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Wireless Gyro-mouse for Text Input on a Virtual Keyboard

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***Abstract**: In this paper, we propose a gyroscopic pointing device that allows a user to type text by using a specialized virtual keyboard. We compare different typing methods that use the dwell time of the pointer as a character selection method. The proposed solution can be used in different applications, such as: computer gaming, virtual reality, remote control and to facilitate communication with people affected by certain disabilities and can easily accommodate more types of users. The performances of different methods have been analyzed by using the speed of typing measured in words per minute, the task success rate, as well as the feedback from the user regarding comfort and perceived ease-of-use.*

1. Introduction

The advent of low-cost Inertial Measurement Units (IMU) Micro-Electro-Mechanical sensors (MEMS), combining gyroscope and accelerometer in a single package, provided the possibility of a wireless accessibility system that increases the capabilities of users and opens up new ways of interfacing with computers.

In the literature, many human-computer interfaces (HCI) including different types of sensors (based on gesture detection, eye tracking, and brain-actuated devices) are presented [1-4]. In [1] a gyro-mouse, which provides a new human-computer interface (HCI) for persons who are disabled in their upper extremities is presented. In [2] is illustrated a hand-gesture-based interface for facilitating communication among speech- and hearing- impaired disabilities. The system presented in [2] includes a wireless sensor glove equipped with five flex sensors and a 3D accelerometer. In [3] the development of a headset-type computer mouse controlled by gyro sensors for disabled people is described.

In this paper, we describe an implementation of an IMU-based pointing device working as a wireless gyro-mouse, intended for text input on a virtual accessibility keyboard. Different accessibility keyboard settings and input methods have been tested and compared in terms of the speed of typing. An online typing test service "10FastFingers" [5] has been used by each user to type text, including the error correction. The speed of typing measured in words per minute (WPM) has been calculated. This value was used to evaluate the system performance.

2. Technical Description of the Proposed Gyro-Mouse Interface

The proposed wireless gyro-mouse interface, shown in Fig. 1, consists of an IMU sensor placed on the user's hand, used to control the cursor movement on the user screen. The device is controlled by moving the IMU sensor along three axes, using Tait – Bryan angles [6], named *roll*, *pitch,* and *yaw* (Fig. 1). These angles are used in aerospace for an aircraft orientation with respect to the world frame [6]. In order to move the cursor on the user screen (which is a movement in the *x*-*y* plane), only the *roll* and the *pitch* angles, illustrated in Fig. 1, are used.

The hardware component of the proposed interface, illustrated in Fig. 1, includes an IMU sensor (MPU 6500) and a Bluetooth-enabled microcontroller (ESP 32). The IMU sensor includes two components: (1) the gyroscope, from which we get angular velocity data in three axes, measured in radians/second, which is further integrated into the approximate angle of the system, and (2) the accelerometer, from which we find out the direction of the gravitational acceleration, that serves as an "anchor" for our measurement. Due to the nature of the sensor, the angular data that results from the gyroscope is less noisy compared to the noise of the accelerometer, but tends to drift because of the integration. By combining it with the data from the accelerometer, which does not drift over time, we obtain stable angle data in three axes and a fast enough update rate to use for input.

The embedded software component of the interface is composed of a modified open-source orientation library [7] used for communicating with the MPU 6500

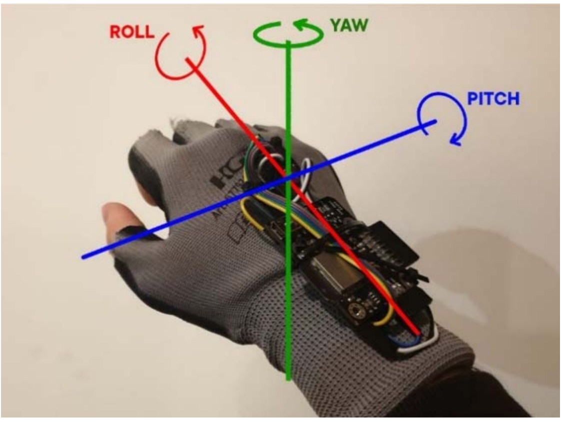


Fig. 1. IMU-based wireless gyro-mouse used for controlling the pointer on the user display and primary rotation axes (*pitch*, *yaw,* and *roll*) of the IMU sensor.

and an open-source human interface device (HID) library [8] that handles interaction with the host device over Bluetooth.

The rotation angles of the sensor in the two planes (around the roll and the pitch axes) are mapped linearly with a number of pixels in the corresponding direction in the X-Y plane, relative to the current cursor location.

