PROCEEDINGS

2019 International Seminar on Intelligent Technology and Its Application

ISITIA 2019

August 28 – 29, 2019

JW Marriott Hotel, Surabaya, Indonesia

IEEE Catalog Number : CFP18TIA-PRT

ISBN 978-1-5386-7652-3

Proceedings

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IEEE Catalog Number : CFP19TIA-USB

ISBN : 978-1-7281-3748-3

Preface

We welcome you all to the joint conference of the 2019 International Seminar on Intelligent Technology and Its Applications, ISITIA, and the 12th AUN/SEED-Net Regional Conference in Electrical and Electronics Engineering, or RCEEE. It is a huge honour for us to be holding the ISITIA and RCEEE joint conference again this year, which would be the second time that the Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember (ITS), organizes these two conferences together.

We thank you for submitting your recent research work to our conference and present your findings in this event. ISITIA 2019 is the fifth ISITIA conference that is annually organized by the Department of Electrical Engineering, ITS, and technically co-sponsored by IEEE Indonesia Section. However, the history of ISITIA goes even further back 20 years ago when the department started its annual national conference called Seminar on Intelligent Technology and Its Applications, or SITIA for short. It is our hope that researchers from different backgrounds and fields can share their findings and latest development in the broad area of electrical and electronics engineering. It is also our hope that through this forum, we can all give contributions that brings positive impact to all of us. Hence, the theme for this year's joint conference, "Creating impact through intelligent devices and systems", was chosen.

This joint conference has received tremendous help and support, therefore we would like to thank all reviewers from various universities in different countries, as well as the honourable keynote speakers in this event. Our gratitude goes to AUN/SEED-Net and JICA for sponsoring the joint conference of RCEEE 2019 and ISITIA. We would also like to thank Institut Teknologi Sepuluh Nopember, Surabaya, for the support and help for the conference, as well as IEEE Indonesia Section and IEEE ITS Student Branch for also co-sponsoring this event.

Lastly, please have a great time at the conference, and we wish you a very pleasant stay in Surabaya, Indonesia.

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KEYNOTE LECTURE

Prof. Ryohei Kanzaki

Director, Research Center for Advanced Science and Technology,
The University of Tokyo, Japan
kanzaki@rcast.u-tokyo.ac.jp

Learning from Senses and Intelligence of Insects: Convergent Future Technology for Sustainable Society

To elucidate the dynamic information processing in a brain underlying adaptive behavior (or biological intelligence), it is necessary to understand the behavior and corresponding neural activities. This requires animals which have clear relationships between behavior and corresponding neural activities. Insects are precisely such animals and one of the adaptive behaviors of insects is high-accuracy odor source orientation. Insects are valuable model systems in neuroscience due to the balance between the moderate complexity of their nervous systems, a rich behavioral repertoire, and the cost of maintenance as experimental animals. Insect brains contain on the order of 105 to 106 neurons. The concept of individually identifiable neurons and small networks composing functional units have been vital for understanding insect brains. Moreover, insects are uniquely suited for multidisciplinary studies in brain research involving a combined approach at various levels, from molecules over single neurons to neural networks, behavior, modeling, and robotics, owing to their seamless accessibility to a wide variety of methodological approaches, in particular genetic engineering, neuroanatomy, electrophysiology, and functional imaging.

To examine the neural basis of the odor-source orientation behavior, we implemented a model of the neural circuit reconstructed from single neurons, and integrated it with a mobile robot. Moreover, in order to understand the dynamics of the neural circuitry, we have developed an "insect-robot hybrid system" in which the insect or an insect brain controls a robot.

Our interdisciplinary research will enable us to use the full potential of the features of insect sensors and brains as model systems for understanding the dynamical sensory and neural substrates of adaptive behaviors (or bilogical intelligece) for the first time. Our interdisciplinary research is predestined to contribute to develop new avenues for applications affecting safety, security, and everyday life.

