Infrared-based Text Entry System for Handicap

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ABSTRACT

Text entry interface or text entry device is an interface to enter text information into an electronic device such as personal computer, mobile phone or tablet. Standard 101/104-keys Windows keyboard are the most common used text entry device which is easily available on market. Other available text entry devices are virtual on-screen keyboard for smartphone and tablet, ITU-T text entry for older mobile phone with keypad, and handwriting recognition system. All of these text entry devices are easy to use for normal people with little or no learning curve, but for people with severe disability or handicapped, these text entry devices are not suitable for them. Hence, a text entry device and a software interface are proposed for handicap people to ease their text entry.

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LIST OF ABBREVIATIONS

KSPC   Keystrokes per Character

PDA   Personal Digital Assistant

GUI   Graphical User Interface

ATM   Automated Teller Machine

IR   Infrared

LED   Light-emitting Diode

KB   Kilobit

SRAM   Static Random-Access Memory

EEPROM   Electrical Erasable Programmable Read-Only Memory

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CHAPTER 1: INTRODUCTION

1.1 Problem Statement

Text entry is a basic operation for personal computer or mobile phone. Text entry is relatively easy for healthy person with no disability by using common input devices such as keyboard, keypad or handwriting recognition devices. For those who are physically challenged, specially designed hardware or software is needed in order for them to perform text entry. People with motor disability often have limited range of movement. This limitation greatly hinders their ability to operate keyboard and mouse like normal people. Even if they can operate keyboard and mouse, they will fall fatigue after some time of usage due to their limited muscle strength and dexterity. Hence, a specially designed text entry method is needed to provide handicap people a more efficient way to perform text entry and prolonged the operating session. However, specialized input device often expensive and may require tuning to suit individual needs.

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1.2 Project Scope

Efficiency is one of the main factors that need to take in account when developing a text entry system for handicap personal. Other factors that need for consideration are ease of use and learning curve to adapt to the text entry system. This project aim is to deliver a text entry method for the handicap people. An input device which is easy to use for the handicap people and text entry software to operate in conjunction with the input device will be developed. The input device is a small size 9-keys input pad with the keys arrangement of 3×3 grid. The input device will be built using low cost components to make it more affordable for public. A software user interface will be developed to operate along with the input device. The software will provide an interface to the user and will also take input from the input device and translate them into text entry action.

1.3 Project Objective

The project objective is to provide a more efficient text entry method for those who are handicapped. This project will focus on developing a low cost input device and a software user interface for text entry. The proposed text entry method will be easy to use for handicap people and minimal learning curve is required.

The term handicap is very broad which include physical disability, sensory disability such as vision or hearing impairment, intellectual disability and mental disorder. This proposed text entry method is only suitable for those who still preserve minor gross motor ability such as minor hand or feet movement in order to operate the input device. People with other disability such as vision impairment can still able to adapt to this text entry method but minor learning and memorizing will be required.

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CHAPTER 2: LITERATURE REVIEW

There are many researches had been conducted on the text entry method. Few of these methods which required minimum movement or minimum key stroke to input text will be discussed.

2.1 Single-switch Scanning Keyboard

In this method, 26 letters and some punctuation marks are arranged in a matrix form and each of the rows will be highlighted sequentially and a switch will be pressed to select the highlighted row (Figure 1). Then individual characters in the selected row will be highlighted sequentially and the same switch will be pressed again to select the desired character (Figure 2).
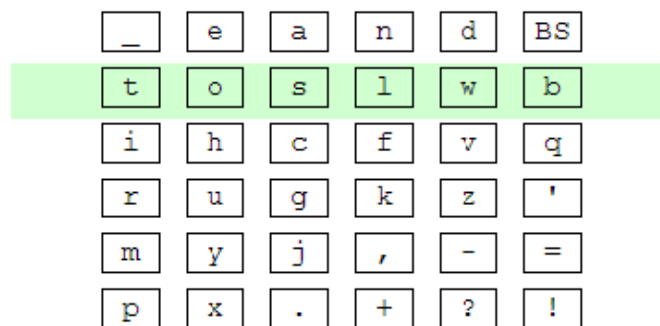
Figure 1: Single-switch scanning keyboard with highlighted second row.

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_	e	a	n	d	BS
t	o	s	l	w	b
i	h	c	f	v	q
r	u	g	k	z	'
m	y	j	,	-	=
p	x	.	+	?	!
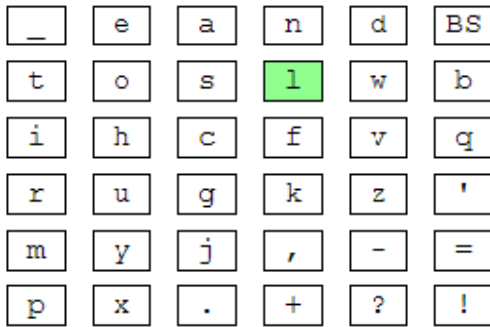
Figure 2: Single-switch scanning keyboard with character 'l' highlighted.

This method is suitable to use for those will heavy motor-impairment and for those who can only perform minor movement since only a single switch press is needed to perform the text entry. However, the text entry speed is very low and greatly affected by the scanning interval.