Holding the device at 0 degrees of deflection means no movement of the cursor, and this position is used to perform a character selection.

3. Experimental Results

The test group included 10 healthy subjects who are students of the Faculty of Electronics, Telecommunications and Information Technology from "Gheorghe Asachi" Technical University of Iasi, Romania. They were informed about the functionality of the system, and they gave consent to participate in the experiment, and for the results to be recorded.

Each subject was allowed a period of accommodation with both mouse and the wireless gyro-mouse system. For all tests, a virtual keyboard provided by OptiKey [9] was used. This keyboard supports different values for dwell time as a selection method for a keypress.

Each subject performed the test with a standard mouse and with the proposed gyro-mouse interface, for five values of the dwell time, respectively, 1250 ms, 1000 ms, 750 ms, 500 ms, and 250 ms. The results obtained with a standard mouse are considered a baseline time and are used to evaluate the proposed interface performance.

Each test consisted of typing randomized words provided by an online typing test service "10FastFingers" [5], with a time limit of one minute. The number of correct and incorrect keystrokes was also recorded for each subject.

The system performance is assessed by the speed of typing and task success rate for each subject, according to the standard test methodologies of computer-human interfaces.

In Fig. 2 the average, the maximum, and the minimum values of the typing speed depending on the dwell time are shown for both the IMU-based gyro-mouse and a standard mouse, obtained for all subjects are illustrated, after performing all sets of tests for each user.

In Fig. 3 the average value of the task success rate depending on the dwell time for all subjects is presented. The task success rate represents the percentage of the corrected typing characters from the total number of keystrokes.

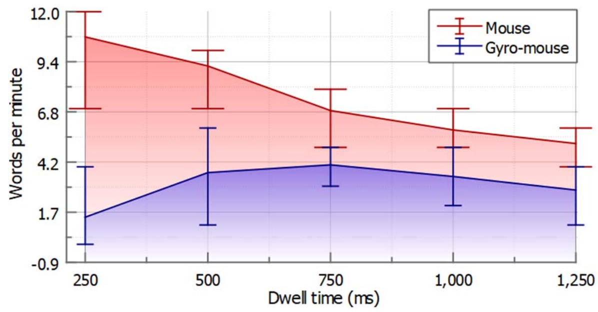


Fig. 2. Average speed of typing for all subjects depending on dwell time for the two analyzed devices (IMU-based wireless gyro-mouse and standard mouse)

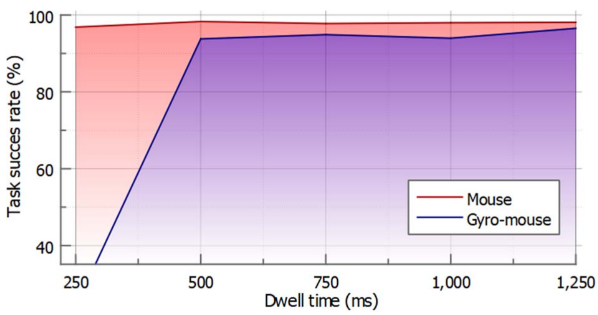


Fig. 3. Average values of the task success rate depending on the dwell time for the two analyzed devices

In Fig. 4 the operation of the proposed wireless gyro-mouse interface for text input using the hand movement of the user around the *pitch* and *roll* axes is illustrated.

According to results presented in Fig. 2 for the wireless gyro-mouse interface, a correlation between the dwell time and writing performance has been found, until the Midas Touch problem [10] comes into effect for dwell time values lower than 750 ms, and becomes more evident after dwell times lower than 500 ms, resulting in erroneous input, leading to a lower speed of typing.

The maximum performance was found around a dwell time of 750 ms for most of the users, as it is shown in Fig. 2. Although some subjects were capable of better performance for a dwell time lower than 750 ms, they also preferred to use a higher value of dwell time for daily use.

All test subjects were capable of using the mouse for text input. The results of the mouse experiment were quite similar for all subjects that tested the system, according to the results illustrated in Fig. 3.

In the experiment, the same sensitivity values and device were used for all subjects, in order to keep bias out of the results.

By observing the subjects during the test, we noted that some of them intuitively try to use the device as a joystick, in which pulling back the hand results in a downwards movement of the cursor on the screen. However, most of the users have preferred the classical way of cursor control, when the direction they are pointing the device is the direction in which the cursor moves. On the other hand, all the test subjects agreed on the functionality of the *roll* axis, correctly assuming that a *roll* action towards the left/right would result in a leftwards/rightwards motion of the pointer on the screen. For consistency, all recorded experiments have been done with the classic control method.

