ISBN: 978-1-7281-1097-4

UNIVERSITAS GADJAH MADA
FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRICAL
AND INFORMATION ENGINEERING

Faculty of Information Technology
King Mongkut's Institute of Technology
Ladkrabang (KMITL), Thailand

ICITEE 2020

Proceedings of

The 12th International Conference on Information Technology and Electrical Engineering

October 6th - 8th 2020

Sponsored by

IEEE INDONESIA SECTION

IEEE PES INDONESIA Power & Energy Society®

IEEE SMC The Indonesia Section Systems, Man, and Cybernetics Society Chapter

ROLLS ROYCE

Welcome Message from the General Chair

On behalf of the organizing committee, I am honored and delighted to welcome all of the participants from around the globe to the virtual meeting for the The 12th International Conference on Information Technology and Electrical Engineering (ICITEE2020). This conference is organized by Department of Electrical Engineering, Faculty of Engineering, Universitas Gadjah Mada, Indonesia and co-organized by Department of Electrical Engineering, Faculty of Engineering, King Mongkuts Institute of Technology Ladkrabang, Thailand.

As we know that the COVID-19 pandemic is still hitting around the world. Therefore, this conference is conducted in virtual meeting. However, we hope that this situation does not diminish our spirit of research activity to contribute for a better world. In this conference, more than 65 scientific papers from more than 5 countries were presented with the acceptance rate is less than 50%.

We hope you have a good time and opportunity to connect with expertise from scientific community, renew friendship, extend our networks, and jointly explore current and future research direction. This conference will be divided into breakout rooms and you are free to join any topic you are interested.

To put a conference of this magnitude is not a small task. As a program chair, I want to thank all committee members for their tireless efforts to organize all sessions and tracks; I thank to IEEE Indonesia Section for guiding us how to run the conference better. I thank to Faculty of Engineering and Department of Electrical Engineering for providing all facilities to run this conference. I also would like to thank all keynote speakers for sharing their research experiences as a keynote speakers. Lastly, we would like to thank all of the conference participants for their contributions which are the foundation of this conference.

Sincerely,

Sigit Basuki Wibowo
General Chair

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2020 12th International Conference on Information Technology and Electrical Engineering (ICITEE), Yogyakarta, Indonesia

The Combination of Foot Switch and Low-Cost IMU for a Wearable Mouse in Human-computer Interaction

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***Abstract*—A wearable mouse using upper arm movement/ gesture is a promising pointing device that can be used by people with lower-arm disablement due to accident or prenatal disablement. The movement of the upper arm could be used to substitute the cursor movement. The use of an inertial measurement system is one way to capture the arm's movement in 3 dimensional spaces. The purposes of this study are the development of a new wearable mouse using the nine degree-of-freedom of inertial measurement unit and a foot switch for clicking action; and the evaluation of its performance on a specified level of difficulties. The device was evaluated by comparing the proposed device and a standard mouse. The performance indicators were throughput, movement time, comfort, and fatigue, based on Fitts' Law formula. The important finding is a significant ($p < 0.01$) difference in throughput between each level of difficulty in the proposed device by means of the target's distances and diameter/width in graphical user input design. The other finding showed no neck fatigue related differences between the proposed device and a mouse.**

Keywords*—*inertial sensor, low-cost IMU, human-computer interaction, wearable mouse

I. Introduction

The number of traffic accidents in Indonesia during 2004-2014 as reported in [1] showed a significant increase. The three levels of severity were described in the Abbreviated Injury Scale (AIS) created by Association for the Advancement of Automotive Medicine; i.e., fatalities, major injuries (AIS > 3+), and minor injuries (AIS < 3). The minor and major injuries, which were the first and second largest, could force the subject into bed rest during the rehabilitation period. Thus, they need an assistive technology to emulate the mouse for their daily work related to the computer. The second background of our study is based on the difficulties of people with special needs and disabilities in Indonesia who do not have a job. According the report in [2], 74.7% and 88.2% of people with special needs in Indonesia do not have jobs and do not continue on to junior high school, respectively. We presume the problem that causes persons with disabilities is not being able to use a mouse to operate a computer. Using our system, we hope new jobs related to computing work would open up for people with special needs.

For people with an injury in the forearm, the upper arm is the only part that could be used to substitute mouse movement. However, the upper limbs are more natural than the lower limbs in this case, since the mouse is moved by hand. By means of those, we used the lower limb as a stimulus for clicking action only and the movement of the upper arm to emulate mouse-cursor movement.

This paper would like to contribute a new wearable mouse using the upper arm and a foot switch, as well as an evaluation of the proposed system. The rest of this paper is organized as follows: Section II discusses the system of a wearable mouse, the evaluation of the system, and the related explanation of the experimental procedure. Section III discusses the result of the experiment. Finally, conclusions and future work are described.