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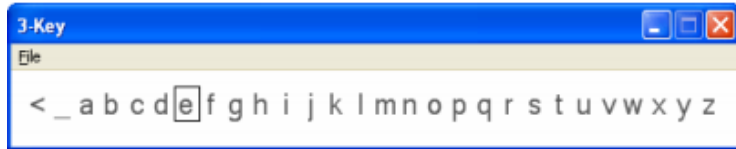
2.2 3-Key Date Stamp

Figure 3: 3-key date stamp method.

3-key method use 2 keys to move the cursor left or right and a selector key to select a letter. It is name date stamp method because of its similarity to a teller's date stamp, where character is select from a wheel which contains all of the available characters. There are few possible layouts for the alphabets arrangements as shown in the following table.

Method	Character Arrangement[a]	Cursor Mode	*KSPC*
#1	_abcdefghijklmnopqrstufwxyz	Persistent	10.66
#2	_abcdefghijklmnopqrstufwxyz	Snap-to-home	10.62
#3	abcdefghijklm_nopqrstuvwxyz	Persistent	9.18
#4	abcdefghijklm_nopqrstuvwxyz	Snap-to-home	6.45

Table 1: Layouts for alphabets arrangement for 3-key date stamp method

There is two type of cursor mode which is persistent and snap-to-home. In persistence mode, the cursor will stay on it current position after a letter is selected by the selector key while for snap-to-home mode, the cursor will move back to left edge of the layout

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after a letter is selected. KSPC (keystrokes per character) is shown for each of the layout where lower KSPC means higher input speed.

The advantage of this text entry method is easy to use and no learning is required to use this method. However, the major drawback of this method is low input speed. The lowest KSPC is 6.45 for method #4, meaning to said that to enter a single letter, 6.45 keystroke is needed. If a word contain 5 letter, 32 keystrokes is needed to complete the word which shown a relatively low input speed.

2.3 5-Key Selection Keyboard
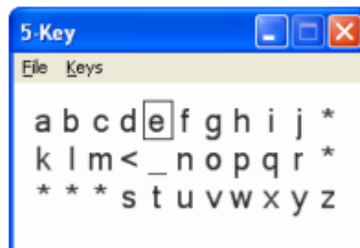
Figure 4: 5-key selection keyboard GUI.

The 5-key method uses 4 directional keys to move the cursor over a matrix of letter and use a fifth selector key to select the desired letter. It have optimized it characters layout to put frequently used characters ('e', 's', 't', 'n', 'o', and 'u') near space. This method shows a KSPC of 3.13 which is faster than 3-key method. Same as 3-key method,

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training are not required to adapt to this input method, but compare to 3-key method, the visual search time for desired letter is significantly increased.

2.4 4-key UDLR technique

This method utilized 4 directional key (Up, Down, Left, and Right) from the standard 101-key Windows keyboard as input device (Evrcinova & Evreinov 2005). Hence, it got its name from the first alphabet of the 4 directional keys.

Figure 5: Directional keys used for 4-key UDLR technique.

Characters are divided into 4 functional groups as shown in table below. Each character can be entered by sequential entering the keystroke by using 2 or 3 fingers.

Left (I)		Right (II)		Up (III)		Down (IV)	1 ↘ selection order
Up	Down	Up	Down	Left	Right	Left	2 ➤ 3
A	E	I	M	Q	U	Y	Left (3)
B	F	J	N	R	V	Z	Right (3)
C	G	K	O	S	W		Up (3)
D	H	L	P	T	X		Down (3)

Table 2: Alphabets input key sequence for 4-key UDLF technique.

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For example alphabet 'A' can be entered by pressing Left, Up, and lastly Left. Below shown some example on few character input button sequence:

S: Up – Left – Up

J: Right – Up – Right

Z: Down – Left – Right

Space: Up – Down

Backspace: Right – Left

Next Line: Left – Right

The advantage of this input method is it has a constant KSPC of 3. On the down side, users need to memorize the character input sequence in order to use this method efficiently. And users might easily get confused by the seamlessly identical input sequence.

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2.5 EdgeWrite

EdgeWrite is stylus-based unistroke input technique designed to use on variety of handheld devices such as Palm PDA (Wobbrock, Myers, and Hudson 2003). Text inputs are performed by using a stylus and moving along the edge and across the diagonals of the square.

Figure 6: Transparent plastic cover used for EdgeWrite text entry.

This technique provides high accuracy for motion for people with motor-impairment. The gesture inputs are guided by a plastic cover with a small square box opening. People with Cerebral Palsy or Parkinson's often have intention tremor which hinder them for performing smooth gesture input. By using the plastic guide cover, smooth gesture input can be performed by sliding the stylus across the square box opening.

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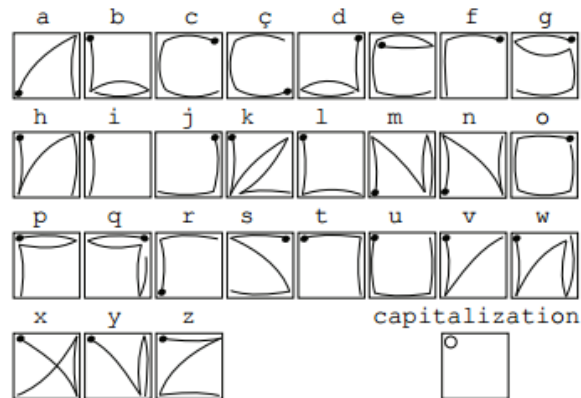
Figure 7: EdgeWrite single stroke characters input.