Ryohei Kanzaki received his B.S., M.S. and D.Sc. degree in Neurobiology from the Institute of Biological Sciences, University of Tsukuba in 1980, 1983 and 1986, respectively. From 1987 to 1990 he was a postdoctoral research fellow at the Arizona Research Laboratories, University of Arizona. From 1991 to 2003 he was a at the Institute of Biological Sciences, University of Tsukuba. From 2004 to 2006 he was a full professor at Department of Mechano-Informatics, Graduate School of Information Science and Technology, the University of Tokyo. Since 2006 he is a full professor at the Research Center for Advanced Science and Technology (RCAST), the University of Tokyo. Since 2016 he has been a director of RCAST. He was a president of the Japanese Society for Comparative Physiology and Biochemistry (JSCPB) from 2012 to 2015. Ryohei Kanzaki is also contributing greatly to science education of children through children's science and technology development projects by Japan Science and Technology (JST) as chairs of the projects.

KEYNOTE LECTURE

Assoc. Prof. Dr. Supavadee Aramvith

Department of Electrical Engineering
Chulalongkorn University, Thailand
Supavadee.A@chula.ac.th

Video Analytics for Surveillance IoT Applications

In this talk, we will present and discuss the current trends and researches in video analytics. As surveillance cameras have been widely installed worldwide, although the main purpose of those cameras is for monitoring, but the most important task is to be able to analyze video contents and extract useful information. Several on-going researches such as image super resolution, real-time multiple face recognition system, video anomaly detection and several implementations of embedded video analytic system on FPGA and Single Board Computers will be discussed.

Supavadee Aramvith (IEEE S'95-M'01-SM'06, IEICE M'04) received the B.S. (first class honors) degree in Computer Science from Mahidol University, Bangkok, Thailand, in 1993. She received the M.S. and Ph.D. degrees in Electrical Engineering from the University of Washington, Seattle, USA, in 1996 and 2001, respectively. She joined Chulalongkorn University in June 2001. Currently, she is currently an Associate Professor at Department of Electrical Engineering, Chulalongkorn University, Bangkok, Thailand. Currently, she is an Associate Professor at Department of Electrical Engineering, Chulalongkorn University, Bangkok, Thailand. She was Associate Head in International Affairs (2007-2016), Head, Communication Engineering Division (2013-2016), Head, Digitial Signal Processiong Laboratory (2017-2018).

KEYNOTE LECTURE

Assoc. Prof. Dr. Tara Julia Hamilton

Macquarie University, Australia
tara.hamilton@mq.edu.au

Silicon Intelligence

In this presentation I will introduce you to the wonderful world of neuromorphic engineering. I will discuss some of my past, present, and future projects in neuromorphic engineering including modelling the nervous system, developing bio-neuro-inspired artificial intelligence, and applications of neuromorphics to designing better analog integrated circuits.

Tara Julia Hamilton (S'97–M'00) received the B.E. degree (Hons.) in electrical engineering and the B.Com. degree from The University of Sydney, Australia, in 2001, the M.Sc. degree in biomedical engineering from The University of New South Wales, Australia, in 2003, and the Ph.D. degree from The University of Sydney in 2009. She is currently an Associate Professor with the School of Engineering, Macquarie University, Australia. She has authored over 100 journal papers, conference papers, and book chapters, and holds patents in integrated circuit design, neuromorphic systems, and biomedical engineering. Her current research interests include neuromorphic engineering, mixed-signal integrated circuit design, and biomedical devices.

KEYNOTE LECTURE

Dr. Muhammad Rivai

Department of Electrical Engineering,
Institut Teknologi Sepuluh Nopember, Indonesia
Muhammad_rivai@ee.its.ac.id

