Experiment on a Novel User Input for Computer Interface Utilizing Tongue Input for Severely Disabled

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ABSTRACT
This paper introduces a novel passive tongue control and tracking device, which require no electrical object to be inserted to user's mouth. The device is intended to be used by the severely disabled or quadriplegic person. The device is able perform two main applications, the keyboard and mouse application. The results show that this device allow the severely disabled person to have some control in his environment, such as to turn on and control daily electrical appliances or to control the wheel chair movement. The LabVIEW programming is used for the software of this device. The system is still in the development and working prototype phase to determine the accuracy and viability of such a setup.

Categories and Subject Descriptors
B.4.2: Input/Out devices

General Terms
Measurement, Experimentation, Human Factors, Verification.

Keywords
Haptic interface, tongue control device, assistive device, computer interface, disabled or quadriplegic.

1. INTRODUCTION
The severely disabled person, who is having complete paralysis of the body on the neck down, is the main focus group of this project as well as many other inventions for an alternative user input interface. Since there is quite a large population of severely disabled persons who need the help to overcome their disability, this project focus is to develop a novel Human Computer Interface (HCI) for the severely disabled person or quadriplegic person. With the help of user input device they will be able to interact with environment and do many activities which will improve their life quality.

Currently, there are many development and invention on the assistive device. Each device employs one control method, and there are several methods currently being use. It consists of : head motion control[1, 2], eye motion control[3, 4], 3D facial tracking control[5], and voice recognition[6]. Each of these methods have their limitation; head and eye motion control will cause headache after prolong use, and the user must be always sit in front the device, facial tracking still shows significant inaccuracy and the method is very expensive, voice recognition is still not available for many languages and it has difficulty coping with different accents.

Referring to the neurophysiology study which is illustrated in the homunculus model of somatosensory and motor cortex[7, 8], it is stated that the size of sematosensory cortex and motor cortex of hands or fingers and mouth or tongue are about the same. From this study, the tongue has the potential to act as a controllable muscle similar to fingers or hands. Furthermore for a disabled person, use of the tongue is still available in many cases. This study is supported by the experiment result of using tongue as a pointing device[9], that tongue performance is only 5-50% slower to finger pointing however with practice and good system design, this speed difference can be reduced.

There are three current HCI projects in existence which utilize tongue to control the assistive device[10-12]. For the first project which use piezoelectric sensor, the user must bite the sensor which inhibit the user to close his mouth. The other two projects uses an inductive sensor and magnetic sensor, requires the user to insert some sets of wire and electrical device on his mouth which is obviously uncomfortable. These devices also have another disadvantage in the inflexibility of the device because each design only can fit for a certain size of mouth cavity and teeth morphology.

This project aims to remove these existing limitations by building a passive haptic interface system using three inductive sensors and to demonstrate the utilization of tongue as a user input in the human computer interface device. Compared to the other similar HCI projects, this project focuses in implementing the inductive sensor which has analog signal output, and to minimize the object invasion inside the mouth.

2. METHOD
2.1 Theory
The analog output inductive sensor is used for the device design. The detection method of the sensor is based on the change of the impedance of the sensor coil which was dampened by the eddy current inducted on the object surface. The change of the coil impedance is measured and evaluated and generates an approximately linear current output ranged from 0-20mA. For

data acquisition purpose the current is converted into dc voltage signal by applying 1 k ohm shunt resistor.

2.2 Experimental Setup

For every experiment on the sensor measurement, a consistent coordinates system where the origin is located at the centre of the sensor surface is configured. The inductive sensors used are IA40-FP-I3-P from Pepperl+Fuchs[13]. The device is a system of two or three sensors integration, one sensor to produce y-coordinate output and at least one sensor to produce x-coordinate output. The mounting of the sensors is required to be as closed as possible because the measurement range of the sensor is 15-40mm. The measurement range also depends on the size of the object and the material of the object.

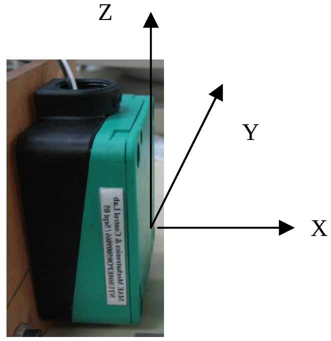


Figure 1: Inductive sensor coordinate system

The object used on this experiment is a square stainless steel object with a hole for the tongue. An acrylic wall is put on the vertical sensor in order to limit the tongue motion into a planar x and y motion. The experiment setup figure is depicted below:

Figure 2: Device experiment setup

The experiment was conducted by an able 21 year old subject, with the trial metal object being covered by plastic wrapper currently clipped to the tongue. It is expected that the final object and size will be reduced significantly.

3. DEVICE OVERVIEW

The overview of the user interfacing concept in this project is as follows: The sensor will send the analog output signal to the data acquisition system. It will then receive the signal from the inductive sensor and do the required data and signal processing and finally send the output signal as the user input signal to the computer system. The data acquisition system is also required to interface with the computer operating system so that the tongue keyboard or mouse function can operate as an alternative user input device.