The advantage of this technique is easy to learn since gesture input feel naturally and closely resemble the traditional input method which is handwriting. User can get use to this method fairly quickly without much training. However, this input method required a touch sensitive screen and a stylus as input devices which are expensive.

2.6 4-Key EdgeWrite

Similar to EdgeWrite, instead of using stylus and a touch sensitive screen, this 4-key method are performed by using 4 physical keys as input device. EdgeWrite letters are mapped into 4 keys. Characters are entered by pressing the button sequentially similar to the gesture stroke from the original EdgeWrite.

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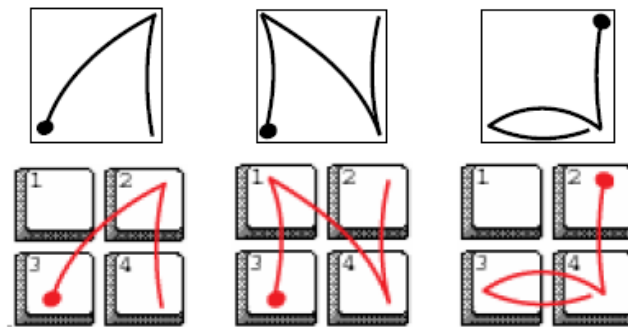
Figure 8: Input key sequence for 4-key EdgeWrite.

The following example show how some of the characters are entered by using 4-key EdgeWrite:

A: 3 – 2 – 4

N: 3 – 1 – 4 – 2

D: 2 – 4 – 3 – 4

The disadvantage of this technique is that the KSPC are not constant. For example the letter 'A' need 3 keystrokes while 'N' and 'D' required 4 keystrokes. However, this input technique required no visual search and easy to use.

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2.7 Square

Square is a text entry device that takes in the form of a small square button. The square button makes use of the 9 geometric element of a square which contain 4 vertices, 4 edges and a face. These 9 geometric elements are mapped to a 3×3 keypad (Youngwoo Yoon & Geehyuk Lee 2008).

Figure 9: Geometrical elements for a square.

This method is implemented by using a small square button and 4 physical switches. These 4 switches are place underneath the square button to interpret the user input.

Figure 10: Physical switches placement under the square button.

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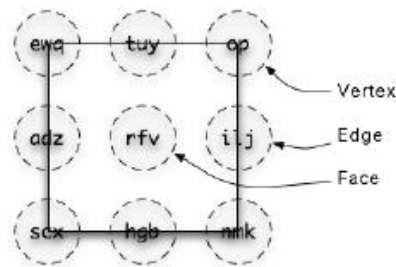Nine combinations can be made as shown in Figure 11. The 4 physical switches underneath the square button will be activated depending on which geometrical elements of the square button are pressed. For example, if top left vertex is pressed, only 1 button at top left will be activated. If left edge of the button is being pressed, 2 switches at the left will be activated. While the face of the button is being pressed, all 4 switches will be activated.
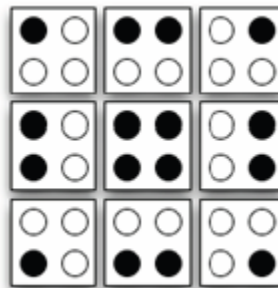
Figure 11: 9 possible combinations for the square button key press.

The advantage of this method is that the 9 geometrical element of the square are very distinct. This allow blind typing and the physical switches will provide tactile feedback to let user know whether they are successfully input the text. The downside of this device is that more force are required when pressing on the face of the square button since all 4 physical switched are needed to be activated. Continuous or extended using will result in muscle strain and fatigue.

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CHAPTER 3: METHODOLOGY AND TOOLS

Input device and a software working conjunction with it are needed to perform text entry task. A prototype input device will be built and a GUI (graphical user interface) will be developed in this project.

3.1 Input Device

A device with 9 hotspots area in an arrangement of 3×3 grid is suggested to receive input from users.

1	2	3
4	5	6
7	8	9

Figure 12: Key arrangement for input device.

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Few approaches are taking into consideration when building this input device:

- Physical switch / push button

  Switches and push button are the most common electrical component widely used in most of the electrical device such as calculator, ATM machine, game controller, and older mobile phones to receive input from users.

Figure 13: Push button.

Push button can provide distinct tactile feedback so user can know whether if the successfully input something and very low cost. However, push button require user to apply some force to depress the button in order to activate it. As we know text entry is a long session task and this will cause muscle strain or fatigue to the user.

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- Capacitive sensor

  Capacitive sensor takes human body capacitance as input. It detects anything that is conductive or has a dielectric different from that of air. Capacitive sensor can perform as same as a physical switch or push button and does not required any force to be activated. Capacitive sensor will register an input when a finger or any human body part touched on its surface.

Figure 14: Capacitive sensor.

The advantage of capacitive sensor is that it requires no force to be activated but it cost higher compare to normal physical switch or push button.

