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Mapping Sensor Activation Time for Typing Tasks Performed with a Tongue Controlled Oral Interface

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Abstract— **Two tetraplegic subjects performed typing tasks on a computer in an experiment using a tongue controlled oral interface. This paper reports mapping of the sensor activation time for a full alphabet text input using 10 inductive sensors. A small cylindrical piece of soft ferromagnetic material activated the sensors when placed at or glided along the surface of the sensor. The activation unit was attached to the tongue as the upper ball of a piercing. The tasks consisted of typing characters according to ordered (rows and columns) or random test strings during 30 seconds, with and without deleting characters typed by mistake. Visual feedback assisted the subjects to perform the typing tasks. Average activation times were of 0.82+/-0.38 and 1.06 +/-0.27 seconds respectively for the two subjects. Analysis of activation times may be useful in characterization of the tongue ability to activate the interface as well as in design optimization of the layout of the sensors.**

I. INTRODUCTION

Assistive devices attempt to restore part of the lost functionality of the disabled. Performance and optimization have been the focus for research groups in the past decades [1-4]. Methods of evaluation range from subjective perception of the user to more measurable functions of performance depending on the functionality of the assistive device. Performance of a device that provides text input is often characterized by speed and accuracy. Movement time during selection of the target (e.g. sensor of a keyboard) reflects primarily the speed of selection. However, due to the size and relative position of the target, an index of difficulty has been often defined as a function of the distance to the target and of the target size (e.g. sensor diameter). A combination of these two parameters is referred as throughput, a performance function for evaluation of text input devices [3-5].

A tongue controlled oral interface has been developed at Aalborg University [6]. Persons that have suffered injury of the spinal cord at a high level resulting in motor control impairment below the neck level are the main target group for this interface. The interface consists of a mouthpiece that encapsulates two sets of inductive sensors (a keyboard pad and a mouse pad). Sensor activation by a small cylindrical piece of soft ferromagnetic material results as a consequence of perturbation of the magnetic field generated by the sensor (i.e. a coil) which in turn induces a voltage into the sensor. The resulted activating signal is processed by driving electronics encapsulated into the mouthpiece and sent wirelessly to an external unit that interfaces an assistive device. The oral interface provides both text input and control in real time of a pointing device (Fig. 1).

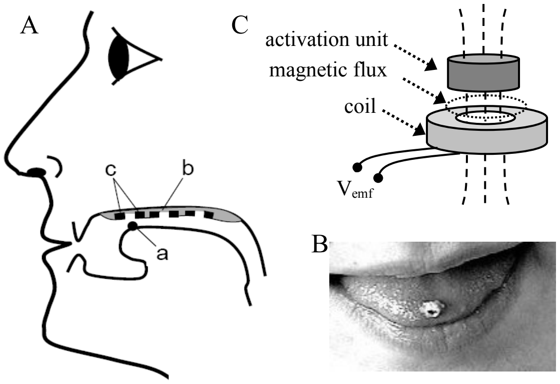

Figure. 1. Tongue controlled oral interface. **A** Placement of inductive sensors on the palate of the oral cavity and the activation unit. **B** Activation unit, glued or pierced to the tongue. **C** Principle of activation. Modified from [6] with permission, © 2006 IEEE.

This paper reports analysis of the sensor activation time when typing tasks have been performed on a computer using the oral interface. Sensors have been designed to provide a fast and reliable text input upon activation. Mapping the sensor activation time for a full alphabet text input has been evaluated to provide insight into design optimization of inductive sensors. Performance of the interface has previously been reported with respect to typing speed and real time control of a pointing device [7-10].

II. METHODS

A. Tongue Controlled Oral Interface

Data presented in this paper was obtained by using the oral interface in the Keyboard Mode for text input. A list of characters corresponded to each of the 10 sensors of the keyboard pad (Fig. 2A). Additionally, sensor number 16 from the mouse pad provided the key 'backspace'. Typing a character required sensor activation and holding it active for a certain time. The user could search for the desired sensor within a predefined dwell time 1 (of 0.9 seconds as used in this experiment). The first character in the list was typed on the screen of the computer upon sensor activation and it was deleted if the sensor was deactivated before the end of the dwell time 1. The first character in the list remained typed on the screen if the sensor was hold active longer than dwell time 1 and released before another predefined dwell time 2 (of 1 second). Continuing to hold active after the dwell time 1 and dwell time 2 resulted in typing of the second character if the sensor was released before a new dwell time 2. The process continued similar to a circular buffer if the sensor