The block diagram which summarized the overview design of the device is depicted below:

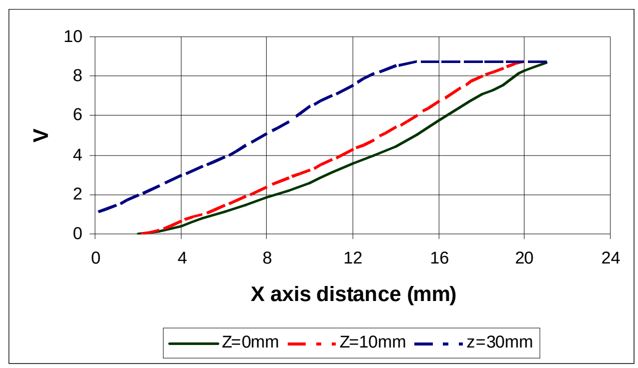
Figure 3: Device overview block diagram

The data acquisition process and the signal processing are done by using the LabVIEW version 8.00 programming environment, and the DAQ card use the DAQ MX series NI 6221(68pins)[14]. Both the software and the DAQ card are acquired from National Instruments. Both are installed in a PC with Pentium4 and 256MB Ram. The fundamental principle of the device is to collect the signal sensing data from inductive sensor and to map a specific range of sensing data to a certain command or task. The mapping result can then be used for some application which for this paper is for computer keyboard and mouse applications. For external applications, the command can be sent through the analog or digital output of the DAQ card to control everyday electrical devices.

4. RESULT AND DISCUSSION

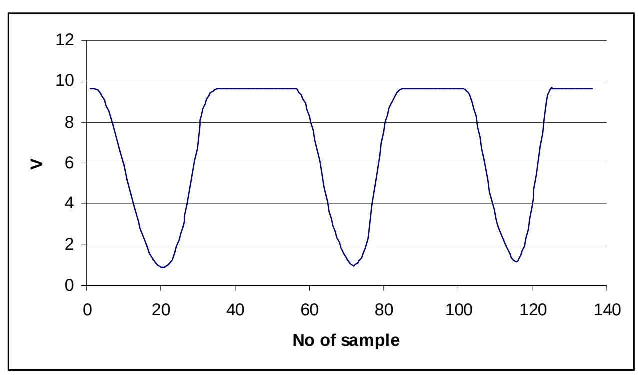
4.1 Sensor Measurement

The first graph depicts the result on sensor measurement, which indicates a usable wide range of the operating signal.



Graph 1: Sensor measurement output signal

Reliability testing on the sensor was done by moving the object to and fro from the sensor surface repeatedly and the response of this testing is depicted below:



Graph 2: Reliability testing result

There are two applications that are performed by the device, keyboard and mouse application.

4.2 Keyboard application

Figure 4: Mapping of measurement area

The upper figure is the real measurement area with the size of 80mmx30mm. The lower figure is the virtual keyboard platform made in LabVIEW environment. On the virtual keyboard, each small box represents a button with its unique key. The size of each button on the real area is about 10mmx10mm. The size resolution of each box can be increased further, however an untrained tongue might not be able to move and hold its position in the smaller size box.

In the three sensors configuration, there is mutual interference which affects the reading of each sensor. The mutual interference occurs when multiple inductive sensors were mounted close one to another. The interference reduces accuracy, reliability and consistency of the sensor output. To eliminate the interference, two solutions were applied. The first solution is by multiplexing the sensor measurement by using Darlington transistor and switching program in the LabVIEW, so that there is only one sensor turned on at one time. While the second solution is to arrange the mounting position of the sensors so that there is no two sensors in parallel or perpendicular.

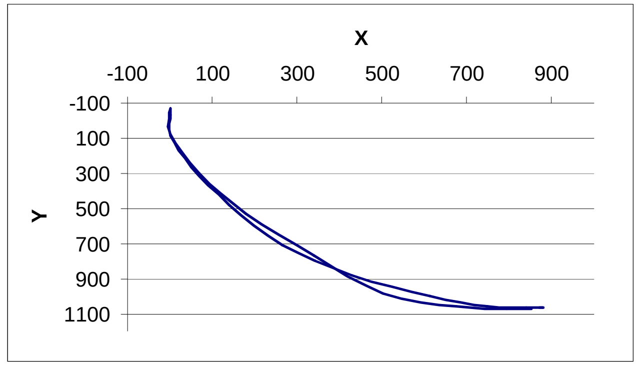
During the experiment of this application the result showed that when the object is located on the top left position, each sensor generates a certain value of voltage that is mapped to the first button and it triggered the LabVIEW program to send a key to be typed on the computer screen. This application can be modified so that each button can represent a certain task or command, such as switching on a light bulb, controlling wheel chair movement.

