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Study of EMG-based Mouse Clicks Type Detection

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***Abstract*— The operation of a computer required humans to use several parts of their body. However, there were some conditions where humans cannot operate computers correctly or in a normal position; examples of these conditions were accident victims and people with disabilities. Therefore, a system was needed to help make it easier for these people to operate the computer. This study developed a system that can classify click types using EMG sensors, the K-NN method, and the SVM method. EMG sensors helped take data in the form of signals from human muscle contractions which will later be classified into left-click and right-click. At the same time, it was useful for classifying these types of clicks for the K-NN and SVM methods. Data from EMG sensors were trained using the K-NN and SVM methods using 54 data sets in each class, namely left-click and right-click classes. The K-NN method was trained using k=3, 5, 7, 9, and 11. The SVM method used linear kernels, Radial Basis Function (RBF), polynomials, and sigmoids. After that, the accuracy values of the two methods will be compared. The study has successfully classified the types of clicks based on the input from the EMG sensor using the K-NN method with the highest accuracy results using k=3, which was 81.81%, and the SVM method using polynomial kernels which were 84.84%. The highest accuracy value was obtained by comparing the two methods, namely using the polynomial kernel SVM method. Adding datasets and conducting experiments using other methods as further comparisons can be used to improve system accuracy.**

Keywords*— *EMG, K-Nearest Neighbor, Support Vector Machine (SVM), classification

I. Introduction

Traffic accidents are unforeseeable and are very much avoided by everyone. This incident involves a vehicle with or without another motorist, which can result in human casualties from only minor injuries, severe injuries, and even death. Some victims of these accidents have jobs they cannot leave behind, one example of which is those who have to operate a computer. Accident victims who have suffered severe injuries such as permanent fractures or cannot sit in a normal position have difficulty operating the computer to the fullest. In addition to victims of traffic accidents, some people have difficulty operating computers, that is, people with disabilities.

A person with a disability is any person who experiences physical, intellectual, or mental. Sensory limitations, and who interact with the environment may experience obstacles and difficulties in participating fully and effectively with others based on equal rights. For example, instead of working physically, it would be better if they worked in front of a computer because it does not require a large amount of physical exertion. To operate a computer, a mouse is a critical apparatus. The purpose of the computer mouse is to move the cursor to a particular icon/shortcut, left-clicking to access a file, right-clicking to open additional menus, and many others. However, not all people with disabilities can operate the mouse optimally due to its limitations.

Not inferior to the development of smartphones that are currently rampant, computer technology also continues to develop. On computer devices, there have begun to be several tools or applications to help people with disabilities, such as speech recognition, typing robots, mice shaped like gloves installed to drive pointing devices, and so on.

In previous research [1]–[3], a prototype of a pointing device using Electromyography and a bend sensor is employed as clicking input. The completed click detector is to detect left clicks only. Based on previous researchers' advice, developing a prototype or an EMG sensor is advisable because the EMG sensor is more comfortable to wear and expends less effort than using a bending sensor.

There have been several previous studies, namely research using a combination of foot switches and low-cost Inertial Measurement Units (IMU) for mice that can be used in human and computer interaction. In this study, the clicks used were to use feet. As a result, this study has a good throughput (TP) and movement time, namely TP=1.37 bps. However, the device in this study still provides a reasonably heavy load for the user's neck [4]. The second study used IMU and bending sensor as a pointing device and click method, but this study only used the left click. As a result, this study has better results with TP = 1.75bps. However, the device used also has shortcomings in comfort [4]. The latter is a study of mice using an android-based upper arm and an ANN that uses hand gestures as click markers. In this study, two gestures were compared, and obtained throughput and movement time results of 0.19 bps and 22.18 s for gesture 1 and 0.19 bps and 22.66 s for gesture 2. Comparing the two gestures showed that gesture one is more comfortable has a low level of fatigue, and is more effective than gesture 2 [5]. However, the research still does not include the convenient click feature on the mouse, which is one of the important features in computer operation.

Electromyograph (EMG) sensor is a unique tool from biosignalplux. The results of the EMG sensor will be classified into two classes, namely, left-click, and right-click.

