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Basic Study of the Android and ANN-based Upper-arm Mouse Hartawan Sugihono

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Engineering Study Program Universitas Ma Chung, **Malang, Indonesia** Abstract— Disability is **a** 26

person's condition in the physical, intellectual, mental, and/or sensory limitations in the long term. This study is reserved for those who do not have the lower arm in order to operate the computer normally. This study uses orientation sensor on the smartphone as the main sensor to move the cursor and click. Delivery of data from smartphone to computer is using Bluetooth. This study will compare two gestures from a combination of orientation sensors on the upper arm: gesture 1 using pitch-yaw motion and gesture 2 using pitch-roll motion; to move the cursor on the monitor. Left-click and right-click using ANN is to detect upper arm jerk movements. Evaluation using

ISO / TS 9241- 411 standard: **ergonomics of human-system interaction;** 1

which includes performance evaluation and comfort of the gesture. Performance results of throughput, movement time, comfort and fatigue between gestures were not significantly different between those gestures. The result of the effort questionnaire is that gesture 1 has the highest effort on the shoulder and gesture 2 has the highest effort on the hand. Keywords— Android, ANN, Fitts'law, ISO/TS 9241- 411, Pointing device I. INTRODUCTION The Constitution of the Republic of

Indonesia number 8 in 2016 [1], describes the disabled as any persons who have limited physical, intellectual, mental, and/or sensory ability in interaction with the environment and may have difficulties to participate effectively. Persons with disabilities have difficulty in the technology processing such as computers. The mouse on the computer becomes one of the obstacles for disabled, especially for those without their forearms (elbows to fingers) to use the computer. Besides the mouse, there is also a cursor triggering tool, that is a remote application in the smartphone. This remote application also use fingers to move the cursor and click. In this case, the disabled without forearms find problems to use. Human computer interaction (HCI) is the science in communication between humans and computers. By making use of HCI, an application for the disabled without forearms can be developed; meanwhile, the application of the study itself will use sensors available in a smartphone. Sensor orientation is used to replace the mouse function. This sensor is available on some smartphones. By using their upper arms to move the computer cursor, the disabled without the forearms can also use it. Based on the existing problems, there are several similar studies with different methods such as gyro-mouse [2]. It is a study of mouse replacements using the gyro sensors placed on the glasses and how to move it by moving the head. The mouse earphone [3] is a study of mouse alternatives using an accelerometer sensor placed on the earphone and how to move it with head movement. These studies are carried out by looking for the computer cursor triggering alternative without having to use a finger.

In this study we propose **a new method** 25

of Android- based mouse alternative for disabled persons with no forearms for both hands. Moving the cursor needs the movement of the upper arm with two gestures. The first gesture uses a pitch-yaw and the second gesture uses pitch- roll. Artificial neural networks (ANN) are used to detect click actions and classify cursor movements (gesture 1 and gesture 2). II. METHODS In general, the system diagram as in Figure 1. Orientation Sensor (Smartphone) 1 Artificial Neural Network Classification 2 3 Orientation Mapping Fig. 1. System diagram The information flow is 1) orientation sensor is processed by using ANN; 2) ANN result includes left click, right click or cursor movement; and 3) send the command of ANN to PC A. Orientation Sensor Orientation sensor [4] is a sensor used relatively to monitor the position and orientation of a smartphone to the earth's surface. The orientation sensor obtains its data by processing proximity sensor's data from the accelerometer and geomagnetic field sensors. Using these two sensor

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE sensors, **the** 13

system provides data for the three orientation angles which are yaw (azimuth), pitch, and roll. Z (Azimuth) X (Pitch) Y (Roll) Fig. 2. Orientation sensor angle on the smartphone B. Upper Arm Movement The proposed upper-arm mouse uses a smartphone that is placed in the upper arm of a human. This experiment uses two gestures to compare its performance with the mouse. Gesture 1 uses a pitch-yaw angle sensor in which the pitch is for up-down movement and yaw is for left-right movement. Gesture 2 uses a pitch-roll angle sensor in which the pitch is for up-down movement and roll is for left-right movement. The following are the explanations for every gesture examined. 1) Gestur1 Gesture 1 is mapped as follows. Control ϴX + ϴY + ϴZ + Windows X + Y + Click Fig. 3. The sensor-cursor mapping of gesture 1 Figure 3 tells ϴx + to be the initial data

