Development of a Non-contact Tongue-motion Acquisition System

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ABSTRACT
We present a new tongue detection system called SITA, which comprises only a Kinect device and conventional laptop computer. In contrast with other tongue-based devices, the SITA system does not require the subject to wear a device. This avoids the issue of oral hygiene and removes the risk of swallowing a device inserted in the mouth. In this paper, we introduce the SITA system and an application. To evaluate the system, a user test was conducted. The results indicate that the system could detect the tongue position in real time. Moreover, there are possibilities of training the tongue with this system.

ACM Classification: H.5.2 [Information interfaces and presentation]: User Interfaces. - Input devices and strategies.

General terms: Design; Human Factors

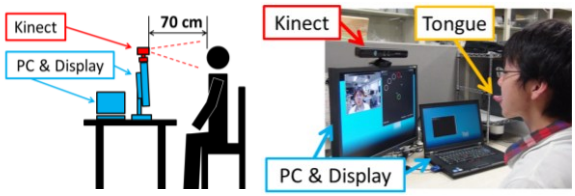
Keywords: tongue–machine interface; device not worn; optical method.

INTRODUCTION
The tongue has two characteristics relevant to this study. The first characteristic is the tongue's great potential for movement. The tongue moves quickly and precisely when we are speaking or eating. The performance of tongue movement enables us to pronounce many types of words and to swallow without leaving food in the mouth.

The second characteristic is the tongue's neural structure. Although the tongue is a motor organ, it differs from others such as hands and legs in terms of the neural pathway to control movement. Thus, the tongue nerve can remain functional even if a person is severely injured or paralyzed.

Huo et al. [1] recently took advantage of these two characteristics in developing a tongue-based interface with a magnetic solution. Using their system, subjects put a small magnet to the tip of their tongue to measure the position of the tongue tip with magnetic sensors held by a headset. Park et al. [2] also put a small magnet to the tongue tips of their subjects, but their method is based on variable inductance according to Faraday's law. Saponas et al. [3] presented an optical method, in which a device containing infrared light-emitting diodes and infrared photodiodes is placed at the bottom of the mouth. This optical method detects some tongue gestures. Thus, there are now many types of devices for measuring the tongue position, although there is no non-contact tongue detection system. Putting a device in the mouth is dangerous owing to the issue of oral hygiene and the risk of swallowing the device. To counter these problems, we present a new method that can detect the tongue position while not requiring the subject to wear a device. With this system, named SITA (Simple Interface for Tongue motion Acquisition), tongue detection can be totally secure and hygienic. To apply the SITA system, myofunctional therapy (MFT) was employed. MFT includes many training tasks to improve the function of the tongue and mouth.

SITA SYSTEM
Hardware
Figure 1(a) shows the components of the SITA system. We used a Microsoft Kinect device, a laptop (Lenovo ThinkPad T520, Windows 7 Professional, Intel® Core i7 CPU 2.80 GHz, 8 GB RAM) and a display monitor. We set the Kinect device on top of the display monitor, facing the subject's face. The tongue tip was determined from depth and RGB data obtained from the Kinect device. Considering the data quality of these two variables, we placed the Kinect device at a distance of 70 cm from the subject's face.



(a) Hardware layout **(b) Experimental scene**

Figure 1. Hardware layout of the SITA system.

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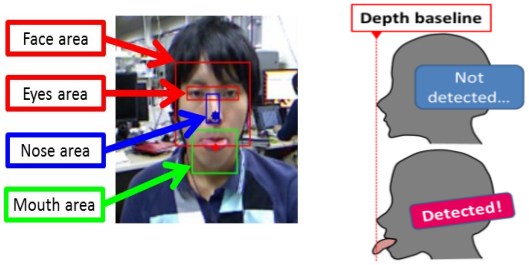

(a) Face segmentation **(b) Tongue detection**

Figure 2. Tongue detection procedure.

Tongue Detection Algorithm

The SITA system uses depth data and RGB data from the Kinect device to determine whether the tongue tip is outside the mouth and to detect where the tongue tip is.

First, with RGB data, the facial area and eye area are detected. Second, the nose area is defined to be below the center of the eye area. In the nose area, depth data are used to determine the location of the tip of the nose. As a mouth area, a 70 60-pixel rectangle is created 20 pixels below the nose area (Figure 2(a)). Depth data are used in the mouth area, as for the nose area, but this time to determine the location of the tongue tip. The depth value of the tongue tip is compared with that of the nose tip. If the tongue tip is shallower than the nose tip, or in other words, nearer the Kinect device, the tongue tip is detected as being outside the mouth. If it is not shallower, the tongue tip is not detected. This method prevents the mistake of the shallowest point in the mouth area being regarded as the tongue tip even if the mouth is closed (Figure 2(b)).

APPLICATION

The application used in this work is a type of shooter game controlled by simple tongue motions. The player is the center green circle on a display, and the circle automatically shoots bullets at regular intervals when the tongue tip is exposed. The player can change the course of the bullet by moving the tongue tip right and left. The player's objective is to shoot target circles. In this game, the player can destroy target circles one by one, in one direction. If the game starts from right to left, then it will start from left to right the next time. These motions are called "lip tracer" in the MFT program. If all targets are destroyed, smaller targets appear.

USER TEST

To evaluate the SITA system, a user test was conducted for five males in their twenties. In this test, the aforementioned application was used. The user test was to play the application for 3 minutes. Each subject played just once.

After the user test, each participant was asked about the system's smoothness and controllability and whether his/her fatigue in playing the game is indicative that the tongue is being trained.

RESULTS

The test results were that five participants agreed that the SITA system was smooth to operate; four agreed that the controllability of the system was adequate; and all agreed that playing the game was tiring for their tongue. Also it was found that the tongue detection sometimes had difficulty when the tongue tip was at the far right or left.

CONCLUSION & FUTURE WORK

We developed a non-contact tongue detection system called SITA. In an evaluation of this system applied to a shooting game, most participants agreed that the SITA system has good smoothness and controllability. Additionally, all participants agreed that, even in the short duration of play, their tongue felt fatigued. Hence, playing this game has great potential to train the tongue as part of MFT training. Moreover, the SITA system can contribute to MFT training through applications such as the shooting game.

The current SITA system can only detect tongue movements associated with a few training tasks of MFT and limited range of the tongue tip position; therefore, SITA needs to be further developed to detect other tongue movements. From another point of view, if the fatigue of using the SITA system can be reduced, the system can be used as a pointing device. We will explore this application as a pointing device in the future.

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