II. Related Studies

A. Electromyography (EMG)

Electromyography, commonly referred to as EMG, is the process of detecting, analyzing, and utilizing electrical signals derived from muscle contraction [6]–[9]. The tool used in this process is called an electromyograph. In contrast, the resulting signal is called an electromyogram or myoelectric signal. EMG is widely used for the rehabilitation process of people with disabilities, either due to amputation or due to other causes such as stroke. EMG signals can be obtained in two ways, through electrode implantation (intramuscular EMG) and without electrode implantation in the patient's body (surface EMG). Intramuscular EMG uses a fine wire-shaped needle placed in the muscle, as shown in Fig. 1. The implanted electrodes provide a better and more direct signal from the desired muscle source [10]–[18]. However, the installation must go through surgical operations, so it is less preferred and avoided. Therefore, electrodes not planted or placed on the surface are more widely used. It is just that the signals obtained are not as good as those planted and are often influenced by signals from the surrounding muscles. The method of electrodes placed on the surface, commonly called Surface EMG is a technique in which electrodes are placed on the skin on top of the muscles to detect electrical activity in the muscles. The installation of the surface EMG can be seen in Fig. 2.

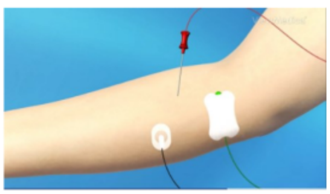

Fig. 1. Intramuscular EMG

Fig. 2. Surface EMG

B. Support Vector Machine (SVM)

The Support Vector Machine (SVM) was developed by Boser, Guyon, and Vapnik and first presented in 1992 at the Annual Workshop on Computational Learning Theory. SVM is a machine learning method that works on the principle of Structural Risk Minimization (SRM), intending to find the best hyperplane that separates two classes in input space [19]. According to Vapnik and Cortes [20], a Support Vector is a machine-learning classification method for two groups. The hyperplane is a function that can be used to separate between classes. The best hyperplane can be found by measuring the margin and looking for its maximum point. Margin is the distance between the hyperplane and the pattern or the nearest outermost object of each class. In SVM, the outermost data object closest to the hyperplane is called the support vector. Support vectors are the most difficult to classify due to their almost overlapping position with other classes. Given its critical nature, only this support vector is considered to find the most optimal hyperplane by SVM.

The SVM algorithm uses a set of mathematical functions defined as kernels. The function of the kernel is to take data as input and convert it into the required form. Different SVM algorithms use different types of kernel functions. Examples of kernel function types in SVM are Linear, Nonlinear, Radial Basis Function (RBF), Sigmoid, and Polynomial.

Linear is the simplest SVM kernel. Linear kernels are commonly used when the analyzed data is already linearly separated. The equation of the linear kernel SVM is as in (1).

$$k(x, y) = x^T . y \quad (1)$$

RBF kernel is a function commonly used in analysis when data is not linearly separated. RBF kernel has two parameters, namely Gamma and Cost. The Cost parameter, commonly referred to as C, works as SVM optimization to avoid misclassification in each sample in the training dataset. The Gamma parameter determines how far the influence of a single sample training dataset with a low-value meaning "far away" and a high-value meaning "near." With a low gamma, a point far from a reasonable dividing line is considered in the calculations for the dividing line. When high gamma means that the points are around, a good line will be considered in the calculation. The equation of the RBF kernel is as in (2).

$$k(x, y) = \exp\left(-\frac{\|x-y\|^2}{2\sigma^2}\right) \quad (2)$$

Sigmoid Kernel, also known as Hyperbolic Tangent Kernel and Multilayer Perceptron (MLP) Kernel. The Sigmoid kernel is derived from the Neural Network, where the bipolar function of the sigmoid is commonly used as an activation function for artificial neurons. The equation of the Sigmoid Kernel is as in (3).

$$k(x, y) = \tanh\,(\alpha x^T y + c) \quad (3)$$

Kernel polynomials are kernel functions used when data is not linearly separated. Kernel polynomials are well suited for problems where all training datasets are normalized. The equation of the Polynomial kernel is as in (4).

$$k(\boldsymbol{x_i}, \boldsymbol{x_j}) = (\boldsymbol{x_i} \cdot \boldsymbol{x_j} + 1)^2 \quad (4)$$