The artificial olfactory system

We have five senses including physical senses (sight, hearing and touch) and chemical senses (smell and taste). Science and technology have developed rapidly, so we can find the three physical senses in various electronic devices. However, the sense of smell and taste is still not much developed. The researchers tried to make an alternative approach by imitating the working principle of the mammalian olfactory system which is the best chemical detector capable of detecting various volatile chemical compounds or odors. This approach uses a sensor array which each element has a response that partially overlaps with the others. Although the identification process cannot be achieved by a single sensor element, the pattern of the sensor array will produce a unique fingerprint for each odor. An artificial olfactory system or electronic nose composed of sensor array, signal conditioning, and pattern recognition that corresponds to the olfactory receptors, olfactory bulb, and olfactory cortex of the mammalian nose, respectively. Chemical sensors commonly used in this method are semiconductor devices, composite conducting polymers, quartz resonators, surface acoustic wave devices, and optical gas sensors. Preprocessing is signal conditioning of sensor signals, which removes irrelevant information to make it more supportive to the next phase, which can include normalization, noise reduction, compression, baseline manipulation, etc. Feature extraction from sensor response is needed to produce several significant features selected for the classification process. This method includes principal component analysis, Fourier transform, wavelet transformation, linear discriminant analysis, etc. Classification methods can be categorized into supervised and unsupervised methods, which include back propagation neural networks, support vector machines, k-nearest neighbors, k-means clustering, self-organizing maps, etc. An efficient chemical sensing system combined with a robust pattern recognition method to achieve accurate quantitative and qualitative information about chemical compounds is a challenging mission in the future, especially applied in the food, medical and environmental fields.

Muhammad Rivai received BE degree from Institut Teknologi Sepuluh Nopember in 1993, ME degree from University of Indonesia in 1997, PhD degree from University of Airlangga in 2006. He is currently a lecturer at Electrical Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. His research interests include odor sensors, electronic circuits, and neural network applications.

KEYNOTE LECTURE

Nicolas Husny Tjioe, M.Sc.

Business Development Manager, Infineon Technologies
NicolasHusny.Tjioe@infineon.com

Trusted Security for Smart Home

Internet of Things (IoT) are affecting our daily lives significantly. A smart home is a home that provides increased user convenience and energy efficiency based on smart and secured devices, functionalities and services which can be controlled remotely or interact or provide data automated based on intelligent sensing and situational awareness. The key building blocks to enable smart homes are made up of sensors, controllers, actuators and security. This means they can collect, interpret and process data and then trigger appropriate actions or responses, all within a secure environment. In this presentation, we will go over several use cases such as Home Appliances and Smart Lighting.

Mr. Nicolas Husny is currently with Infineon Technologies as an experienced Business Development Manager with a demonstrated history of working in the semiconductors industry, specializing in embedded security solutions, IoT, and smart card. Mr. Nicolas Husny obtained his Masters degree in Computer Science from Arizona State University (2008 - 2010), and his Bachelor in Computer Engineering from the Arizona State University (2004 - 2007).

The IMU and Bend Sensor as a Pointing Device and Click Method

Romy Budhi Widodo
Ma Chung Human-Machine Interaction Research Center,
Informatics Engineering Study Program, Ma Chung University
Malang, Indonesia
romy.budhi@machung.ac.id

Agustinus Bohaswara Haryasena
Ma Chung Human-Machine Interaction Research Center,
Informatics Engineering Study Program, Ma Chung University
Malang, Indonesia
bohaswarasena@gmail.com

Hendry Setiawan
Informatics Engineering Study Program, Ma Chung University
Malang, Indonesia

Mochamad Subianto
Informatics Engineering Study Program, Ma Chung University
Malang, Indonesia

Paulus Lucky Tirma Irawan
Informatics Engineering Study Program, Ma Chung University
Malang, Indonesia

Ari Yudha Lusiandri
Politeknik Pelayaran Surabaya, Gunung Anyar, 60294
Surabaya, Indonesia

Didik Dwi Suharso
Politeknik Pelayaran Surabaya, Gunung Anyar, 60294
Surabaya, Indonesia

Ardiansyah
Politeknik Pelayaran Surabaya, Gunung Anyar, 60294
Surabaya, Indonesia

