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

By Romy Budhi Widodo

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

line 1: 1st Given Name Surname
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address or ORCID

line 1: 2nd Given Name Surname
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address or ORCID

line 1: 3rd Given Name Surname
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address or ORCID

line 1: 4th Given Name Surname
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address or ORCID

line 1: 5th Given Name Surname
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address or ORCID

line 1: 6th Given Name Surname
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address or ORCID

***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**

II. INTRODUCTION

C. 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.

D. Related Work

As can be seen in many 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.

III. EVALUATION OF THE PROPOSED DEVICE

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

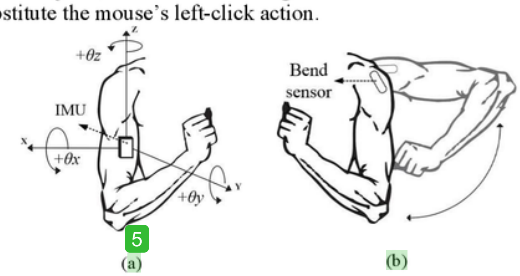


Fig. 1. (a) The placement of IMU on the upper-arm; (b) The placement of bend sensor in handling the click action.

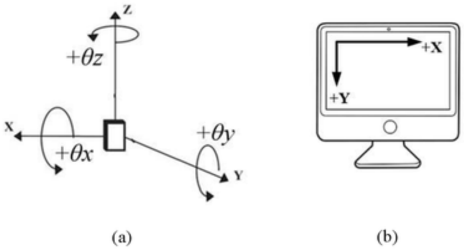


Fig. 2. (a) Sensor space; (b) Cursor space.

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 with a user operates a pointing device. By means of the speed and accuracy measurements of a pointing device, the 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).

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

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

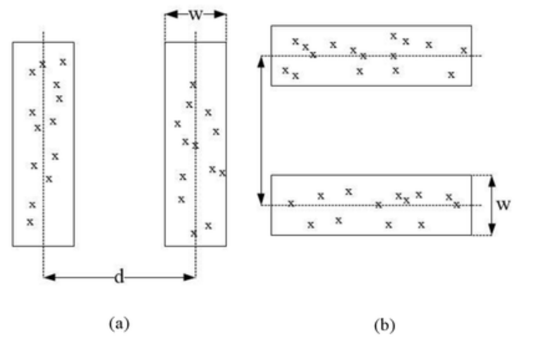


Fig. 3. Horizontally and vertically designed one-directional tapping test. The "x" mark indicates the spreading of the tapping coordinate by participant. The area inside the bar is the tap target.

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.

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

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.

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.

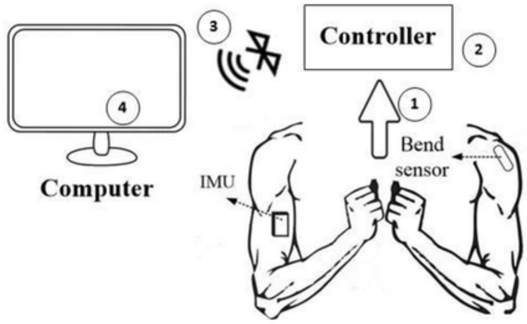
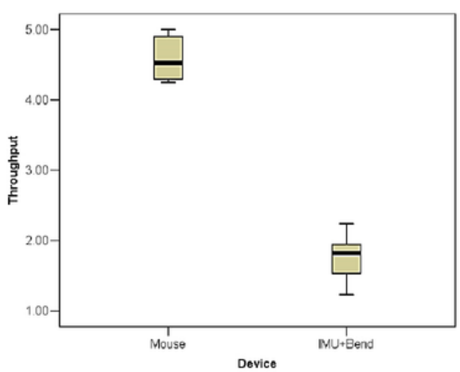


Fig. 4. Block diagram of input devices. Numbers 1 to 4 indicates the order of the process