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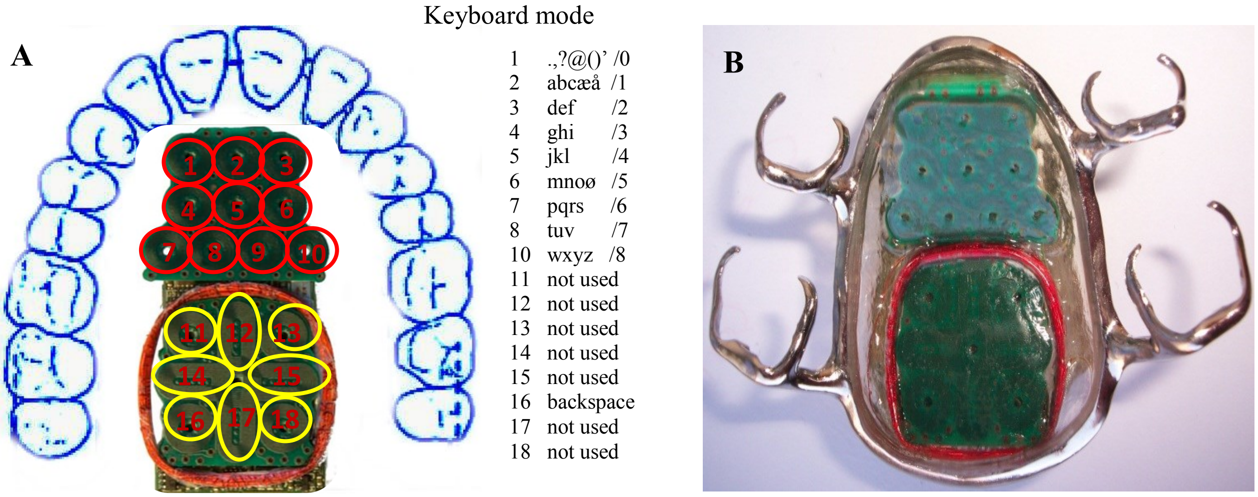

Keyboard mode

1	.,?@()’	/0
2	abcæå	/1
3	def	/2
4	ghi	/3
5	jkl	/4
6	mnoø	/5
7	pqrs	/6
8	tuv	/7
10	wxyz	/8
11	not used	
12	not used	
13	not used	
14	not used	
15	not used	
16	backspace	
17	not used	
18	not used	

Figure 2. **A** Position of sensors relative to the upper palate of the oral cavity. The list of characters associated to each sensor, corresponding to the Keyboard Mode. **B** Physical layout of the mouthpiece

was held active. The subject sat in his own wheelchair in front of a 23 inch screen computer. A mouthpiece (Fig. 2B) was inserted in the mouth and attached to the upper palate of the oral cavity using dental retainers. The mouthpiece was powered by an inductively charged battery. Data was sent wirelessly to an external electronics, processed and interfaced with a computer through a USB serial port.

B. *Experimental Protocol*

Two tetraplegic subjects gave written consent to participate in the experiment. Experimental protocol was approved by the Ethics Committee. The subjects performed both typing and pointing tasks, however, this paper reports data obtained from performing typing tasks only. The subject trained for three consecutive days, two sessions each day. A test string contained a predefined set of characters, ordered by rows and columns or randomized. The typing task was performed within 30 seconds, with or without deleting characters typed by mistake. Each test string was repeated two to eight times each session. Detailed description of the experimental protocol and typing tasks was previously reported [7].

C. Sensor Activation Time

The sensor activation time was defined by the time required by the activation unit to move from the position of the current activated sensor to the position of the next sensor intended to be activated. The user was instructed to type the first character in the test string. All text input as well as the number of the sensor that generated the character upon activation were recorded. The following character was requested to be typed if the first character was typed. This procedure repeated for all characters. Data analysis and graphics was performed in Matlab R2010a.

The user was assisted by visual feedback showing graphically the set of sensors. Sensor activation could be traced by a change in the color of the corresponded sensor. The end of the periods defined by the dwell times were marked as well by change of colors so that the user could decide activation of a new sensor.

III. RESULTS

Mapping of the sensor activation time was performed for all the 18 sensors of the mouthpiece (Fig.2A). Data corresponding to the pairs start – end sensors without recorded transitions were artificially set to 10, for illustration purposes (i.e. not all of the pairs start –end sensors produced data). For the 10 sensors corresponding to the keyboard pad data were clustered along the bisecting line of the map with an average of 0.82+/-0.38 for subject 1 and 1.06 +/-0.27 for subject 2. Neighbor sensors had activation times within the range from 0.17 to 0.64 seconds, whereas non-neighbor sensors had activation times within the range from 1.23 to 3.89 seconds.

Sensors located in the mouse pad were activated when attempted to activate sensor number 16, representing ‘backspace’ in trials where correction of characters typed by mistake was requested.