Iskandar
Politeknik Pelayaran Surabaya, Gunung Anyar, 60294
Surabaya, Indonesia

***Abstract*— A pointing device is one of the important interfaces between human and computer. A mouse is usually used as a pointing device; however, people with physical impairments who can not use a mouse due to its operation should use a table. One candidate for solving this problem is using an upper-arm movement combined with an inertial measurement unit sensor. The upper-arm gestures would be mapped and used to manipulate the mouse cursor on the monitor display. The 'clicking' action will be accomplished using a bending sensor attached on the opposite upper-arm. This study evaluates the combination of the IMU and bend sensor (IMU+Bend) as a substitute for the mouse. The evaluation is based on ISO/TS 9241-411: Ergonomics of human-system standard. The results mentioned that the use of IMU is a promising way to emulate the movement of cursor. However, the usage of bend sensor is uncomfortable when it is used as a clicking method. The throughput of the proposed is 1.75 bps, and qualitative results show that the mean of comfort is 4.85 on a Likert scale ranged from 1 to 7.**

Keywords*— *HCI, IMU, ISO 9241-411, mouse

I. Introduction

A. Background

In Indonesia, according to [1], above 70% of people with special needs have no jobs and do not continue education after junior high school. This includes those with adult-onset disability due to reasons such as work accidents, congenital factors, and diseases. New job opportunities would emerge if people with special needs could operate computers using a mouse specially design for them.

B. Related Work

As can be seen in much of the literature, the inertial measurement unit (IMU), which consists of an accelerometer and gyroscope, can be used as a pointing device, such as in [2] using an accelerometer in a head-pointing device, and in [3] using a handglove inserted accelerometer to identify the hand gestures. The combination of accelerometer and gyroscope, called the IMU, is also used in many applications, such as in [4], [5], for gait measurement devices. The representation of angle using Euler notation is commonly employed. The movement on the three dimensional space results in the roll, pitch, and yaw orientation measured in degrees. human body movement also has three axes, i.e. sagittal, frontal, and transversal axes. Therefore, the sensor and human body movement are aligned in movement perspectives.

Researchers used an ISO standard from ISO 9241 part 9 in the new version, such as ISO 9241 part 411, to fulfil the evaluation procedure. The ISO instrument was used to evaluate the performance and comfort of a new physical input device, as in some articles [6]–[8].

The rest of this paper focus on the discussion of the use of IMU and a bend sensor to emulate the movement of mouse's cursor and click actions, respectively. We also continue to evaluate the performance and comfort using Annex B of ISO 9241-411.

II. Evaluation of The Proposed Device

A. The System Design

The proposed system consists of the input-process-output phase. The input phase is handled by an IMU sensor and a bend sensor. The IMU detects the upper arm movement along the axes of human movement. the bend sensor was attached in the opposite upper-arm in order to detect the abduction of

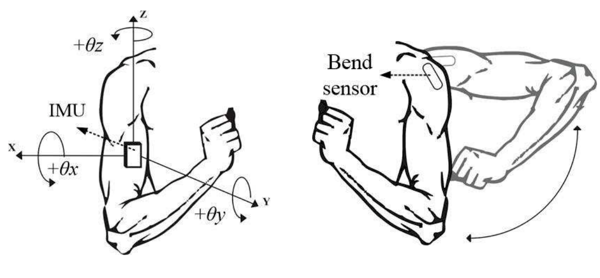
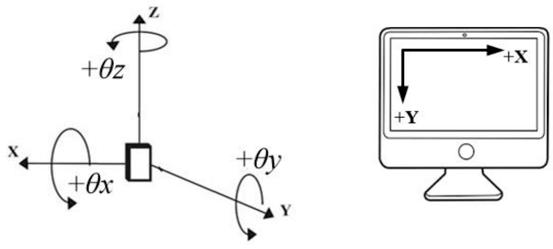


Fig. 1. (a) The placement of IMU on the upper-arm; (b) The placement of bend sensor in handling the click action.



(a) (b)

Fig. 2. (a) Sensor space; (b) Cursor space.

shoulder joint, as illustrated in Fig.1. The abduction would substitute the mouse's left-click action.