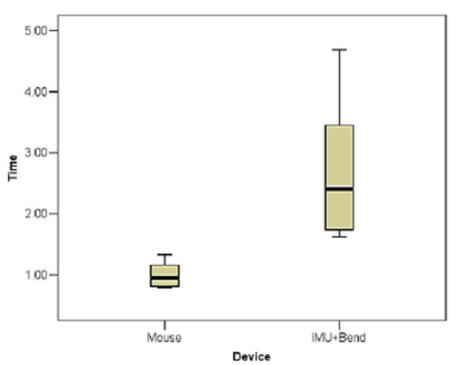
IV. EXPERIMENT RESULTS

C. *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.



(a)



(b)

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

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.

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)

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

D. *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

V. 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.

VI. Conclusion

This study focused on the development of a mouse substitution system using the combination of IMU+Bend sensor. Whereas 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 its support of this research through the PTUPT 2019 grant.

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.

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

ORIGINALITY REPORT

17%

SIMILARITY INDEX

PRIMARY SOURCES

1	www.en-t.org Internet	184 words — 7%
2	www.j-sens-sens-syst.net Internet	72 words — 3%
3	Romy Budhi Widodo, Takafumi Matsumaru. "Measuring the performance of laser spot clicking techniques", 2013 IEEE International Conference on Robotics and Biomimetics (ROBIO), 2013 Crossref	34 words — 1%
4	R B Widodo, R M Quita, S Amrizal, R S Gunawan et al. "Grasping and Attached Mode in Human-Computer Interaction in the Study of Mouse Substitution", Journal of Physics: Conference Series, 2019 Crossref	27 words — 1%
5	epdf.tips Internet	17 words — 1%
6	www.yorku.ca Internet	16 words — 1%
7	Romy Budhi Widodo, Reyna Marsya Quita, Rhesdyan Setiawan, Chikamune Wada. "A study of hand-movement gestures to substitute for mouse-cursor placement using an inertial sensor", Journal of Sensors and Sensor Systems, 2019 Crossref	14 words — 1%

8 John Paulin Hansen. "Gaze beats mouse", Proceeding of the twenty-sixth annual CHI conference extended abstracts on Human factors in computing systems - CHI 08 CHI 08, 2008
Crossref
13 words — < 1%

9 www.bandwidth10.com
Internet
12 words — < 1%

10 homepages.cwi.nl
Internet
10 words — < 1%

11 "Human-Computer Interaction. Interaction Platforms and Techniques", Springer Science and Business Media LLC, 2016
Crossref
9 words — < 1%

12 dl.ifip.org
Internet
9 words — < 1%

13 www.proceedings.blucher.com.br
Internet
9 words — < 1%

14 adam.sporka.eu
Internet
8 words — < 1%

15 Poika Isokoski, Roope Raisamo, Benoît Martin, Grigori Evreinov. "User performance with trackball-mice", Interacting with Computers, 2007
Crossref
8 words — < 1%

16 Nikolaos Papatheodorou, Alexandros Pino, Georgios TH. Kouroupetroglou, Vasilios Constantinides et al. "Upper Limb Motor Skills Performance Evaluation Based on Point-and-Click Cursor Trajectory Analysis: Application in Early Multiple Sclerosis Detection", IEEE Access, 2019
Crossref
8 words — < 1%

17 www.journal-of-sensors-and-sensor-systems.net
Internet
8 words — < 1%

18 Reyna Marsya Quita, Romy Budhi Widodo. "A Mathematical Proof Concerning the Geometrical Aspect of Very Low Index of Difficulty in Multidirectional Tapping Task of the ISO 9241 - Part 411", MATEC Web of Conferences, 2018
Crossref
7 words — < 1%

EXCLUDE QUOTES	ON	EXCLUDE MATCHES	OFF
EXCLUDE BIBLIOGRAPHY	ON		

The IMU and Bend Sensor as a Pointing Device an...