II. Wearable Mouse System

The proposed system, as illustrated in Fig. 1, consists of an inertial measurement unit (IMU), foot switch, and a standard laptop with WIFI communication. The IMU typically determines attitude (roll and pitch) by combining the data from two sensors: accelerometer and gyroscope. The magnetometer is added when heading is necessary [3], [4]. The application of IMU as a three dimensional sensor is wide, such as in gait analysis [5], [6], and some effort using part of the IMU for people with special needs support tools, as in [7], [8]. The foot switch works based on the action of the pressure of the foot muscle and tendons. The '0' and '1' logic was introduced when the foot released and pressed the switch, respectively. The communication between the proposed device and the laptop wireless, using WIFI.

A. IMU GY-951 and Angle Determination Method

IMU GY-951 is a product of SMAKN®, and consists of an accelerometer using an ADXL345 chip, a gyroscope using an ITG3205 chip, and a magnetometer/digital compass using an HMC5883L chip; all sensors have 3 axes. The controller is a

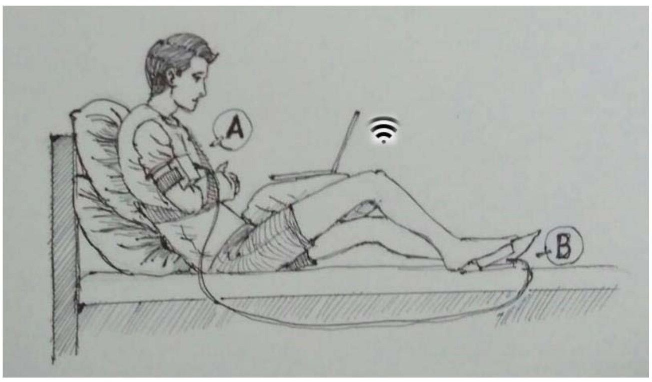
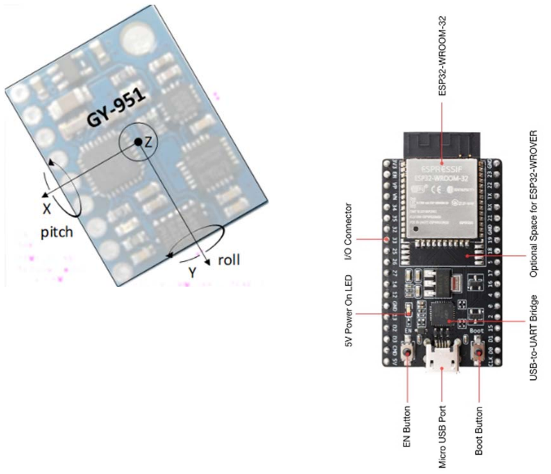


Fig. 1. Upper-arm wearable mouse system used by the bedridden: A) IMU sensor for cursor movement; B) Foot switch for clicking emulation.



(a) (b)

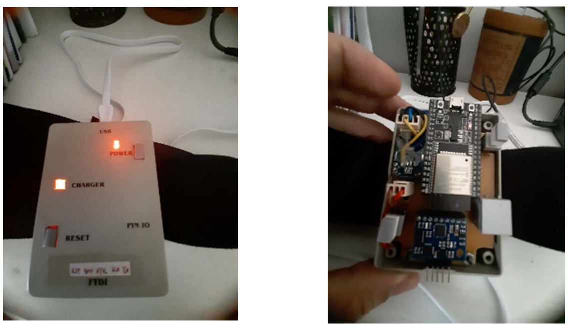
Fig. 2. a) Orientation of axes for GY-951; b) ESP32-DevKitC Board

Microchip 8-bit AVR microcontroller ATmega328. Figure 2a shows the orientation of the axes of sensitivity for IMU.

There are many methods to yield the roll, pitch, and yaw. In GY-951, the fusion of three sensors is done using a Direction Cosine Matrix (DCM) based on [9]. Many other fusion methods are also often used, such as a Kalman filter [4], [10], [11] and a complementary filter [12], [13].

B. *ESP32-DevKitC Board*

The ESP32-DevKitC board was used to handle the input from the foot switch and to control the communication between the foot switch, the IMU, and the laptop. Fig. 2b illustrates the ESP32-DevKitC board, which board consists of an ESP32-WROOM 32 chip, which is the main part of the board; an EN button; the boot button; the USB to UART bridge chip; a micro USB port; a 5V power on LED; and an I/O connector, which also supports PWM, ADC, DAC, I2S and serial communication protocol (i.e., I2C and SPI). Figure 3 shows the proposed device set.