The process phase worked to control the movement of the cursor in a PC monitor. The key aspect of this phase is mapping of three-dimensional angles in the sensor space onto the two dimensional axes in PC monitor. The rotation of θ_x in degree will be called pitch, and θ_y will be called roll. Figure 2 illustrates the sensor and cursor space.

Table I describes the sensor-cursor mapping between the pitch and roll of IMU sensor and the translation of $x - y$ axis on the PC monitor.

TABLE I
THE SENSOR-CURSOR MAPPING

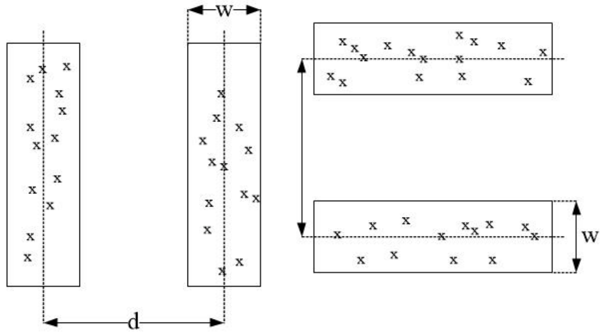
Gesture	DOF	Sensor (control)	Cursor (display)
Pitch-Roll	x		● +
	y		● -
	z		
	θ_y	● +	
	θ_x	● +	
	θ_z		

"+" and "-" sign correspond with the directions in Fig.2.

The ISO/TS 9241-411 consist of many tasks, such as the one-directional tapping test, multi-directional tapping test, dragging test, and tracing test [9]. In this study we chose the one-directional tapping test. We consider that the primary users of this device would be people with special needs; therefore we choose the very common usage of the mouse as a tapping apparatus within the direction of the horizontal and vertical cursor. The Annex B of ISO only indicates a one-directional horizontal test; therefore, in this study we modified the test to run both horizontal and vertically.

The ISO main measurement of performance is *Throughput* (TP). This measurement is based on Fitts' law as explained in [10], [11]. TP is the rate of information transfer when a user operates a pointing device. By means of the speed and accuracy measurements of a pointing device, a TP unit is bits per second (bps), where the values depend on movement time (t_m) and effective index of difficulty (ID_e). ID_e measures user precision in segments by using the distance to the target (d) and the effective target width (w_e). The formula is as follows in (1) and (2).

$$TP = \frac{ID_e}{t_m} \quad (1)$$



(a) (b)

Fig. 3. Horizontally and vertically designed one-directional tapping test. The "x" mark indicates the spreading of the tapping coordinate by participant. The area inside the bar is the tap target.

$$ID_e = \log_2\left(\frac{d}{w_e} + 1\right) \qquad w_e = 4.133.s_x \quad (2)$$

The ideal target is the center line of each target bar; however, when a participant tapped the target, it commonly spread across the center line. By using the w_e, we used the distribution of the clicked coordinate by employing the standard deviation (s_x) of the tapping coordinates. Figure 3 illustrates the modified one-direction tapping test.

The test as in Fig. 3 has two pairs of bars, the horizontal and vertical pairs. The participant should tap the indicated bar alternately left to right and then vice versa when the horizontal movement is tested. While the vertical test is executed, the participant should tap the top and bottom bar alternately. The design of experiment is 4 modes x 3 blocks x 50 trials. The modes represent the level of difficulties, which consists of high, intermediate, low, and very low levels of difficulty as suggested in [9]. We combined the d and w to obtain the four levels of difficulty as follows $I_D > 6$, $4 < I_D \leq 6$, $3 < I_D \leq 4$, and $I_D \leq 3$ [9]. The calculation of the levels of difficulty (I_D) was based on (3), where d and w is the distance to the target and the target width, respectively.

$$I_D = \log_2 \frac{d + w}{w} \quad (3)$$

B. Method

1) Participants

We recruited twelve participants, five males and seven females from university alumni and staffs. The average age was 28, with a standard deviation of 13 years.

