Study of the Android and ANN-based Upper-arm Mouse

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Abstract— ***Disability is a 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; 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 uses 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. The other references in this study are eye-tracker [4], color pointer detection [5] and voice controller [6]. 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 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 Fig. 1. 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 [7] 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 sensors, the system provides data for the three orientation angles which are yaw (azimuth), pitch, and roll. Figure 2 shows three orientation angles that work on a smartphone.

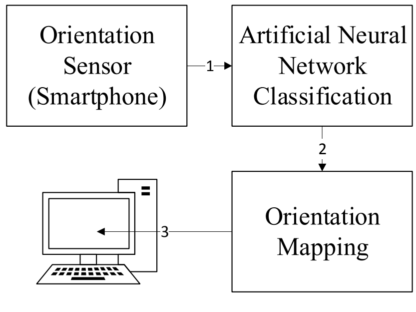

Fig. 1. System diagram

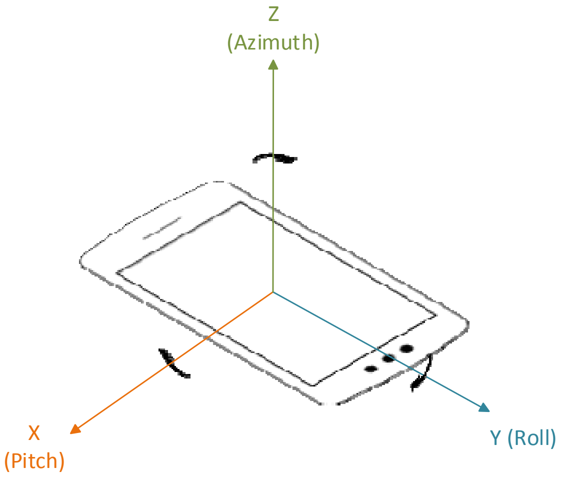

Fig. 2. Orientation sensor angle on the smartphone

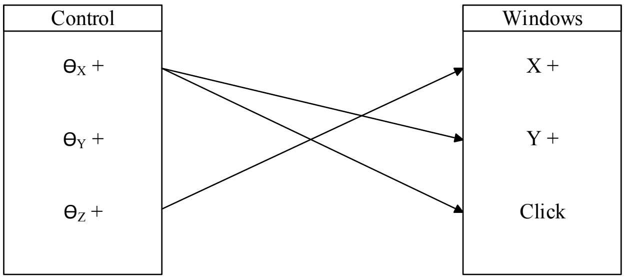

Fig. 3. The sensor-cursor mapping of gesture 1

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 described in Fig. 3. Fig. 3 tells Θ_x + to be the initial data to move the cursor on screen in the Y + axis and click method. The Θ_z + axis becomes the initial data to move the cursor on screen in the X + axis.

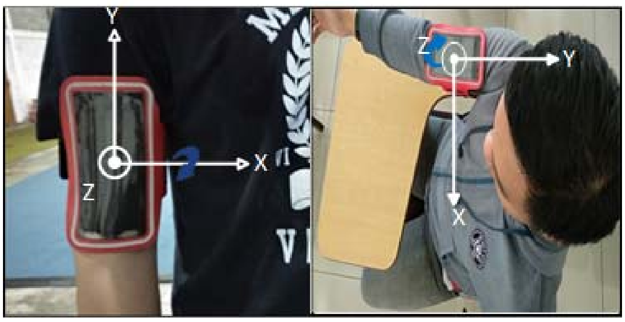

Fig. 4. Gesture 1

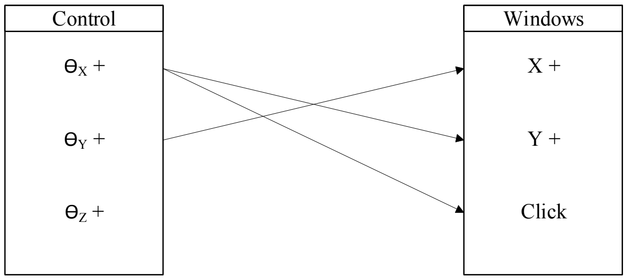

Fig. 5. The sensor-cursor mapping of gesture 2

How to use gesture 1 is illustrated in Fig. 4.