C. K-Nearest Neighbor

K-Nearest Neighbor, commonly called K-NN, is included in supervised learning, where the results of new instance queries are classified based on the majority of the proximity of the closest k-neighbors of the categories in K-NN. Supervised learning is an approach with already trained data and targeted variables. Hence, this approach aims to group data into existing data. The use of KNN for classification is very widely used by researchers [21]–[25]. To use the K-NN algorithm, it is necessary to determine the number of k closest neighbors used to classify new data. The number k, preferably an odd number, for example, k = 1, 3, 5, and so on. The determination of the value of k is based on the amount of data present and the size of the dimensions formed by the data—the more data, the lower the number of k chosen. However, the more significant the dimension size of the data, the higher the k number is preferred. In simple terms, K-NN works based on the minimum distance from the new data to the training data to determine the K-nearest neighbor. The closest way to calculate the closest distance of the new data to its neighbors is to use the Euclidean Distance formula.

D. Feature Extraction

Feature extraction is a method that selects and combines variables into features, effectively reducing the amount of data to be processed while wholly and accurately describing the original data set.

1. Max EMG Value
Looks up the highest (maximum) value of the total number of samples used (1000 samples/second)

2. Min EMG Value
Looks up the lowest (minimal) value of the overall number of samples used (1000 samples/second)

3. Wave Length
Used to find the wavelength obtained by the EMG sensor, which will later be used as one of the classification features.

$$\boldsymbol{WL} = \frac{1}{N}\sum_{i=1}^{n-1}|x_{i+1} - x_i| \quad (5)$$

4. Mean Absolute Deviation

$$\boldsymbol{MAD} = \frac{\sum_{i=1}^{n}|x_i - \bar{x}|}{n} \quad (6)$$

Notes:

$\bar{x}$: mean
x_i : signal value
n : number of values

III. SYSTEM DESIGN

A. Needs Assessment

The device used for the detection of muscle contractions is the Biosignalsplux EMG sensor. There are three electrodes attached to the user's upper arm. One electrode acts as a reference or ground, which will be installed on the left shoulder, and the other two electrodes will be placed on the biceps muscle on the left arm. The data will be read using an application from Biosignalsplux called OpenSignals (r)evolution. The data read directly (real-time) in this application is in the form of a signal according to muscle contraction, then stored in the form of a .txt that can be transformed into a .csv form. The .csv data will later be used as input in two methods, K-NN and SVM, which have the output detected left-click or right-click. After learning each method, it will be compared to determine which is better. Finally, the output will be displayed on the computer screen with a click.

B. System Flow

The system's flow starts from the contraction of the muscles in the human upper arm to indicate a left or right click. Then the three electrodes will read the data and send the data to the EMG sensor. The data will be received by the Hub and transmitted to the computer using Bluetooth. The sensor will read the data in real-time. The data obtained will be processed by K-NN and SVM to be identified and classified into left-click and right-click. After that, it will be displayed on the screen with a click. When we can click, the computer will display the position of the pointer on the screen that can be used to run prototype tests with ISO 9241-411 assessment instruments. The EMG sensor will only function as a click; to move the cursor, another tool is needed, namely the mouse. The tests will produce data records containing accuracy data, errors, and so on that will be used for statistical data processing as a benchmark for the success rate of the prototype.

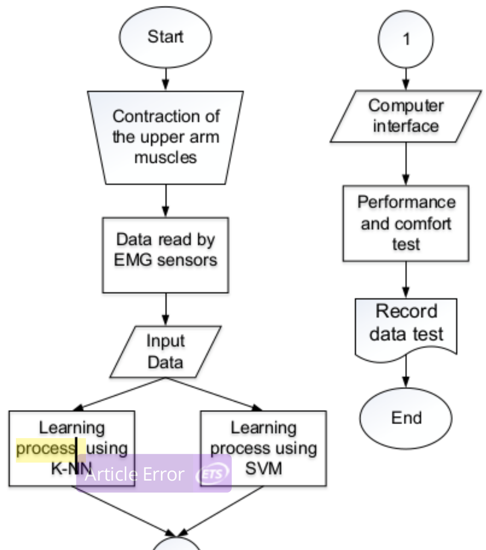

Fig. 3. Flow of System

C. Implementation

Next is the implementation of a pre-designed system. System creation is created with several programming languages that support the creation of this system. When implementing the system into a coding line, many things need to be considered and done to get good results. Improvements will continue to be made to get better results before proceeding with the testing phase. This system will be created with various software and programming languages as follows.

