. Figure 21 shows the code snippet for the plane drawing function:

```
void drawPlane()
{
    static GLuint displayList = 0;

    if (displayList)
    {
        glCallList(displayList);
    }
    else
    {
        displayList = glGenLists(1);
        glNewList(displayList, GL_COMPILE_AND_EXECUTE);
        glPushAttrib(GL_ENABLE_BIT | GL_LIGHTING_BIT);
        const GLfloat mat[] = {0, 0, 1};
        glEnable(GL_LIGHTING);
        glMaterialfv(GL_FRONT_AND_BACK, GL_AMBIENT_AND_DIFFUSE, mat);
        glPolygonOffset(1,1);
        glEnable(GL_POLYGON_OFFSET_FILL);
        glBegin(GL_QUADS);
        glNormal3f(0,0,1);
        glVertex3f(-0.1, -0.15, 0);
        glVertex3f(1.8, -0.15, 0);
        glVertex3f(1.8, 0.35, 0);
        glVertex3f(-0.1, 0.35, 0);
        glEnd();
        glDisable(GL_POLYGON_OFFSET_FILL);
        glPopAttrib();
        glEndList();
    }
}
```

Figure 21: The plane code snippet

The stiffness of the plane (strength of haptics force feedback) can also be adjusted just like the text's stiffness. It uses the same function, which is hlMaterialf() function. The bigger the parameter as the input, the more stiff the plane will be. Figure 22 below shows the code snippet for this purpose:

```

// Plane shape.
hlBeginShape(HL_SHAPE_FEEDBACK_BUFFER, gPlaneShapeId);
hlMaterialf(HL_FRONT_AND_BACK, HL_STIFFNESS, 0.8);
hlMaterialf(HL_FRONT, HL_STATIC_FRICTION, 0);
hlMaterialf(HL_FRONT, HL_DYNAMIC_FRICTION, 0);
hlTouchModel(HL_CONTACT);
drawPlane();
hlEndShape();

```

Figure 22: The plane stiffness adjustment code snippet

How does the OpenGL program transfer the virtual world's coordinates and haptics force feedback data to the Phantom Haptics device to be simulated? How does the program tell the Phantom Haptics device on how to react at certain surface of the text or plane? This functionality is handled by the blue cursor. The blue cursor acts like a finger, whereby the user will move it around to feel the text and plane. The movement of the cursor is controlled by the movements of the hands of the Phantom Haptics device. Figure 23 below shows how the blue cursor is shaped and how it is programmed to send the virtual world's information to the haptics device:

```

void drawCursor()
{
    static const double kCursorRadius = 0.5;
    static const double kCursorHeight = 1.5;
    static const int kCursorTess = 15;
    Hldouble proxyxform[16];

    GLUquadricObj *qobj = 0;

    glPushAttrib(GL_CURRENT_BIT | GL_ENABLE_BIT | GL_LIGHTING_BIT);
    glPushMatrix();

    if (!gCursorDisplayList)
    {
        gCursorDisplayList = glGenLists(1);
        glNewList(gCursorDisplayList, GL_COMPILE);
        qobj = gluNewQuadric();

        gluCylinder(qobj, 0.0, kCursorRadius, kCursorHeight,
                   kCursorTess, kCursorTess);
        glTranslated(0.0, 0.0, kCursorHeight);
        gluCylinder(qobj, kCursorRadius, 0.0, kCursorHeight / 5.0,
                   kCursorTess, kCursorTess);

        gluDeleteQuadric(qobj);
        glEndList();
    }

    // Get the proxy transform in world coordinates.
    hlGetDoublev(HL_PROXY_TRANSFORM, proxyxform);
    glMultMatrixd(proxyxform);
}

```

Figure 23: The cursor code snippet

The last subcomponent to be discussed in the OpenGL haptics program is the Phantom haptics device error handling. This program will display an error message when the Phantom haptics device could not be detected by the system. This is done to ensure that the Phantom Haptics device is being connected properly and fully working. Everytime the OpenGL starts to run, it will first check for the presence of the Phantom Haptics device and if it fails to locate the device, the error message will be displayed and the program will terminate. Figure 24 shows the code snippet for the Phantom Haptics device detection & error handling:

```
void initHL()
{
    HDErrorInfo error;

    hHD = hdInitDevice(HD_DEFAULT_DEVICE);
    if (HD_DEVICE_ERROR(error = hdGetError()))
    {
        hduPrintError(stderr, &error, "Failed to initialize haptic device");
        fprintf(stderr, "Press any key to exit");
        getchar();
        exit(-1);
    }
}
```

Figure 24: The Phantom Device error handling code snippet

4.4 Discussion on test results

The preliminary tests were conducted with two different groups. This preliminary test is conducted in order to get general opinions regarding the prototype software by people who are related to 'Dyslexic children'. The two groups are former Dyslexic children who are now adults, and a group of parents who have experience in handling Dyslexic children (their own children).