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- Touchscreen

  Touchscreen is an input device normally layered on top of an electronic visual display.

  Most of the modern mobile phone and tablet nowadays are using touchscreen as input device. Touchscreen allow users to interact directly with the content of it display. Touchscreen can be operated by using stylus or fingers.
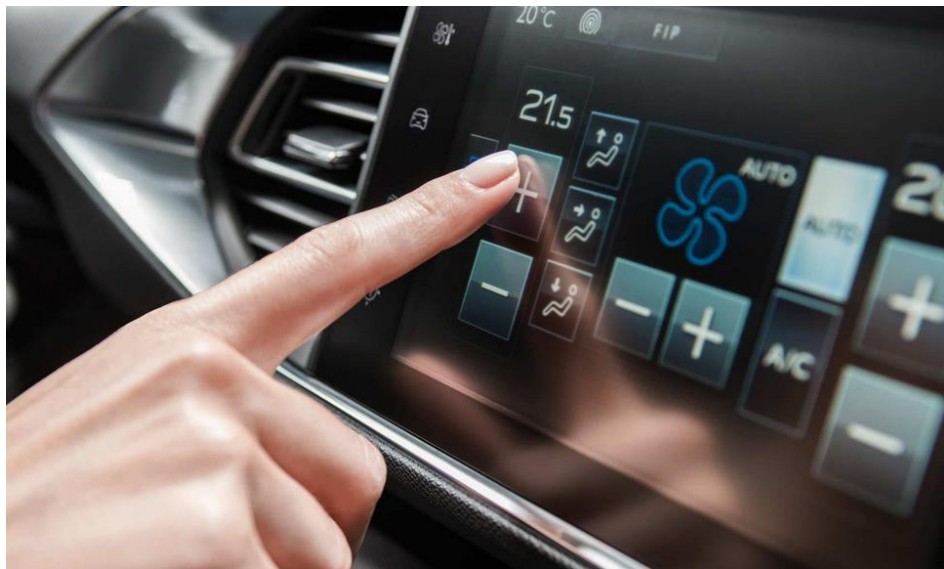
Figure 15: Touch screen.

The advantage of the touchscreen is that it allow user to interact directly with the displayed contents. A software GUI can be displayed on the screen to allow user interaction. However, touchscreen are very expensive and the software needs to be programmed to work with the touchscreen.

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- IR LED Transmitter and Receiver

An IR (Infrared) LED (Light Emitting Diode) is a 2-lead semiconductor light source that emits infrared when activated. An IR LED transmitter will emit infrared when a suitable voltage is applied to it. The IR LED receiver will be used to react with the infrared emitted by the transmitter.

Figure 16: IR LED transmitter and receiver.

The cost of the IR LED is very low and easily available. Its energy consumption is also very low. This makes it a very suitable option to use in this project.

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3.2 Developing Platform

3.2.1 Arduino Uno

Arduino is an open source computer hardware and software company. They focus on design and manufactures kits for building digital devices and interactive objects that can sense and control the physical world. There are several model of Arduino prototyping board available on the market and Arduino Uno will be choose as the project developing platform.

Figure 17: Arduino Uno.

The Arduino Uno is a microcontroller board based on the ATmega328. The ATmega328 has 32KB (with 0.5 KB used for the bootloader) and it also features 2 KB of SRAM and

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1KB of EEPROM which can be read and written with the EEPROM library. The Arduino Uno can be programmed by using Arduino IDE. The C Language is used as Arduino Uno programming language. Below are the hardware specifications for the Arduino Uno:

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7 – 12V
Input Voltage (limit)	6 – 20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 3: Arduino Uno hardware specifications.

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The Arduino Uno is chosen to use as the project developing platform because of it friendly price tag and relatively small footprint (2.7 inches in length and 3.1 inches in width). It also has sufficient analog input pins for the input keypad.

3.2.2 Input Keypad

An input keypad with 9 key (arranged in 3×3 grid) will be the initial design. The key press will be detected by using infrared LED. Below is the circuit diagram for the IR LED arrangement:
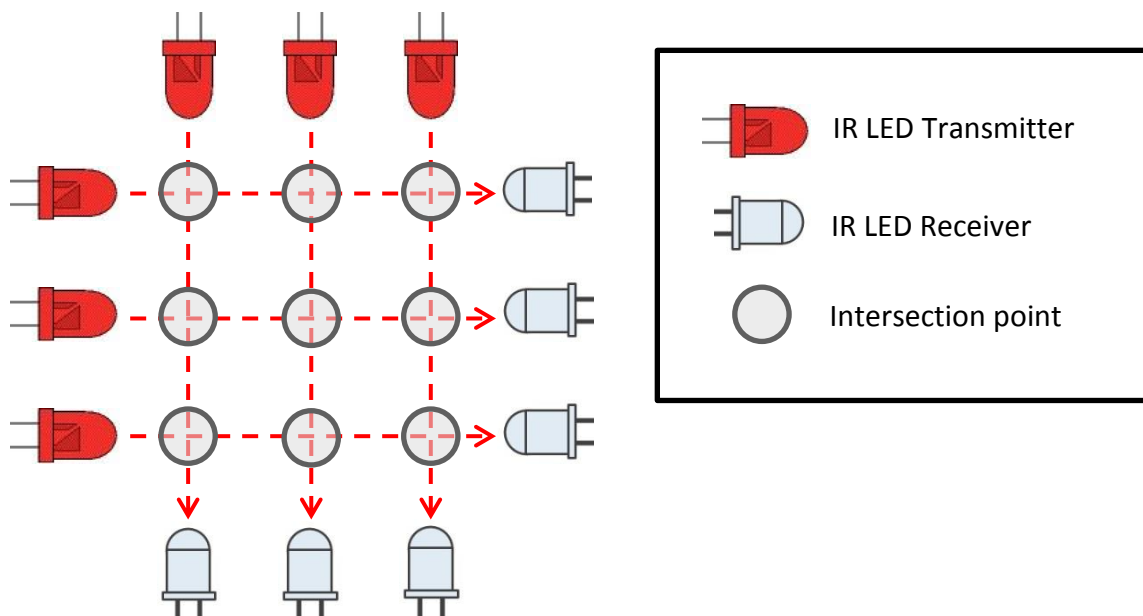
Figure 18: IR LED arrangement for input keypad.