a. Data: h5 file
b. Programming language: Python 3.5.4
c. Software: Opensignals

In addition, the hardware used to create and develop this system is as follows.

a. Sensor: EMG Biosignalplux
b. Operating system: Windows 10 Home 64-bit
c. Processor: Intel(R) Core(TM) i5-7200U
d. RAM: 8GB

D. Evaluation

The learning process of the K-NN and SVM methods is evaluated by conducting tests using a confusion matrix. Judgment from the accuracy results of each method. These two methods will also be compared to determine which has a higher accuracy value and a minor error and is better at classifying. Then the results of this study will be compared with previous studies with different tools but with the same accuracy calculation method. Finally, accuracy testing uses the value of accuracy, precision, recall, and f-measure

IV. RESULTS AND DISCUSSION

A. Data Collection Results

The data came from an EMG sensor affixed to the respondent's upper left arm. The dataset retrieval is retrieved using an application already provided by biosignalplux. The application can record the contraction results produced by the sensor, and the results obtained can be saved to become a dataset. An example of the data retrieval process can be seen in figure 3. The red box is contracted when doing a left click, the blue box contraction is for a right click, and the yellow box is for the no-click data.

Fig. 4. Example of Muscle Contraction Signal

The number of subjects is 9 (88% males and 12% females). The respondents' age range is 23-27 years, the weight is 48-98 kg, and the height is about 166-178 cm.

The results obtained from the muscle contraction record are exported into txt and h5 files. The result of resulting data can be seen in the txt file. Table 1 shows an example of muscle contraction data.

TABLE I. EXAMPLE OF SIGNAL CONTRACTIONS DATA

Sequence	EMG (mV)
0	32696
1	32732
2	32640
…	…
30031	42296
30032	43332
30033	43876

Based on the analysis results from the data obtained, it can be seen that before the contraction, the resulting EMG results are stable at 32000. However, if there is a contraction, the EMG results will increase by approximately 37000–44000 according to the strong results of muscle contractions carried out by respondents. Each respondent has a different range of numbers because each respondent also has different muscle mass and fat.

As for the h5 file data results, the file will be used as a system input and processed as training data and testing data. In addition, H5 data can be read and processed faster by a computer. Therefore, the use of h5, which is focused on storing and processing data by computers, is the right choice to be used as a data source in making systems.

The initial process is to process the EMG results with a predetermined formula to obtain data on wavelength, mean absolute deviation, min value, and max value. Then, these four features will be used as training model input.

After the four features are successfully retrieved, the data still cannot be entered for training models. This is because data with different range variants will cause the results of one feature, especially those with a range that is too small from the others, not to have the same impact as other features with a more extensive range. Then the normalization of the Min-Max Scaler is carried out. After the normalization results, all existing features will be in the range of 0-1 so that each feature can contribute equally to the model training that will be carried out.

The dataset will be divided into 80% as training data, and the remaining 20% will be made into testing data. The initial datasets amounted to 54 data for each class, so it was divided into 43 data as training data and 11 as testing data for each existing class. The data amount is also equal to maximize system learning and accuracy value.

B. *Experiment Results*

Testing using the K-NN method is carried out by trying the k parameter. The parameter k is worth an odd random number from values 3 to 11. Each k parameter value is tested to obtain the precision, recall, f1-score, and accuracy values. The following are the test results of each value of the k parameter. The first k-parameter experiment is 3, getting the value shown in Table II. The accuracy value obtained from k=3 is 81.81%.

TABLE II. KNN TEST RESULTS USING PARAMETER K = 3

	precision	*recall*	*f1-score*
No Click	0,83	0,91	0,87
Left Click	0,83	0,71	0,77
Right Click	0,78	0,88	0,82

The second experiment is with the parameter k valued at 5, getting the value specified in Table III. The accuracy value obtained from k = 5 is 78.78%.

TABLE III. KNN TEST RESULTS USING PARAMETER K = 5

	precision	*recall*	f1-*score*
No Click	0,82	0,82	0,82
Left Click	0,77	0,71	0,74
Right Click	0,78	0,88	0,82

The third experiment is with the parameter k worth 7, getting the value set in Table IV. The accuracy value obtained from k = 7 is 81.81%.