By: Romy Budhi Widodo

As of: Jun 3, 2019 12:06:35 AM
2,805 words - 32 matches - 20 sources

Similarity Index

17%

Mode: Similarity Report ▼

paper text:

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

line 1: 1st **Given Name Surname line 2: dept. name of organization (of Affiliation) line 3: name of organization (of Affiliation) line 4: City, Country line 5: email address or ORCID line 1: 4th Given Name Surname line 2: dept. name of organization (of Affiliation) line 3: name of organization (of Affiliation) line 4: City, Country line 5: email address or ORCID line 1:** 2nd **Given Name Surname line 2: dept. name of organization (of Affiliation) line 3: name of organization (of Affiliation) line 4: City, Country line 5: email address or ORCID line 1:** 5th **Given Name Surname line 2: dept. name of organization (of Affiliation) line 3: name of organization (of Affiliation) line 4: City, Country line 5: email address or ORCID Abstract—** A pointing device **is** 1

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** 2

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 II. INTRODUCTION C. 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. D. 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

line 1: 3rd Given Name Surname line 2: dept. name of organization (of Affiliation) line 3: name of organization (of Affiliation) line 4: City, Country line 5: email address or ORCID line 1: 6th **Given Name Surname line 2: dept. name of organization (of Affiliation) line 3: name of organization (of Affiliation) line 4: City, Country line 5: email address or ORCID** 1

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 14

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** 13

and click actions, respectively. We also continue to evaluate the performance and comfort using Annex B of ISO 9241-411. III. EVALUATION OF THE PROPOSED DEVICE C. 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 shoulder joint, as illustrated in Fig.1. The abduction would substitute the mouse’s left-click action.

(a) (b) Fig. 1. (a) The placement **of** IMU on **the** upper-arm; **(b)** 16

The placement of bend sensor in handling the click action.

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE (a) (b) Fig. 2. 7

(a) Sensor space; (b) Cursor space. 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 θx in degree will be called pitch, and θy 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) x + y - Pitch-Roll z θy + θx + θz “+” 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 3

[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 3

operates a pointing device. By means of the

speed and accuracy measurements of a pointing device, a TP 20

unit is bits per second (bps), where the values depend on

movement time (tm) and effective index of difficulty (IDe). 15

IDe measures user precision in segments by using

the distance to the target (d) and the effective target width (we). The formula is 6 as follows in (1) and (2). TP ? IDe tm (1) ? d ? we ? 4.133 .s x (2) IDe ? log 2 ?? we ? 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. 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 we, we used the distribution of the clicked coordinate by employing the

standard deviation (sx) **of the tapping coordinates.** Figure 3 illustrates **the** modified one **- direction** 3

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 ID > 6, 4 < ID ≤ 6, 3 < ID ≤ 4, and ID ≤ 3 [9]. The calculation of the levels of difficulty (ID) was based on (3), where d and w

is the distance to the target and the target width, 8

respectively. I D ? log2 d ?w w (3)

B. Method 1) Participants We recruited twelve participants, **five** 3

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. 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 11 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. Fig. 4. Block diagram of input devices. Numbers 1 to 4 indicates the order of the process IV. EXPERIMENT RESULTS C. The Throughput (TP) and Movement Time (tm) 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. (a) (b) Fig. 5. The

data distribution related to: (a) throughput (in bps) and (b) movement time (in seconds) 2

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. 9

TABLE II EXPERIMENT RESULT Measurement Device Mousea IMU+Bend Sensora TP (bps) tm (ms) Err.rate (%) 4.59 (0.28) 1.75(0.29) 990(200) 2670(1060) 2.81(2.30) 20.49(20.29) amean (sd)

Figure 5 presents the boxplot of all the data distribution of throughput and movement time. 2
D. 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 4

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 10

and fatigue are presented in Table III, where

7 is the best impression, indicating the height of comfort 2

and no any fatigue. TABLE III QUALITATIVE RESULT Assessment Device Mousea IMU+Bend Sensora