4.3 Mouse Application

In this application, the device performs a tongue motion tracking system. The linear analog output as depicted on graph 1 is mapped to become the coordinate of cursor position on the screen.

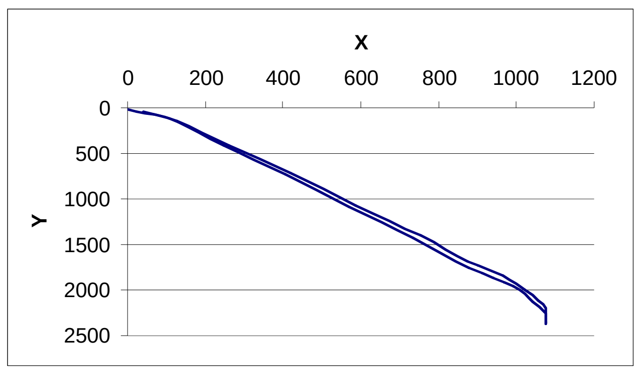
On the experiment, the device tracked a horizontal, diagonal and circular motion. The object was guided by a ruler for straight motion and unguided for circular motion. The coordinate system as depicted on the graph follows the computer screen coordinate system configuration. The range of the computer screen coordinate system is 1151x863 in y and x axis respectively. The graph plotted the x and y coordinates of the cursor as the result of voltage signal mapping, using the linear line equation:

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1} = \frac{v - v_{\min}}{v_{\max} - v_{\min}}$$

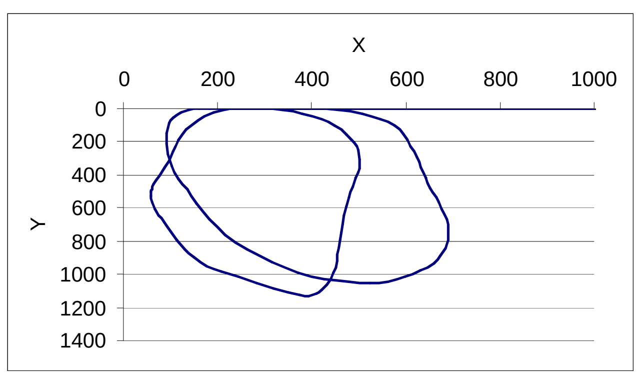


Graph 3: Horizontal motion

The curve result on the graph depicted is suspected due to the doughnut shape effect of the magnetic field emitted from the sensor. In order to make the result become a straight line, a polynomial formulation which is able compensate the parabolic curve completely by changing it to a straight line on the same Z level measurement is required. For the other two motions, diagonal and circular, the computer screen coordinate range was enlarged in order to reduce the curve effect on the cursor motion.



Graph 4: Diagonal motion



Graph 5: Circular motion

Both diagonal and circular motion depicted a good response on the cursor coordinate mapping. From the result of the three motions, this device has the capability to perform as a tongue motion tracking device.

For the left or right click, a limit switch is attached on the vertical sensor, and the user can click it by pressing it gently with his chin. The characteristics of the inductive sensor are identified such as the operating range, effect of material on measurement, analog voltage output signal, mutual interference, and doughnut effect.

The identification of these characteristics enables the author to establish the working principle design of the device. The workable range and the resolution of the device have also been identified, and the output range is between 0 – 30 mm for each sensor. By integrating two or three sensors the area made by this range is able to cover the tongue motion range outside the mouth.

5. CONCLUSION

Motivated by the large number of disabled people who need helps to do daily task, and to study of haptic interface system development, this project aims to build an innovative model of a passive tongue tracking device. The device use inductive sensor, and it does not require any electrical device to be inserted to the mouth as compared to the other HCI projects [11,12].

Two main applications were performed by this device, they are keyboard and mouse application. Each application serves a different purpose which describes the wider range of application for this device. The keyboard application demonstrates a discrete haptic control, whereby the 21 keypad button could represent 21 different tasks to be performed by this device. The resolution of the keypad button can be expanded further by having a more extensive experiment on the tongue motion.

The mouse application shows that this device could become a tongue motion tracking system, by mapping the approximately linear voltage output to the cursor coordinate on the screen. The result for this application shows that this device performs well as tongue tracking system and it can be expanded further such as to make a tongue motion recognition system.

The current stage of this project is in the first phase which is to establish the working principle of a passive tongue control and tracking device. The other two projects[11, 12], also have not reached the clinical phase.. This project also aims to do the clinical experiment on the severely disabled or quadriplegic person in the next phase of the project.

After successfully establishing the principle of this tongue control and tracking device, there are some aspects that need to be done on the next phase of this project. The device's prototype design for the next phase could include the portable design. The object used for the experiment also made some discomfort; therefore the design of the object is required on the next phase. The recommendation of the object design is a metal sheet coated by rubber design. So that the user will become more comfortable and he can still talk or close his mouth with the object is on his tongue tip.

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