TABLE IV. KNN TEST RESULTS USING PARAMETER K = 7

	precision	*recall*	f1-*score*
No Click	0,82	0,82	0,82
Left Click	0,79	0,79	0,79
Right Click	0,88	0,88	0,88

The fourth experiment is with the parameter k worth 9, getting the value set out in Table V. The accuracy value obtained from k = 9 is 81.81%.

TABLE V. KNN TEST RESULTS USING PARAMETER K = 9

	precision	*recall*	f1-*score*
No Click	0,82	0,82	0,82
Left Click	0,79	0,79	0,79
Right Click	0,88	0,88	0,88

The fifth experiment is with the parameter k valued at 11, getting the value set out in Table VI. The accuracy value obtained from k = 11 is 81.81%.

TABLE VI. KNN TEST RESULTS USING PARAMETER K = 11

	precision	*recall*	f1-*score*
No Click	0,77	0,91	0,83
Left Click	0,83	0,71	0,77
Right Click	0,88	0,88	0,88

Based on the five k-parameter experiments that have been carried out, it can be concluded that the highest accuracy value is at the time k = 3, 7, 9, and 11, which is 81.81%. Because the highest accuracy value obtained is in the four k values, the most optimal k value will be taken using the smallest k value, namely k = 3.

Testing using the SVM method is done by trying four types of kernels. The kernels tested were Linear, Polynomial, RBF, and Sigmoid Kernels. Here are the test results of each kernel.

The first experiment was to use a linear kernel. In this experiment, we get the values as shown in Table VII. The accuracy value obtained from the linear kernel is 78.78%.

TABLE VII. SVM TESTING RESULTS USING LINEAR KERNELS

	precision	*recall*	f1-*score*
No Click	0,71	0,91	0,80
Left Click	0,83	0,71	0,77
Right Click	0,86	0,75	0,80

The second experiment was to use a polynomial kernel. In this experiment, we get the values as shown in Table VIII. The accuracy value obtained from the polynomial kernel is 84.84%.

TABLE VIII. SVM TESTING RESULTS USING POLYNOMIAL KERNELS

	precision	*recall*	f1-*score*
No Click	0,77	0,91	0,83
Left Click	0,85	0,79	0,81
Right Click	1,00	0,88	0,93

The third experiment was to use the RBF kernel. In this experiment, we get the values as shown in Table IX. The accuracy value obtained from the RBF kernel is 78.78%.

TABLE IX. SVM TESTING RESULTS USING RBF KERNELS

	precision	*recall*	f1-*score*
No Click	0,77	0,91	0,83
Left Click	0,82	0,64	0,72
Right Click	0,78	0,88	0,82

The fourth experiment was to use the sigmoid kernel. In this experiment, we get the values as shown in Table X. The accuracy value obtained from the sigmoid kernel is 42.42%.

TABLE X. SVM TESTING RESULTS USING SIGMOID KERNELS

	precision	*recall*	f1-*score*
No Click	0,52	1,00	0,69
Left Click	0,00	0,00	0,00
Right Click	0,38	0,38	0,38

Based on the four kernel experiments that have been carried out, it can be concluded that the highest accuracy value is when using polynomial kernels, namely with an accuracy value of 84.84%.

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PAGE 2

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Sentence Cap. Remember to capitalize the first word of each sentence.

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Proofread This part of the sentence contains a grammatical error or misspelled word that makes your meaning unclear.

Confused You have used **an** in this sentence. You may need to use **a** instead.

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Sentence Cap. Remember to capitalize the first word of each sentence.

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Article Error You may need to use an article before this word.

Dup. You have typed two **identical words** in a row. You may need to delete one of them.

Frag. This sentence may be a fragment or may have incorrect punctuation. Proofread the sentence to be sure that it has correct punctuation and that it has an independent clause with a complete subject and predicate.

Sentence Cap. Remember to capitalize the first word of each sentence.

Missing "," You may need to place a comma after this word.

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Verb This verb may be incorrect. Proofread the sentence to make sure you have used the correct form of the verb.

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Sentence Cap. Remember to capitalize the first word of each sentence.

Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

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