2) Apparatus

Figure 4 shows the apparatus in the overall block diagram. The GY-951 was employed as the 9 DOF IMU in this study. It consists of the triaxial accelerometer ADXL345, the three-axis gyroscope (ITG3205), and the three-axis magnetometer (HMC5883L). The controller was an ATMEGA328 programmed with the sensor-fusion algorithm. The ATMEGA328 was embedded in GY-951 board produce the Direction Cosine Matrix (DCM) algorithm's result. The roll and pitch was produce by the DCM.

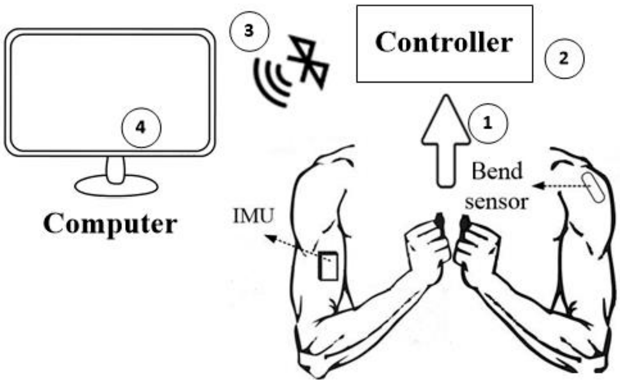
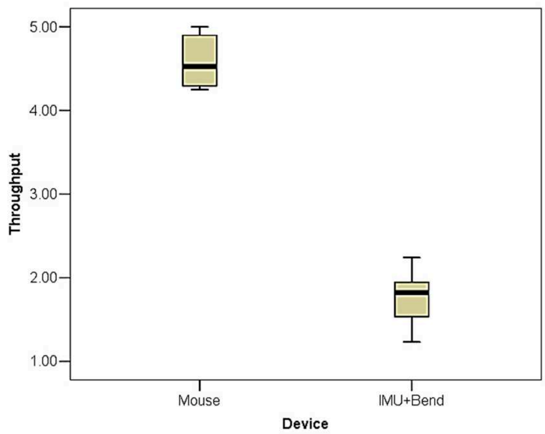


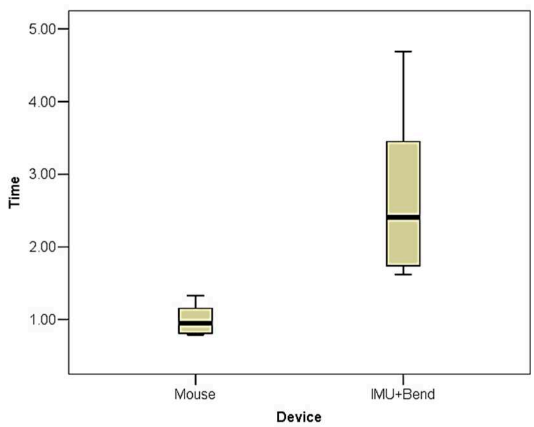
Fig. 4. Block diagram of input devices. Numbers 1 to 4 indicates the order of the process

Arduino Uno was used as the controller receiving the input from *Flex Sensor Flexible Bend* and GY-951. The bluetooth transmitter handled transmitting the data to the laptop.

A laptop with the specification Intel(R) Core (TM) i5-2450M CPU-2.5GHz was used to develop a one-direction test, using C# programming and the application to emulate the mouse cursor for users of the proposed system.



(a)



(b)

Fig. 5. The data distribution related to: (a) throughput (in *bps*) and (b) movement time (in *seconds*)

TABLE II
EXPERIMENT RESULT

Measurement	Device	
	Mouse[a]	IMU+Bend Sensor[a]
TP (bps)	4.59 (0.28)	1.75(0.29)
t_m (ms)	990(200)	2670(1060)
Err.rate (%)	2.81(2.30)	20.49(20.29)

[a]mean (sd)

III. EXPERIMENT RESULTS

A. The Throughput (TP) and Movement Time (t_m)

The proposed system using IMU and a bend sensor (IMU+Bend) was compared with a mouse as a baseline control. A larger throughput indicates a superior performance. However, a smaller movement time indicates a better speed. Table II represents the quantitative result of this study.