2) Gesture 2

Gesture 2 is mapped as described in Fig. 5. Figure 5 tells Θ_x + to be the initial data to move the cursor on screen in the Y + axis and click method. The Θ_z + axis becomes the initial data to move the cursor on screen in the X + axis. How to use gesture 2 is illustrated in Fig. 6.

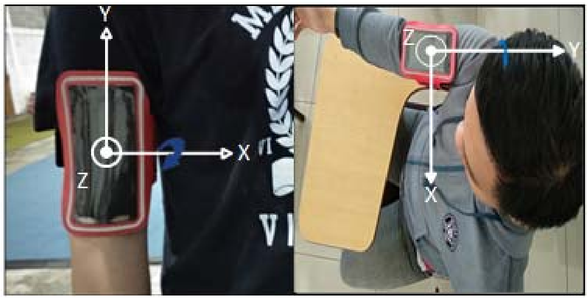

Fig. 6. Gesture 2

C. Artificial neural network

Artificial neural network (ANN) is a 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 [8]. 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 [9]

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.

We use 200 data in terms of Pitch, which include 100 upward jerks for left click and 100 downward jerks for right click. Figure 7 tells 1 data in terms of pitch has 100 inputs. 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.

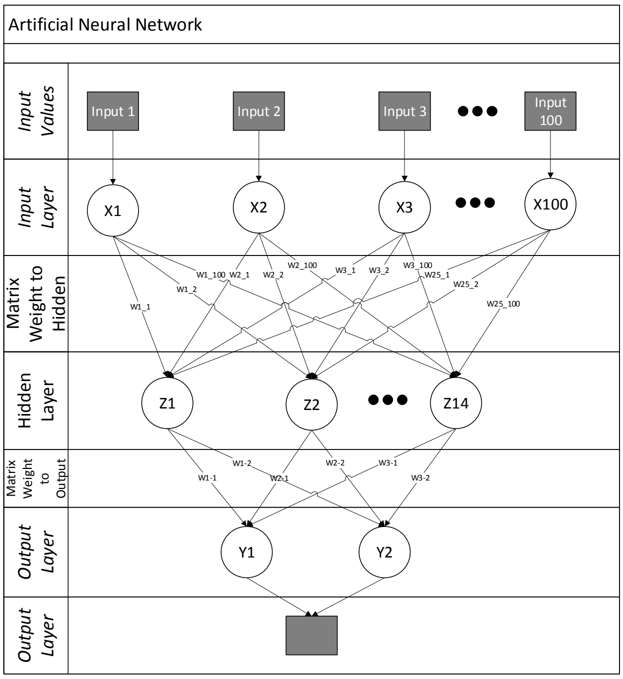

Fig. 7. Artificial neural network architecture

D. ISO 9241-411

ISO 9241 is a standard from International Organization for Standardization (ISO) that works on ergonomic human-system interactions [10]. 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: $I_D <= 3$ (mode 1)
2. Easy: $3 < I_D <= 4$ (mode 2)
3. Medium: $4 < I_D <= 6$ (mode 3)
4. Hard: $I_D > 6$ (mode 4)

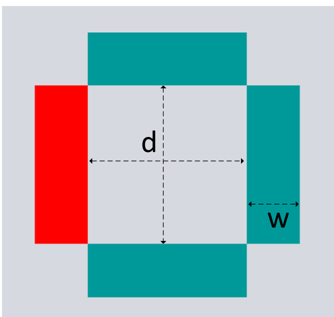

Fig. 8. One directional tapping test

$$\text{Index of difficulty } (I_D) = \frac{d}{w} \quad (1)$$

where d is distance and w is width in pixels.