to move the cursor on screen in the	2

Y + axis and click method. The ϴz + axis becomes the initial data

to move the cursor on screen in the	2

X + axis. Fig. 4. Gesture 1 2) Gesture 2 Gesture 2 is mapped as follows. Control Windows ϴX + X+ ϴY + Y+ ϴZ + Click Fig. 5. The sensor-cursor mapping of gesture 2 Figure 5 tells ϴx + to be the initial data

to move the cursor on screen in the	2

Y + axis and click method. The ϴz + axis becomes the initial data

to move the cursor on screen in the	2

X + axis. Fig. 6. Gesture 2

C. Artificial neural network Artificial neural network (ANN) is a	15

way to demonstrate how neural network in the human brain works in doing a task. Many application used the ANN as an example in measuring the step-length, as in [5]. Neurons are depicting of the human brain's working system in organizing its constituent cells. The goal of organizing these cells is to recognize certain patterns with a very high network effectiveness. The levenberg-marquardt training algorithm is one of the famous due to the speed [6] Like humans, ANN also needs a learning to recognize patterns. The result of ANN training is the value used for the classification. ANN training requires an activation function to enable or disable neurons. The activation function used in this study is symmetric sigmoid. Artificial Neural Network

Input Values Input 1 Input 2 Input 3 Input 18

100 W H e i M i d a gt d h ri t ex t no I L n a p yu et r X1 X2 X3 X100 W1_100

W2_1 W2_2 W2_ 100 W3_1 W1 _2 W1_1 W3_ 2 W3_ 10W025 _1 W25 _2 11

W25_100 Matrix Output W1-2 W2-2

W3-1 to W1-1 W2-1 W3-2 24

Output Output Weight Hidden Layer Z1 Z2 Z14 Layer Y1 Y2 Layer Fig. 7. Artificial neural network architecture We use 200 data in terms of Pitch, which include 100 upward jerks for left click and 100 downward jerks for right click. Other than that, we use one hidden layer with 14 neurons. The output from ANN is 2 neurons with 01 for left click, 10 for right click, and others counted as cursor movements. D. ISO 9241-411 ISO 9241 is a standard from International Organization for Standardization (ISO) that works on ergonomic human-system interactions [7]. ISO is an international independent agency that sets standards in various fields such as technology, industry, health and others. ISO's objective makes this standard to provide the quality, efficiency, and security of a product or service. ISO 9241-411 is an evaluation method for input devices. The evaluation method that is utilized used to evaluate the performance of the cursor movement use one directional tapping tests shown in Fig 8. This method uses a block-shaped target in which the color of the target click is red. This evaluation has four difficulty levels: 1. Very easy: ID <= 3 (mode 1) 2. Easy: 3 < ID <= 4 (mode 2) 3. Medium: 4 < ID <= 6 (mode 3) 4. Hard: ID > 6 (mode 4) Index of difficulty (ID) = (1)

where d is distance and w is width in pixels. The Effective Index of Difficulty (IDe) is 14