Table II also present the average of error rate of four modes. An error was recorded when the participant tapped the area outside the target.

Figure 5 presents the boxplot of all the data distribution of throughput and movement time.

B. The Qualitative Results of the Experiment

The Annex B of ISO presents a twelve-point questionnaire. It consists of seven questions for comfort assessment and five questions for fatigue assessment. Each question using a seven-point Likert scale. The items of comfort assessment are: 1) Force comfortability; 2) Smoothness; 3) Effortless; 4) Accuracy; 5) Operation speed; 6) General comfort; and 7) Overall operation of input device. In contrast, the items of fatigue assessment are: 1) Finger fatigue; 2) Wrist fatigue; 3) Arm fatigue; 4) Shoulder fatigue; and 5) Neck fatigue.

The result of comfort and fatigue are presented in Table III, where 7 is the best impression, indicating the height of comfort and no any fatigue.

TABLE III
QUALITATIVE RESULT

Assessment	Device	
	Mouse[a]	IMU+Bend Sensor[a]
Mean of comfort	6.46	4.85
Mean of fatigue	6.48	6.25

[a]On average, using a 7-point Likert scale—7 is the best impression

IV. DISCUSSION

The results of the normality test using the Shapiro-Wilk test indicates that the *TP* of mouse, the t_m of mouse, and the t_m of IMU+Bend sensor is not in normal distribution ($p < 0.05$). The non-parametric analysis was conducted between two independent groups: mouse and IMU+Bend using Mann-Whitney U test both for *TP* and t_m. It can be concluded that the *TP* in the mouse group was significantly higher than in the IMU+Bend group ($U = 0.0005$, $p = 0,0005$). We also concluded that the t_m in IMU+Bend group was significantly higher than for the mouse group ($U = 0.0005$, $p = 0,0005$).

The statistical results are not the main goal of our study. Since the standard mouse is a well-known interface in human-computer interaction, we used a standard mouse as a baseline study. Many researchers work with a standard mouse to compare performances among interaction devices, such as in [8], [12]. From our experiment the results of our mouse's *TP* is 4.59 bps; this is in line with others'. By means of this comparison, the results of the experiment is not different from other researchers.

Using the *TP*'s result of the IMU+Bend— 1.75 *bps*— indicates that the *TP,* which indicates the speed and accuracy of the device, is low when compared with the mouse. We presume that the click method using the bend sensor might be not the best choice. However, since the IMU could measure the three axes of human body, we think that the used of IMU as a substitute for the mouse cursor is a good choice. In the near future we would like to find other methods for clicking devices to improve the performance of the device.

The qualitative results, generated through a questionnaire as in Annex B of ISO, consists of seven questions of comfort assestment and five questions of fatigue assesment. The Mann-Whitney-U test was tested in each question between mouse and the IMU+Bend. The result showed that all answers in comfort assesment is significantly different between the mouse and the IMU+Bend. This indicates that the combination of the IMU+Bend for our clicking method caused discomfort when compared with the mouse.

While the fatigue assessment used five questions, all subjects indicated that two questions, i.e. wrist and shoulder fatigueness, is significantly different between mouse and IMU+Bend. This result implies that the use of IMU in the upper arm with the bend sensor in the opposite upper arm of a subject caused more fatigue than when a mouse is used. we suppose that this is caused by the movement of upper arm in pitch and roll orientation as in Fig. 1a and Fig. 2a. Regarding wrist fatigue, it indicates that the IMU+Bend has higher mean rank than mouse, which indicates that a IMU+Bend has significantly lower wrist fatigue than the mouse does. The other three questions (i.e. finger, arm, and neck fatigue) indicates that the mouse and the IMU+Bend did not have a statistically significant difference. For the arm and neck fatigue, we suppose both mouse and IMU+Bend cause fatigue to the subjects due to the movement of the arm during operation and due to tension in the neck. The finger fatigue due to mouse operation makes sense; however, the finger fatigue in IMU+Bend usage is beyond our prediction because the operation of IMU+Bend was not using fingers at all. We presume that this is due to the tension of finger muscles from arm movement during the operation.