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As shown in the Figure 18, 9 intersection points will be formed as input hotspot for the input device. When a finger is touching on one of these hotspots, the IR emitted by the IR LED will be blocked and a hardware interrupt will be generated. By using this concept, the hotspot that being pressed can be known and the input will be send over to the software GUI for further processing.

3.2.3 Software GUI

In order to interpret the input coming from the input device, a software GUI is needed. The GUI will be design in a fashion that is identically similar to the input device. 9 on screen button in the arrangement of 3×3 grid will be the visual aid for the user to perform text entry.

0 1	2	3
ABC	DEF	GHI
4		5 6
JKL		MNO
7	8	9
PQRS	TUV	WXYZ

Figure 19: Text entry software GUI.

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The 9 touch hotspots will be mapped into these on screen buttons. The working principle is very simple: all 26 alphabets and 10 numbers are arranged in these 9 on screen buttons. User can easily search they desired alphabet or number from the button. For example, if user want to input alphabet 'A', the top left button need to be pressed and this will bring the GUI to the second stage as shown in the following figure:
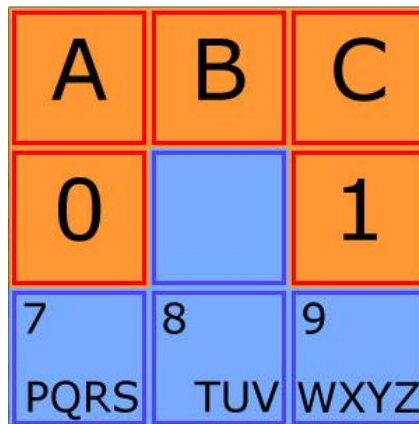
Figure 20: Text entry software GUI with alphabets selection.

The alphabets and numbers from the top left button will expand to the neighboring buttons. Each of the alphabet and number will be arranged into single button. To input alphabets 'A', the top left button will be pressed. Same goes for other alphabets and numbers, the button corresponding to the position can be pressed to input the characters.

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3.3 Timeline

The whole project progress will be divided into several stages:

- Stage 1

  The first stage is to build the input device using IR LED and Arduino Uno. The device will be tested to ensure its functionality.

- Stage 2

  After the input device had been built, a software GUI will be developed to receive the input from the device and translate them into text entry operation.

- Stage 3

  Integration between the input device and the software GUI will be done on this stage. The GUI need to perform correctly when it receives the input signal from the device.

- Stage 4

  Project finalization and documentation will be done on this stage.

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3.3.1 Gantt Chart

Project stage	Academic Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stage 1					■	■								
Stage 2							■	■						
Stage 3									■	■	■			
Stage 4												■	■	
Presentation														■

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CHAPTER 4: 9 KEY IR BASED INPUT DEVICE AND GUI IMPLEMENTATION

In this project, an actual input device and a GUI (Graphical User Interface) are developed to work together. The input device will handle the key press by user while the GUI provides the visual feedback to aid in user input.

4.1 9 key IR Based Input Device

4.1.1 Design Principle

Since this input device is designed for handicapped, several essential design principles need to be take into account:

➢ Minimum movement required

  Handicapped with motor disability will have limited range of movement. The device will be implemented in such a way that minimum movement is required to perform text entry.