a measurement in the bits of the user's precision achievement during the task. (2) Throughput (TP) is used to measure the average velocity of each target shift. (3) Movement time is used to measure the average time spent for each target move. Other studies using the other type of tapping test, i.e., multi direction tapping test according to its application and its evaluation of this test, as in [8],[9],[10], and [11]. However, we simplify this study using modified one-directional tapping test as suggested by ISO for horizontal and vertical movement as in Figure 8. d w Fig. 8. One directional tapping test E. Experimental method Data collection was done at the university under the supervision of the researcher. Each subject is given an explanation or guidance regarding the process of data collection and how to operate of the application. Subjects are given the flexibility to determine the position of the test such as sitting, standing and the distance between the respondent and the computer as long as it is in Bluetooth range. The number of subjects in this experiment was seven people with an age range from fifteen to twenty-five. The average age of subjects is twenty-one years old with a standard deviation of 2.79. All subjects use the right hand in operation. The tools needed for this experiment are laptop and smartphone. The Netbeans application and Bluetooth driver is pre-installed in the laptop. Should the laptops do not have bluetooth hardware, the test can still use bluetooth dongle as the replacement. This study uses a screen with a resolution of 1366 x 768. Minimum requirement of smartphone used is to have Bluetooth and sensor: accelerometer, magnetometer, and orientation. Experimental data were obtained from tapping tests and questionnaires filled or tested by respondents. Trial data from tapping tests contains of coordinates (x, y), target width and length, distance between targets, errors (if clicks are not on target), time required for each click, and index of difficulty for each trial. The questionnaire consists of several types, i.e.: 1) independent forms, consisting of 7 questions on comfort and 5 questions on fatigue; 2) dependent forms, which are used to compare gesture 1 and gesture 2 in terms of comfort and fatigue; 3) Borg questionnaire rating of perceived exertion scale, used to determine the effort needed during the use of gestures. During the test, every subject uses the same rules for each tools, such as the mouse, gesture 1, and gesture 2. Subjects try the test program randomly for the mouse and both gestures; then, subjects do tapping tests for three blocks, with 4 modes on each block, from the easiest to the hardest. The subjects try each mode once. Block Mode tm(s) 1 1 0.94 2 0.96 3 1.06 TABLE I. DETAILS OF EXPERIMENTAL RESULTS Mouse Gesture 1 TP(bit/s) tm(s) TP(bit/s) 2.24 13.03 0.15 3.43 16.33 0.18 3.96 20.21 0.18 Gesture 2 tm(s) TP(bit/s) 9.69 0.21 13.58 0.21 21.79 0.17 4 1.58 3.55 40.57 0.15 40.01 0.14 2 1 0.82 2.53 10.39 0.21 8.36 0.22 2 0.98 3.16 13.80 0.22 13.68 0.21 3 0.95 4.32 16.21 0.24 15.90 0.25 4 1.34 4.51 43.57 0.13 43.75 0.13 3 1 0.85 2.39 6.75 0.31 6.57 0.33 2 1.08 2.82 9.81 0.31 10.15 0.29 3 1.02 4.09 17.27 0.24 18.34 0.21 4 1.40 4.14 46.10 0.12 45.37 0.13 Means 1.08 3.43 21.17 0.20 20.60 0.21 III. EXPERIMENTAL RESULTS A. Quantitative Data The following are the steps in counting the quantitative data. 1) Fitts'law Calculations The Fitts' law calculation begins once the data has been filtered in order for the data to be statistically analyzed. The classification of these calculations are type (mouse, gesture 1, gesture 2), block number, and mode to get data in every tool or gesture based on block and mode. We will then determine We and time of each mode, using the following equation: (4) Sx

is the standard deviation of the click **coordinates** with **the** midpoint **of** tapping. **The** 5

next calculation step is to process We and time to get IDe and Throughput (TP). The results of IDe and TP calculations will be tested by using statistical calculations. 2) Analysis After Fitts' law calculation is obtained, statistic test can be done to get the difference between the mouse and the two gestures. Quantitative data analysis will be divided into TP and movement time (tm). a) Throughput (TP) The statistical test for TP begins with a normality test using the Shapiro Wilk test. From the result of normalization of TP data it can be concluded that TP is normally distributed. This conclusion is obtained from the p value (mouse: p = 0.379, gesture 1: p = 0.318, gesture 2: p = 0.483). Since the data is normally distributed, the next test is a homogeneous test with Levene's test.

Levene's test results were statistically significant (p < 0.05); means **the** 12 variant on the mouse and the two gestures are not the same. It can be assumed that the homogeneity of the variant is not fulfilled. Since the variants are not the same on the mouse and the two gestures, the next test is Welch ANOVA used to find out the average difference of TP value on the mouse and both gestures. The results of Welch ANOVA test is $F(2, 19.593) = 95.055$, $p < 0.05$, which means there is

a significant difference in the transfer speed of the devices. 7

We use Games-Howell post-hoc to see the detail in the significant difference between mouse and the two gestures; this then determines that while there is significant difference of TP between mouse and the two gestures, the difference is not significant between the two gestures themselves. b) Movement Time The statistical test for movement time begins with the normality test with Shapiro Wilk test. From result of normality of movement time data can be concluded that movement time is not normally distributed. This conclusion is obtained from the probability value (mouse: $p = 0.052$, gesture 1: $p = 0.009$, gesture 2: $p = 0.012$). Results of Kruskal Wallis test obtained p value < 0.05 which means there is significant differences between mouse and both gestures. Mann-Whitney U post-hoc test is used to see details of significant differences. a. The movement time value of the mouse is faster than gesture 1 and gesture 2. b. The movement time value of gesture 1 is not faster than gesture 2. Therefore, in terms of moving from one target to another, mouse has a faster movement time than the two gestures. Meanwhile, there is no difference in movement time between gesture 1 and gesture 2. Other than that, the comparison of time needed between the two gestures to move from one target to another also do not differ. 3) Error Rate Calculations During the tapping test, we received more than 50 data, which was our target for every trial. This excess data is caused by the click's mistargeting in the subject during the test. The following is a graphic of the error rate for The average rate shows that the mouse has the best every block. levels of comfortability and fatigue. The statistic result of comfortability and fatigue states that there is