V. CONCLUSION

This study focused on the development of a mouse substitution system using the combination of IMU+Bend sensor. Wherein the IMU was used to map the upper arm movement to cursor movement, and the bend sensor was used to emulate the clicking action. The evaluation of performance consists of quantitative and qualitative measurement by using the instrument from Annex B of ISO 9241-411. The ISO used throughput and movement time to evaluate the performance of the system. The results show that the proposed IMU is the best choice for emulating the movement of cursor. However, using the Bend sensor for the clicking method resulted in a lack of comfort based on the results of qualitative measurements. The throughput and movement time results indicate that the performance of the proposed system as a mouse substitute is a baseline for future research. However, the system has shown promising results; we recommend that the combination of IMU and other sensors as a clicking method should be explored in future studies.

ACKNOWLEDGMENT

We would like to thank all the people who participated in our experiment. We are also grateful to the Higher Education of Indonesia Government for financial support for this research and all colleagues who support in reviewing our paper.

REFERENCES

[1] F.A. Prasetyo, "Disability and Health Issues: Evolution Concepts, Human Rights, Complexity of Problems, and Challenges (in Indonesian)," Jakarta, 2014.
[2] L. Ribas-xirgo and F. López-varquiel, "Accelerometer-Based Computer Mouse for People with Special Needs," *J. Access. Des. All*, vol. 7, no. 1, pp. 1–20, 2017.
[3] K. S. J. Perng, J.K.; Fisher, B.; Hollar, S.; Pister, "Acceleration sensing glove (ASG)," in *Wearable Computers*, 2002, pp. 178–180.
[4] R. B. Widodo and C. Wada, "Artificial neural network based step-length prediction using ultrasonic sensors from simulation to implementation in shoe-type measurement device," *J. Adv. Comput. Intell. Intell. Informatics*, vol. 21, no. 2, 2017.
[5] F. Dadashi, B. Mariani, S. Rochat, C. J. Büla, B. Santos-Eggimann, and K. Aminian, "Gait and Foot Clearance Parameters Obtained using Shoe-Worn Inertial Sensors in a Large-Population Sample of Older Adults," *Sensors*, vol. 14, pp. 443–457, 2014.
[6] K. L. Norman and K. D. Norman, "Comparison of Relative Versus Absolute Pointing Devices," *Human-Computer Interact. Lab*, pp. 1–17, 2010.
[7] S. A. Douglas, A. E. A. E. Kirkpatrick, and I. S. MacKenzie, "Testing pointing device performance and user assessment with the ISO 9241, Part 9 standard," *Proc. SIGCHI Conf. Hum. factors Comput. Syst. CHI is limit CHI 99*, vol. 15, no. May, pp. 215–222, 1999.
[8] I. S. MacKenzie and S. Jusoh, "An Evaluation of Two Input Devices for Remote Pointing," *Eng. Human-Computer Interact.*, vol. 2254, pp. 235–250, 2001.
[9] International Organization for Standardization, *Technical Specification ISO*, vol. 2002, no. 912018581. Switzerland, 2012.
[10] I. S. Mackenzie, "Fitts' Law," in *Handbook of human-computer interaction*, vol. 1, Wiley, 2018, pp. 349–370.
[11] R. W. Soukoreff and I. S. MacKenzie, "Towards a standard for pointing device evaluation, perspectives on 27 years of Fitts' law research in HCI," *Int. J. Hum. Comput. Stud.*, vol. 61, no. 6, pp. 751–789, 2004.
[12] I. S. MacKenzie, T. Kauppinen, and M. Silfverberg, "Accuracy measures for evaluating computer pointing devices," *Proc. SIGCHI Conf. Hum. factors Comput. Syst. - CHI '01*, pp. 9–16, 2001.