(a) external view (b) internal view

Fig. 3. The set of the proposed device

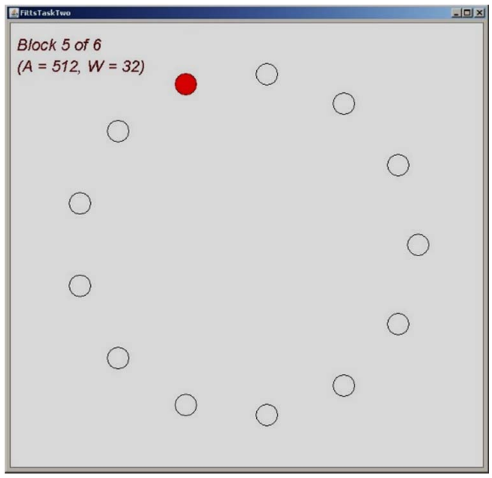


Fig. 4. The FittsTaskTwo software (produced by Prof. I. Scott MacKenzie, York University, http://www.yorku.ca/mack/FittsTaskTwo.html).

C. *Experiment Design*

Twelve participants, including one with lower arm disablement, participated in our study (average age 22.4 years old; s.d.: 4.3). Since within-subject design was used, we divided the participants into four groups and used a 4 x 4 Latin square design to arrange the four levels of difficulty for every group. The multidirectional task instrument based on Fitts' law theorem in ISO/TS 9241-411 (Ergonomics of human-system interaction standard) was used. The software was produced by Prof. I. Scott MacKenzie, York University, Canada; the original name of the software is FittsTaskTwo and the application name is GoFitts. Figure 4 illustrates the FittsTaskTwo software. The red circle is the target. "*A*" means the distance to the next target, while "*W*" is the target's diameter. The four levels of difficulty were based on the targets' distances and target diameter. Each subject tried 3 blocks in each difficulty level for the proposed device and a standard mouse, so the number of trials was 3 blocks x 4 levels of difficulty x 2 devices = 24 trials.

The IMU was attached to the biceps, as shown in Fig.1. The up-down movement of the cursor on the laptop monitor was brought about by the pitch movement of the upper arm, while the left-right movement of the cursor was brought about by the roll of the upper arm. The left-click action of the mouse was produced by foot press on the foot switch. The participant was free to determine whether to use their left or right foot on the foot switch.

The test measured the quantitative and qualitative aspects of human movement. The quantitative measurement was represented by throughput (*TP*) and movement time (t_m), while the qualitative measurement was represented by questionnaires concerning comfort, fatigue, and assessment of effort.

Fitts's law indicates that TP is the conclusion of speed and accuracy, and higher is better. The t_m indicates the average of time movement from initiation to target selection, a faster t_m indicating better performance. Higher comfort, lower fatigue, and lower effort indicate better performance. Figure 5 illustrates one of the experiment sessions.

Fig. 5. The experiment of the proposed device

III. EXPERIMENT RESULTS

A. Quantitative Results

The spread of the data is represented using boxplots for the throughput (*TP*) and movement time (t_m), as illustrated in Fig. 6 and Fig. 7.

Table I describes the experiment results in detail, whereas Table II shows the diameter of the target and distance to the next target as the parameters for mode of difficulty.

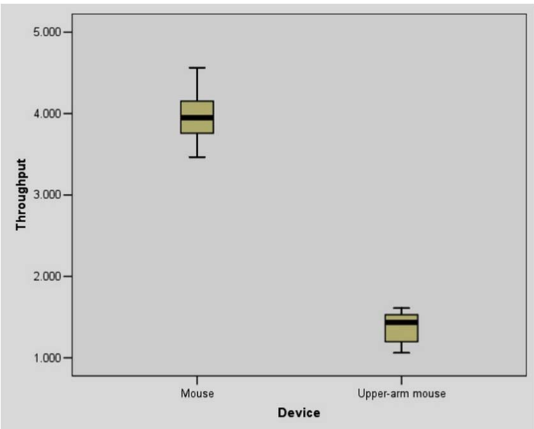


Fig. 6. The boxplot of throughput between a standard mouse and the proposed device

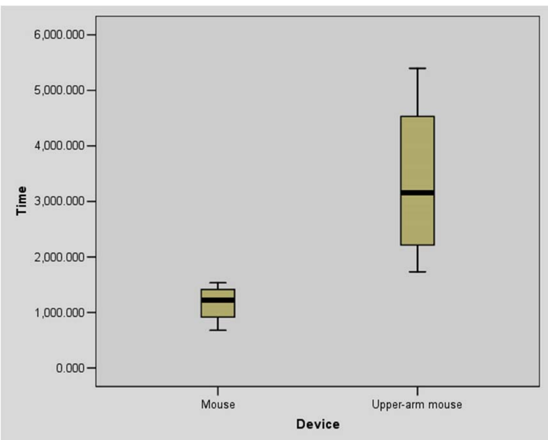


Fig. 7. The boxplot of movement time between a standard mouse and the proposed device