The Effective Index of Difficulty (*IDe*) is a measurement in the bits of the user's precision achievement during the task.

$$I_{De} = \log 2 \frac{d+w}{w} \quad (2)$$

Throughput (*TP*) is used to measure the average velocity of each target shift.

$$\text{Throughput} = \frac{ID_e}{t_m} \quad (3)$$

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 [11],[12],[13], and [14]. However, we simplify this study using modified one-directional tapping test as suggested by ISO for horizontal and vertical movement as in Fig. 8.

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. Table 1 shows the detail data of experimental result that will be processed statistically.

TABLE I. DETAILS OF EXPERIMENTAL RESULTS

Block	Mode	Mouse		Gesture 1		Gesture 2	
		tm(s)	*TP(bit/s)*	*tm(s)*	*TP(bit/s)*	*tm(s)*	*TP(bit/s)*
1	1	0.94	2.24	13.03	0.15	9.69	0.21
	2	0.96	3.43	16.33	0.18	13.58	0.21
	3	1.06	3.96	20.21	0.18	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 W_e and *time* of each mode, using the following equation:

$$W_e = 4.133 * S_x \tag{4}$$

S_x is the standard deviation of the click coordinates with the midpoint of tapping. The next calculation step is to process *We* and *time* to get ID_e and Throughput (*TP*). The results of ID_e 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 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. 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.

- The movement time value of the mouse is faster than gesture 1 and gesture 2.
- 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

Fig. 9. Graph error rate on each block

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 every block.

As seen on Fig. 9, block 3 has less error rate compared to the mouse or two gestures in block 1 and 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 test shows $p = 0.120$ ($p > 0.05$), which means that statistically, there is no significant difference between the error rate of each block in the mouse and two gestures.

We performed statistical tests on the data showed in Fig. 10 to see the effective modes for gesture 1 and gesture 2. Gesture 1 and gesture 2 were statistically tested using Mann-Whitney U test with mode 1 and mode 2 put in group 1 and mode 3 and mode 4 put in group 2. The result of statistical test of error rate in each mode says that there is significant difference in group 1 and group 2 ($p < 0.05$).

B. Qualitative Data

The statistical data is obtained from the form filled by the subject after the test. There are seven questions of

Fig. 10. The error rate graph in each mode

comfortability test and five questions of fatigue test questions. Data from each subject will be averaged to determine the level of comfortability and fatigue of the mouse and both gestures.

TABLE II. COMFORTABILITY AND FATIGUE

Assesment	Mouse	Gesture 1	Gesture 2
Comfort	6.95	4.46	4.97
Fatigue	6.61	5.89	5.87

* Likert scale 7 point

Table II shows the average rate that the mouse has the best 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 ($p < 0.05$), 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, 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 that gesture 1 has more effort on the shoulder, and on the hand for gesture 2.

IV. Discussion

Statistics shows that there is no difference in the transfer speed of information (*TP*) of gesture 1 and 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 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 movements become one of our obstacles as it requires more effort and that jerk movements, though little, can impact the cursor's accuracy.

To validate the experimental procedure and methodology, the result of performance assessment i.e., *throughput,* revealed that the mouse's *TP* is 3.22 bps. This is in line with other studies by researchers which is the range of the mouse's *TP* is 3.0-5.0 bps as reported in [15] and [16].

Basically, the method in recognizing jerk movements worked well. From Fig. 9 and 10, we found that the error rate of gesture 1 and gesture 2 was two times higher than that of the mouse. Possibly, the characteristic of the smartphone's orientation sensor affects the accuracy.

We have 200 test data, where 70% is used for training, and 30% to test the score of the jerk movement detections whether they go smoothly. However, during the implementation, this jerking movement detection affects the cursor position; therefore, we need to reevaluate the click method so that it will not affect the cursor position.

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 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.

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