Three adults (former Dyslexic children) have been asked to test the prototype software in the lab. This is done in order to get their opinions regarding the suitability of the prototype to support the learning process of Dyslexic children. These adults are above 20 years of age and they are all former Dyslexics, which means that they have experienced Dyslexia during their childhood and in fact, some of them still having minor symptoms of Dyslexia such as slow reading.

For the prototype testing, these three testers have been asked to use and interact with the software at different sessions (one tester at a time). They will go through the software and fully interact with all the programs. The session ends after they have tested the OpenGL haptics program. After each session has ended, the testers will be asked to tell their experiences in using the prototype. Below are the summary of their experiences & opinions:

- **Tester 1:** "The physical feelings of the words are realistic, as if I am really feeling them with a pen. When I was a kid, I like to touch and feel objects."
- **Tester 2:** "I think that this would help the Dyslexic children to learn because of the excitement due to the technology used. It is something new."
- **Tester 3:** "The force on the device that allows me to feel the letters was good. It gives me a new definition of 'software'. I always thought that software only means some program inside the computer, I never imagined that I can feel it with my hands."

For the second preliminary test, a group of parents who have experience in handling or taking care of Dyslexic children will be interviewed through phone. Two parents were called through phone and the working principles of the prototype software were explained to them verbally. All of the aspects including the literature review, justifications regarding the characteristics of the software, why haptics is being used, how the software will be used and why it is beneficial for Dyslexic children were communicated to them via the phone. Below are the summary of their opinions:

- **Parent 1:** “The real ‘feel’ of the words will motivate the kids to learn better. It is a new thing, I saw my son playing with computers before but I have never seen him touching anything inside it.”
- **Parent 2:** “If this can be something complementary with what they are learning now, it would be good.”

The results from these preliminary tests look promising. Based on the opinions from the testers and parents, it seems like the software can be something complimentary to the current learning process for the Dyslexic children. The technology introduced is new in this specific field and furthermore it adds on some extra values by providing an additional element in technology that the current software could not provide to the Dyslexic children, that is the kinesthetic element to help them learn better.

The usability test of the prototype with real end users (Dyslexic children) will be done in the future, once the developers get the approval from Kementerian Pendidikan Negeri Perak. The test is planned to be held at a government Dyslexic school in Batu Gajah town, in Perak.

CHAPTER 5

RECOMMENDATIONS

There are a few recommendations that can be implemented into this project. The first one would be the bounding box implementation into the OpenGL-haptics program. The bounding box is a 3 dimensional box, drawn in an OpenGL program. The idea is to implement this box into the OpenGL program that contains the haptics feedback element, in order to restraint or limit the movement of the cursor. When the user tried to move the cursor (using Phantom haptic device) outside the bounding box, there will be an opposite force trying to push it back into the box. This implementation is recommended because the prototype will later be used by Dyslexic children aged 5-10. Some of these children are hyperactive and they may cause damage to the Phantom if they mishandle it or perform extreme movement out of it (pushing or pulling it too hard outside its physical boundary). With the bounding box embedded inside the program, damage to the Phantom can be prevented.

Another recommendation for future development of this project would be to add extra interactivity into it. Smoother and more attractive fonts in OpenGL should be used as the current prototype uses OpenGL default fonts and they appear a little bit jagged and not smooth. Other than that the developer may choose to include sounds as Dyslexic children, just like normal children, like to listen to sounds as they learn. For a higher level of interactivity, the developer may use this project as a basis to develop interactive learning games for Dyslexic children. It would definitely be a fun experience for them to be able to play games that are integrated with haptic devices (Phantom haptic device).

CHAPTER 6

CONCLUSION

Haptics feedback and haptics devices provide a great experience and benefits to its users especially those who really need them. Through haptics concept, the users will be able to use their sense of touch to interact with computer software and computer generated objects. They can feel the objects as if they are physically real even though they are not.

The features and benefits of haptics can be extended more if they are integrated into Dyslexia education-related approaches. This is because the normal learning process among Dyslexic children mostly involves visual and auditory only. The kinesthetic element (the sense of touch) is not being emphasized eventhough it can help them with their learning experience. With haptics feedback integrated into a prototype software designed for Dyslexic children, the kinesthetic element is being introduced together with technology. With multisensory learning (visual, auditory and kinesthetic element), the slow learning process of Dyslexic children can be improvised as these children can learn better and remember better if it involves physical body movements including touches (haptics).

In conclusion, haptics feedback has an important role in supporting the learning process of Dyslexic children. This project can help them to improve faster, remember better and have a better learning experience with technology.

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APPENDIX: TECHNICAL REPORT