IV. DISCUSSION

Inductive sensors have been manufactured in a sandwich structure in the printed circuit board technology. This structure allows activating the sensor by gliding of the activation unit at the surface of the sensor. The visual feedback provides almost continuous tracking of the path followed by the activation unit between two points within the keyboard or mouse pad, guiding the user in selecting the desired target sensor. Alternative activation may be done by jumping from one sensor to another. This might seems as the fastest solution for non-neighbor sensors, however, the rate of success in positioning the activation unit on top or very close to the target sensor is relative low. Even though the tip of the tongue has high touch sensitivity and easily reaches all of the teeth, sensing the position of the activation unit relative to the sensor is rather difficult. The lack of reference in positioning the tongue along the sensors pad decreases the rate of success when jumping from one sensor to another.

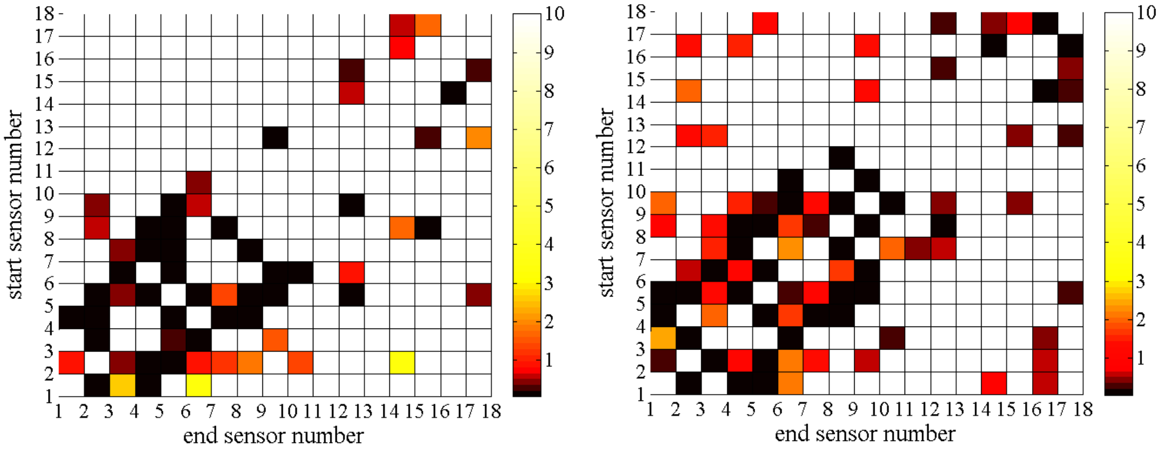

Figure 3. Mapping of the sensor activation time (expressed in seconds, color bar) for subject 1 (left panel) and subject 2 (right panel) for typing tasks with or without deleting characters typed by mistake. White squares indicate that the sensor activation time was not recorded.

Analysis of typing speed is usually performed by evaluating the time required between activation of two consecutive characters. This is represented physically by the time required to move between two target sensors (often called as transition) responsible for generating the two characters, respectively. The term sensor activation used in this paper might be easily confused with the time required to hold active a certain sensor in order to scroll through the list of characters associated to each sensor. However, as previously defined, sensor activation time is equivalent to the time required by the activation unit to move from the position corresponding to the current activated sensor to the position of the following sensor to be activated. As consequence, the sensor activation time analyzed in this paper may be regarded as building blocks or atoms of the path between the two target sensors. A condition though is the continuous gliding of the activation unit at the surface of the sensors' pad. Having this condition fulfilled, results obtained from the analysis of the sensor activation time as defined in this papers may be compared with results for the character activation time as used in characterizing the performance of text input devices [10].

Results show that sensor activation times for neighbor sensors are considerably smaller than the ones corresponding to non-neighbor sensors activation (i.e. jumping required). Data for the same start – end sensor are higher than the ones corresponding to the neighbor sensors. Deactivation by gliding would result in neighbor sensors activation. Consequently, data for the same start – end sensor may be obtained only by removing the activation unit from the surface of the sensor and replacing it again (i.e. jumping). The only sensor used from the mouse pad was the sensor number 16, providing 'backspace'. Data from subject 2 illustrate best the higher values of the activation time for non-neighbor sensors.

Gliding and jumping data may be easily identified and treated separately if required. The present analysis considered, however, both types of data to illustrate the differences between them.

The main benefit in analyzing the sensor activation time is given by the information obtained from discretization of tongue movements over the sensors' pad. The information obtained may be easily related to optimization of design of the sensors. Analysis of tongue movements may be used in design of sensor pads for users with a reduced control of the tongue.

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