TABLE I. EXPERIMENT RESULTS IN DETAIL

B[1)]	M[2)]	Mouse		Upper-arm mouse (IMU+Foot switch)	
		t_m (s)	TP (bps)	t_m (s)	TP (bps)
1	1	0.836	3.465	1.896	1.494
	2	1.115	3.926	2.770	1.567
	3	1.353	3.976	4.222	1.192
	4	1.525	3.694	5.397	1.061
2	1	0.840	3.569	1.733	1.490
	2	1.001	4.102	2.533	1.612
	3	1.328	4.189	3.844	1.244
	4	1.475	4.117	4.986	1.120
3	1	0.677	4.563	1.751	1.480
	2	0.992	4.284	2.570	1.574
	3	1.355	3.823	3.535	1.394
	4	1.533	3.901	4.837	1.204
Mean		**1.169**	**3.97**	**3.34**	**1.37**

Notes: t_m = movement time; *TP* = throughput.
[1)]B = block
[2)]M = mode (difficulty level): 1=very low; 2=low; 3=high; 4=very high

TABLE II. THE DESIGN OF DIFFICULTY LEVEL

Mode	Level of difficulty	Target diameter (W) (pixels)	Distance to the next target (A) (pixels)
1	Very low	80	200
2	Low	40	400
3	High	20	550
4	Very high	10	650

The mean comparison using paired-samples t-test (dependent t-test) results are as follows:

1. The proposed device has a statistically significant difference in *throughput* and *movement time* between each level of difficulty; i.e., between modes 3 and 4, between modes 2 and 3, and between modes 1 and 2 ($p < .05$).
2. The standard mouse only has statistical difference in *movement time* between each level of difficulty ($p < .05$).
3. The average *throughput* and *movement time* between the proposed device and mouse are statistically significant different ($p < .05$).

B. Qualitative Results

The seven questions of comfort level and five questions of fatigue were employed. The comfort level questions included:1) force required for actuation, 2) smoothness during operation, 3) effort required for operation, 4) accuracy, 5) operation speed, 6) general comfort, and 7) overall operation of input devices. The fatigue questions included: 1) finger fatigue, 2) wrist fatigue, 3) arm fatigue, 4) shoulder fatigue, and 5) neck fatigue. The Wilcoxon signed-rank test was used to compare differences between the proposed device and a standard mouse. The comfort level test indicates that a mouse is superior to the proposed device. Whereas in the fatigue test, neck fatigue (question number 5) did not show a significant difference between either device.

The Spearman's rank order correlation was used to determine the relationship between the proposed device and the mouse's effort. It shows a weak and positive correlation, which were statistically significant in the arm ($r_s = .582, p =$

.047). The Spearman's correlation in the shoulder and neck was reported as ($r_s = .227, p = .478$) and ($r_s = .537, p = .072$), respectively.

IV. Discussion

The important finding is the significant difference of *throughput* and *movement time* between each level of difficulty. The level of difficulty depends on the distance between two opposite targets and the diameter of the target, as shown in Table II. Therefore, the GUI design when using this proposed device should consider the size of the target. The smallest target in mode 4 resulted in poor *throughput* and *movement time*. The new proposal of using a foot switch as a clicking method resulted in *TP* = 1.37 bps (as in Table 1), which has a better result than a clicking method using the same arm as in our previous study (*TP* = 0.2 bps) [14]. We presume the use of one arm for cursor movement and clicking method at the same time would cause unstable cursor movement. The mouse performance is superior to the proposed device; in this study the mouse was only used as a baseline to check that our procedure was in line with other researchers.

The comfort level showed that a standard mouse has better comfort than the proposed device. We surmise that up to 90% of participants have more than 10 years of experience using a mouse. Although each participant learned to use the proposed device before the experiment, the mouse was still more comfortable. Neither device showed a difference in fatigue, which means that both devices have a great effect on neck fatigue. We presume that when a person uses the proposed device, the movement of the upper arm (pitch-roll) overburdens the neck muscles.

The correlation test shows that only the arm has a significant difference between the proposed device and a mouse; this means that both devices use significant effort in the arm, although the correlation not too high. For the effort in the shoulder and neck, neither device has a correlation. We presume the neck muscles did not use much effort during the use of the proposed device. However, for the mouse or other computer work, there is limited evidence of this causing tension neck syndrome, as stated in Table 1 in [15]. This result gives us the opportunity to consider neck fatigue in the next design of a wearable mouse.

V. Conclusion

In this paper we discussed a new wearable mouse using the IMU and foot switch for bedridden people or people with special needs. The combination of IMU and foot switch could increase the throughput and better movement time compared with our previous study. The qualitative result finds that neck effort for the proposed device causes fatigue. This is a suggestion for our next study. The effect of using either the left or right foot to press the foot switch is out of the scope in this study; however, it also a suggestion for the next study to investigate.

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