Mean of comfort 6. 46 4. 85 Mean of fatigue 6. 4

48 6.25 aOn average, using a 7

-point Likert scale—7 is the best impression V. DISCUSSION The results of the 2

normality test

using the Shapiro-Wilk test indicates that the TP of mouse, the 5

tm of mouse, and the tm 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 tm. It can be concluded that the TP

in the mouse group was significantly higher than in the IMU+Bend group 18

(U = 0.0005, p = 0,0005). We also concluded that the tm in IMU+Bend group was

significantly higher than for the mouse group (U = 0.0005, p = 0,0005). The 2

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. 5

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** 4

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** 19

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. VI. 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** 17 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** 12

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 its support of this research through the PTUPT 2019 grant. 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.

sources:

1 184 words / 7% - Internet from 23-Feb-2019 12:00AM
www.en-t.org

2 72 words / 3% - Internet from 19-Feb-2019 12:00AM
www.j-sens-sens-syst.net

3 34 words / 1% - Crossref
Romy Budhi Widodo, Takafumi Matsumaru. "Measuring the performance of laser spot clicking techniques", 2013 IEEE International Conference on Robotics and Biomimetics (ROBIO), 2013

4 27 words / 1% - Crossref
R B Widodo, R M Quita, S Amrizal, R S Gunawan et al. "Grasping and Attached Mode in Human-Computer Interaction in the Study of Mouse Substitution", Journal of Physics: Conference Series, 2019

5 14 words / 1% - Crossref
Romy Budhi Widodo, Reyna Marsya Quita, Rhesdyan Setiawan, Chikamune Wada. "A study of hand-movement gestures to substitute for mouse-cursor placement using an inertial sensor", Journal of Sensors and Sensor Systems, 2019

6 13 words / < 1% match - Crossref
John Paulin Hansen. "Gaze beats mouse", Proceeding of the twenty-sixth annual CHI conference extended abstracts on Human factors in computing systems - CHI 08 CHI 08, 2008

7 12 words / < 1% match - Internet from 04-May-2019 12:00AM
www.bandwidth10.com

8 10 words / < 1% match - Internet from 21-Sep-2018 12:00AM
homepages.cwi.nl

9 9 words / < 1% match - Internet from 21-Dec-2017 12:00AM
dl.ifip.org

10 9 words / < 1% match - Internet from 22-Mar-2019 12:00AM
epdf.tips

11 9 words / < 1% match - Internet from 03-Aug-2017 12:00AM
www.proceedings.blucher.com.br

12 9 words / < 1% match - Crossref
"Human-Computer Interaction. Interaction Platforms and Techniques", Springer Science and Business Media LLC, 2016

13 8 words / < 1% match - Internet from 19-Feb-2019 12:00AM
www.journal-of-sensors-and-sensor-systems.net

14 8 words / < 1% match - Internet from 08-Feb-2017 12:00AM
www.yorku.ca

15 8 words / < 1% match - Internet from 01-Nov-2018 12:00AM
www.yorku.ca

16 8 words / < 1% match - Internet from 16-May-2019 12:00AM
epdf.tips

17 8 words / < 1% match - Internet from 13-Feb-2014 12:00AM
adam.sporka.eu

18 8 words / < 1% match - Crossref
Nikolaos Papatheodorou, Alexandros Pino, Georgios TH. Kouroupetroglou, Vasilios Constantinides et al. "Upper Limb Motor Skills Performance Evaluation Based on Point-and-Click Cursor Trajectory Analysis: Application in Early Multiple Sclerosis Detection", IEEE Access, 2019

19 8 words / < 1% match - Crossref
Poika Isokoski, Roope Raisamo, Benoît Martin, Grigori Evreinov. "User performance with trackball-mice", Interacting with Computers, 2007

20 7 words / < 1% match - Crossref
Reyna Marsya Quita, Romy Budhi Widodo. "A Mathematical Proof Concerning the Geometrical Aspect of Very Low Index of Difficulty in Multidirectional Tapping Task of the ISO 9241 - Part 411", MATEC Web of Conferences, 2018