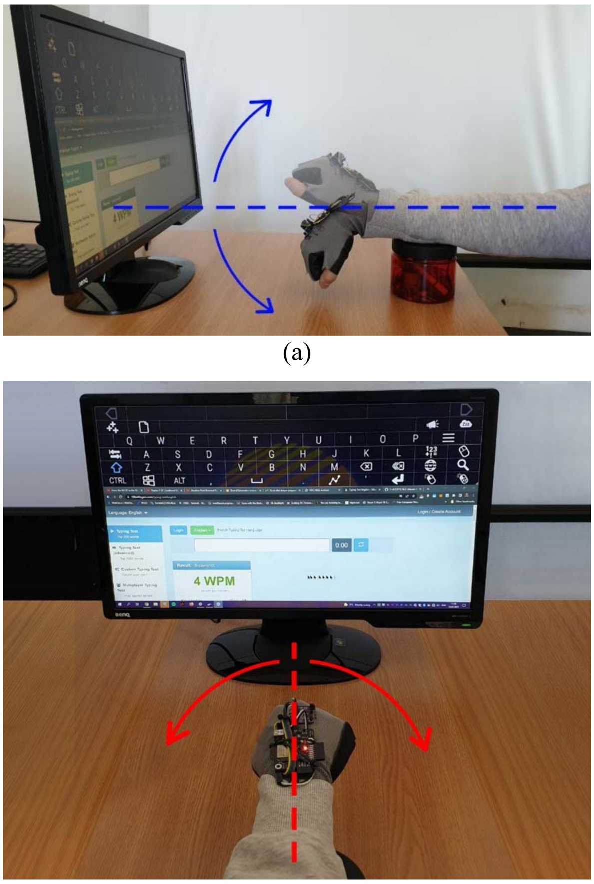
However, the *roll* axis was not devoid of problems, with many test subjects being observed as trying intuitively to use the *yaw* axis instead, resulting in erroneous input and confusion in the test subjects until the functionality of the device was explained.

In a future development, in order to increase the performance of the proposed system, a method of swapping *roll* and *yaw* axis will be investigated.

Due to the less common method of input, some users had difficulty in accommodating to the device, citing too high of a sensitivity, or inaccuracy of the system, while others rapidly considered it intuitive. This would indicate a need for more accessibility options as each user interacts with the device in a different way, with a very personal set of options, such as dwell times, sensitivity values, and even the position of the sensor. Our system allows changing these values according to the user's needs.

According to the experimental results, in order to get better performance, the sensitivity and the dwell time values of the system need to be modified depending on user experience in using the system.

Users with less experience in using the system preferred a longer dwell time, higher than 750 ms, and requested a lower sensitivity.



(a)

(b)

Fig. 4. Text input using the proposed wireless gyro-mouse interface: a) vertical movement of the cursor by rotating the hand around the *pitch* axis; b) horizontal movement of the cursor by rotating the hand around the *roll* axis.

One of the possible applications of the proposed method of typing is for communication with neuromotor disabled people, as it is shown in [4]. Depending on the degree of the disability, the sensor can be placed on different body parts, such as the head or lower and upper limbs. Other applications could be in computer gaming and virtual reality (VR) environments, such as different types of simulators.

In order to increase the performance of the proposed system, a selection method different from dwell time should be implemented, such as finger movement or sip/puff sensors. Another possibility to increase the performance of the proposed interface would be to use data from more fingers of the hand in order to increase the speed of typing and the degrees of freedom for the movement.

The experiment concluded that a great number of accessibility options and personal preferences should be considered in an eventual consumer implementation of the technology, such as the ability to swap axes, invert axes, and the possibility to set the sensitivity, or a self-tuning system that learns and adapts accordingly based on past user data.

In a future study, a software package that implements these functionalities and additional options will be implemented.

4. Conclusions

In this paper, a robust method of typing based on a wireless gyro-mouse has been presented. The proposed interface includes a specialized virtual keyboard with dwell time as a selection method and a wireless gyro-mouse based on an IMU sensor that combines an accelerometer and gyroscope in a single package.

The proposed device has been tested on 10 healthy subjects, students of "Gheorghe Asachi" Technical University of Iasi, Romania.

According to the obtained results, all subjects succeeded in using the device as intended, and obtained good performances in the typing test. All subjects rapidly and easily learned to use the device and succeed in completing the required tasks.

The best performance results have been obtained for a dwell time of 750 ms, where the average speed of typing for all subjects was 4.1WPM.

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