➢ Minimum learning curve and easy to use

  The input device will be very straight forward and easy to use so that user can adopt to it in a very short duration without steep learning curve.
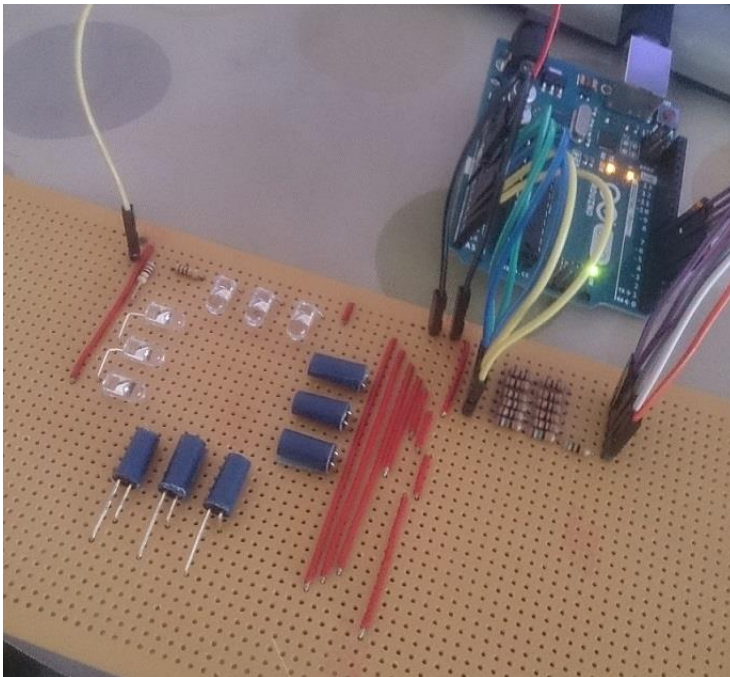
➢ Low cost and easy to manufacture

  IR led is very lost cost component and wide availability. The power consumption is also very low. For the first prototype, arduino UNO will be used to test the

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functionality of this input device. The arduino can be replaced by other microcontrollers which are much more low cost compare to arduino to further reduce to manufacture cost.

4.1.2 Hardware Implementation

The first prototype is built on a strip board by soldering method. 6 units of IR transmitter and 6 IR receiver led are used to formed a square with 9 intersections spot to detect user input. The IR transmitters are powered from the digital pins of arduino. Digital pins 2 to 7 which can provide up to 5 volt of voltage and maximum 40 amps per pins are used to power each of the IR transmitters. 6 of the IR receiver are connected to the analog pins of the arduino to read the analog value of the IR receivers.

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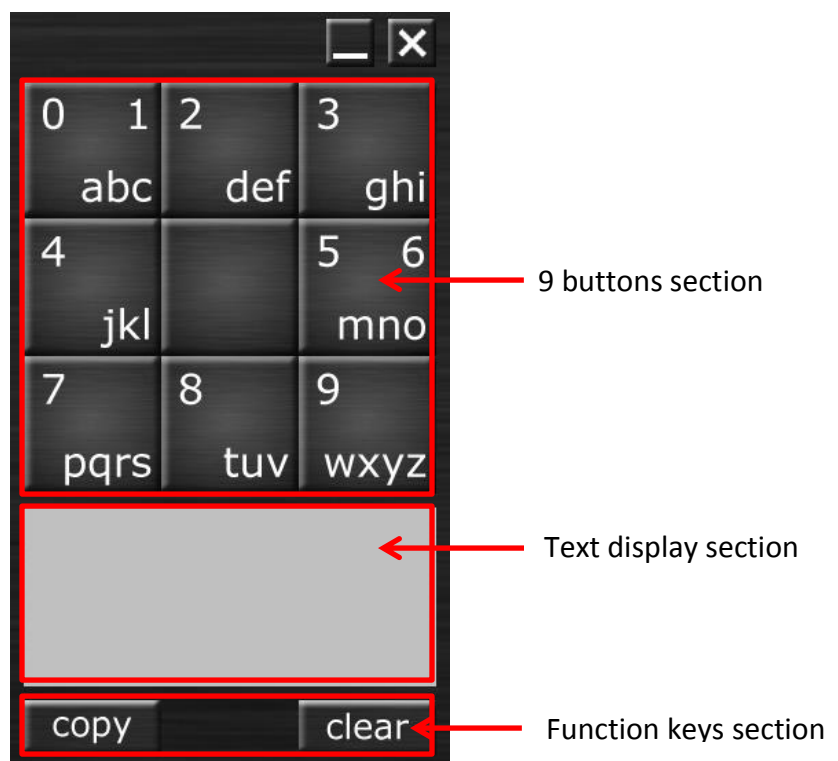
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4.1.3 GUI Design

The GUI is written with JAVA programming language. The GUI will consist of 9 buttons to provide visual feedback to user to aid in their text entry. A text area if placed below the 9 buttons to show to user the text that had been entered. Two function buttons are provided which are "copy" and "clear" button. Further detail and explanation on the GUI will be discussed on the following section.

4.1.4 GUI Explanation

The GUI can be divided into 3 sections: 9 buttons section, text display section, and function keys section.

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➢ 9 buttons section

In this section, user will be presented by a 3 times 3 buttons. All of the buttons except the middle button will consist part of the alphabet from A to Z and numeric from 0 to 9. The alphabet and the numeric presented on the button indicate that those alphabet and numeric can be access through that particular button. The middle button without any alphabet and numeric act as the functions button and will be discussed on the next section.

➢ Text display section

This area will display the text that had been entered by the user.

➢ Function keys section
2 function buttons are placed in this sections which is "copy" and "clear". "copy" button are used to copy all the text displayed in the text area to clipboard. User then can paste the text into other places to do further processing. The "clear" button is used to delete all the text in the text area.