a significant difference between mouse and the two gestures (p < 0. 7

05), whereas it states no significant difference between gesture 1 and gesture 2 ($p > 0.05$). Therefore, we conclude that gesture 1 and gesture 2 are less comfortable, tiring their users much more easily. Assessment of effort uses Borg rating of perceived exertion scale in which the score 0 indicates the best value and the score 10 indicates the opposite. Mouse has the lowest level of effort for three categories (arm, shoulder, Fig. 9. Graph error rate on each block neck). For gesture 1, the highest level of effort lies on the shoulder with a score of 7.29, whereas for gesture 2, it lies on the arm with a score of 7.71. Therefore, we conclude As seen on figure 9, block 3 has less error rate that gesture 1 has more effort on the shoulder, and on the compared to the mouse or two gestures in block 1 and hand for gesture 2. block 2. The data can also be processed statistically in order to prove the conclusion that there is a significant difference in every block. The result of Kruskal Wallis IV. DISCUSSION test shows $p = 0.120$ ($p > 0.05$), which means that Statistics shows that there is no difference in the statistically, there is no significant difference between the 5

transfer speed of information (TP) of gesture 1 and error rate of each block in the mouse and two gestures. gesture 2, whereas there is a significant difference for transfer rate of information from the mouse to gesture 1 and gesture 2. The same thing happens when we compared the movement time between the mouse, gesture 1, and gesture 2. From this, we conclude that gesture 1 and gesture 2 are not different in terms of TP and movement time statistically. We also categorize mode 1 and 2 as group 1, and mode 3 and 4 as group 2 in terms of error rate. The result shows that gesture 1 and gesture 2 are only applicable on

mode 1 and mode 2, whereas mode 3 and mode 4 21

cannot be used for gesture 1 and gesture 2. In total, the calculated performance of the mouse is much better than gesture 1 and gesture 2 in terms of TP and movement time. The click method which uses jerk Fig. 10. The error rate graph in each mode movements become one of our obstacles as it requires We performed statistical tests on the data showed in more effort and that jerk movements, though little, can Fig. 10 to see the effective modes for gesture 1 and impact the cursor's accuracy. gesture 2. Gesture 1 and gesture 2 were statistically tested To validate the experimental procedure and using Mann-Whitney U test with mode 1 and mode 2 put methodology, the result of performance assessment i.e., in group 1 and mode 3 and mode 4 put in group 2. The throughput, revealed that the mouse's TP is 3.22 bps. This result of statistical test of error rate in each mode says that is in line with other studies by researchers which is there is significant difference in group 1 and group 2 (p <

the range of the mouse' s TP is 3.0-5.0 bps 1

as reported in 0.05). [12] and [13]. B. Qualitative Data Basically, the method in recognizing jerk movements worked well. From Fig. 9 and 10, we found that the error The statistical data is obtained from the form filled by rate of gesture 1 and gesture 2 was two times higher than the subject after the test. There are seven questions of that of the mouse. Possibly, the characteristic of the comfortability test and five questions of fatigue test smartphone's orientation sensor affects the accuracy. questions. Data from each subject will be averaged to determine the level of comfortability and fatigue of the We have 200 test data, where 70% is used for training, mouse and both gestures. and 30% to test the score of the jerk movement detections whether they go smoothly. However, during the TABLE II. COMFORTABILITY AND FATIGUE implementation, this jerking movement detection affects Assesment Mouse Gesture 1 Gesture 2 the cursor position; therefore, we need to reevaluate the comfort 6.95 4.46 4.97 click method so that it will not affect the cursor position. fatigue

6.61 5.89 5.87 * Likert scale 7 point V. CONCLUSIONS Based on the result of the research and test, we conclude that. 1. Average calculation of throughput and movement time for mouse is 3.22 bps and 1.14 s, 0.19 bps and 22.18 s for gesture 1, and 0.19 bps and 22.66 s for gesture 2. We conclude

that there is a significant difference between mouse and 1

gesture 1 or gesture 2, however, there is no significant difference for gesture 1 and gesture 2. 2. As for the levels of comfortability and fatigue, mouse has the highest level of comfortability and the lowest level of fatigue. Gesture 1 comes on the second position, and gesture 2 on the last in terms of this. Mouse is the most effective tool in terms to effort. Gesture 1 comes on the second position, and gesture 2 concluded as ineffective. [11] [12] [13]

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