4.1.5 GUI Usage
Text entry can be performed by the action of press-drag-release. For example, if alphabet 'c' needs to be entered, user can press on the top left button, once the button has been pressed, the 9 key button interface will change to show all the alphabet and numeric corresponding to the button clicked. If the top left button had been pressed, the interface will hide all other button and only display the alphabet and numeric on the pressed top left button which are 'a', 'b', 'c', '1', and '2'. User now can drag their finger to top right button which show 'c' alphabet and release it to enter the alphabet 'c'. Hence, every

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single alphabet or numeric can be entered by "press-drag-release" actions. Figures below will illustrate how to perform text entry by this "press-drag-release" action.

First, identify which character need to be entered, if 'c' needs to be entered, top left need to be pressed since the alphabet 'c' lies within that button. Same goes for other alphabet and numeric.

Once the top left button have be pressed, all of the alphabet and numeric corresponding to the button will be shown ('a', 'b', 'c', '1', and '2'). Alphabet 'a' will be highlighted since the user finger position is now on that button. Now, user needs to drag their finger to top right button which indicate the alphabet 'c'.

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When user drag their finger to top right button which indicate the alphabet 'c', the button will be highlighted in blue. In order to enter the character 'c', user just need to release their finger from the button.

Now the alphabet 'c' had been input and shown in the text display area.

All other alphabet and numeric can be entered by the same process of "press-drag-release".

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4.1.6 GUI Function button Usage

The middle button on the 9 keys section without any alphabet and numeric written on it is a 'Function' key. The functions that can be triggered by this key include: Shift, Caps Lock, Num Lock, Back Space, Space, Punctuation, Enter and Further Function (Fn...) which include Save .txt, Copy, and Clear. Each of these functions will be explained.
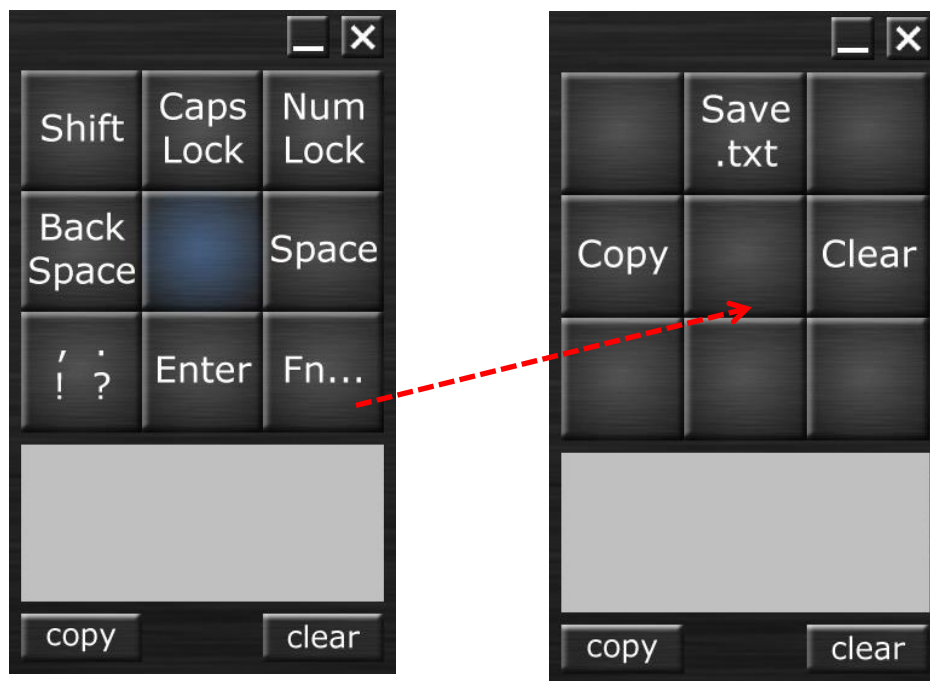
> ➢ Shift

> This function will change all the alphabet from lower case to upper case, but it will only work for the next 1 character. After this function is activated, the next character to be inputted will be upper case, and the following character after that will be switched back to lower case.

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➢ Caps Lock

This function acts the same as normal keyboard "Caps Lock" button. This function is used to switch the character from lower case to upper case, and vice versa. If the current characters are on lower case, activate this function will switch them to upper case, while character on upper case, activate this function will switch them to lower case. Unlike 'Shift' function which the effect will only work for next character, this effect will stay permanent for every subsequent character entered until user decide to switch it.

➢ Num Lock

This function will limit the input to numeric only. All of the alphabet will be hided and left only with numeric. This function is added to provide user with easier numbers input.

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➢ Backspace

This function is used to delete a single character from the text display area. If user mistakenly input a wrong or undesired character, this function can be used to make the correction.

➢ Space

This function is used to input a space after the user is complete a word. It is same as pressing a spacebar key on a regular keyboard.

➢ Punctuation (, . ! ?)
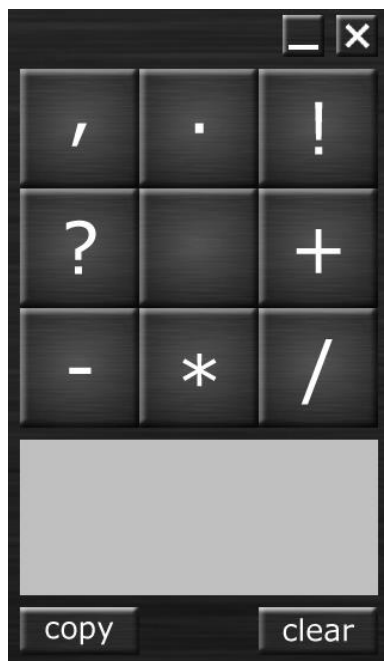
This function is used to input commonly used punctuation. For the moment, only 4 commonly used punctuations are provided: comma (,), dot (.), exclamation mark (!), and question mark (?). 4 mathematical symbol are also included such as plus (+), minus (-), multiply (*), and divide (/).

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> ➤ Enter

This function is used to enter a newline into text display area. This function is same as pressing the 'Enter' key on normal keyboard in term of text entry.

> ➤ Further Function (Save .txt)

This function allow user to save all the text entered to the text display area into a text file (.txt). The file saved will be named with the date and time when the text is saved. A popup message will be displayed after the text file had been saved. User can close the message popup be pressing any key.

Text saved as : 2015 Aug 23 [17h_46m_45s].txt

Touch anywhere to close
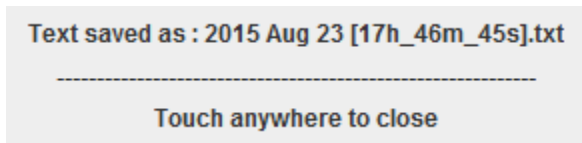
> ➤ Further Function (Copy)

This function allow user to copy all the text in the text display area into the clipboard. User then can paste it to other place to do further word processing.

> ➤ Further Function (Clear)

This function allow user to clear all the text on the text display area.

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CHAPTER 5: System Evaluation and Result

In order to measure the performance and evaluate the efficiency of this input device, a "Test Mode" version is built. Functionality wise, the Test Mode version is identical to the original version, but with added evaluating method to calculate the Word per Minute for the user.
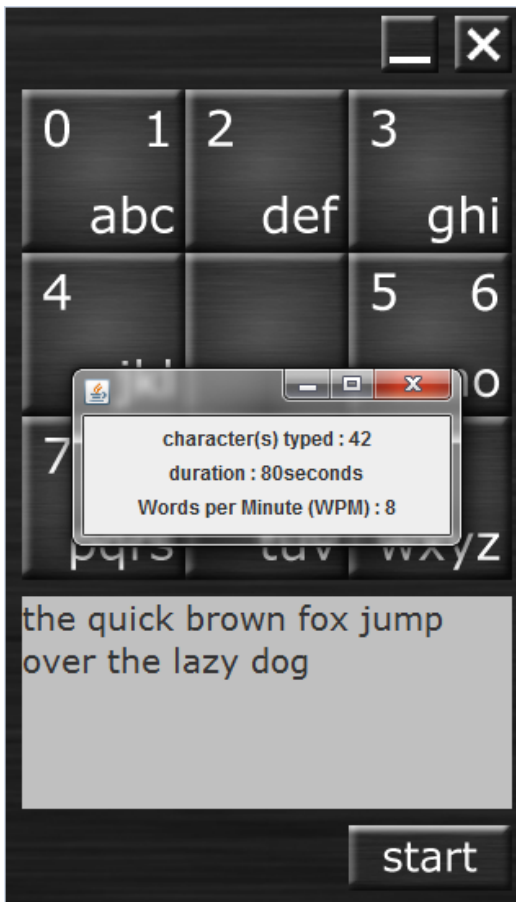
5.1 Evaluation Method

Words per Minute method is used to evaluate the efficiency of this input device. Words per Minute is a calculation on how fast is the typing speed with no error penalties. The typing speed is calculated by taking all words typed and dividing by the time it took to type the words in minutes. Each word is standardized to be 5 characters long in English, including space and punctuation. For example, "I ate" is counted as 1 word instead of 2, since it consist of 4 alphabet and 1 space, which total up in 5 characters.

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To start the evaluation, user need to click the start button located at the bottom of the GUI. This will ready the timer to record the duration. Once the user started to type, the timer will activate. When user done the typing, he will need to click on the stop button to get the evaluation result.

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5.2 Evaluation Result

The Table below shows the Words per Minute that can be achieved after several session of training.

Session	Words per Minutes
1st	8
2nd	8
3rd	10
4th	11
5th	11
6th	13
7th	13
8th	16
9th	16
10th	18

Table 4: Evaluation result for Words per Minute.

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CHAPTER 6: CONCLUSION

Throughout the process of project development, many of the learnt knowledge had been applied. Foundation and knowledge from course subject such as Electronic Circuit and Device and Embedded System Design had helped a lot along the project development.

AS for software GUI, course subject such as Programming Concept and Design and Object-Oriented Programing had provided sufficient skills and knowledge to complete the GUI implementation.

This project also provided an opportunity to learn about hardware programming using arduino platform. The skill and knowledge learned will be useful for future career or further study.

Objectives that are proposed during the early stage of the project had been achieved. The input device that is developed is very lost cost and easy to manufacture. While for it usage, minimum learning time is required to fully adopt the system.

Although the project had been complete, further enhancement can be made to it such as better GUI presentation and other features implementation can be done on the software side.

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