Motion Recognition Uses Accelerometer and Gyroscope Sensors Using Learning Vector Quantization Method

Adlian Jefiza[1], Muhammad Arif Fardiansyah[2], Ika Karlina Laila Nur Suciningtyas[3],Diono[4], Indra Daulay[5], Dodi Prima Resda[6], Fadli Firdaus[7], Jhon Hericson Purba[8], Agus Kurniawan[9]

{adlianjefiza@polibatam.ac.id[1], m.ariffardiansyah@gmail.com[2], ikakarlina@polibatam.ac.id[3], diono@polibatam.ac.id[4], indradaulay@polibatam.ac.id[5], dodi.prima@polibatam.ac.id[6], fadlifirdaus@polibatam.ac.id[7], jhonhericson@polibatam.ac.id[8], aguskurniiawan1600@gmail.com[9]}

Electrical Engineering Department, Politeknik Negeri Batam, Indonesia[1,2,3,4,5,6,7,8,9]

Abstract. Determining the correct position and orientation in the technical system has an important role. This determination can be made by combining the use of the Accelerometer sensor with the Gyroscope sensor. This position determination will be carried out to determine the form of movement, namely standing, sitting, lying down, and prayer movements in the form of bowing, prostration, and sitting between two prostrations using the orientation of the x, y, and z axes. This determination uses an artificial neural networks method, namely the Learning Vector Quantization (LVQ) method. In order to retrieve data, a device designed consisting of accelerometer and gyroscope sensors that have been installed on the MPU 6050 sensor with a control system using the Arduino Nano AT Mega 328 microcontroller. Data obtained in formed of values processed to know the accuracy level which Learning vector quantization showing 100% for data training and 72% for data testing.

Keywords: Learning Vector Quantization, Accelerometer, Gyroscope, Arduino Nano AT Mega 328.

1 Introduction

Humans make movements every day with different patterns. Movement or motion is a process that involves some or all parts of the body in unity which produces static in place and dynamic movement by changing places. Human motion can be the same and different depending on thehuman will. In general, humans move 16 to 18 hours a day. The experiments carried out includedmovements in daily activities such as sitting, standing, and sleeping.

Movement can be detected by utilizing technology that has been developed[1]. An exampleof a tool that can detect motion is a tool that uses an Accelerometer sensor and a Gyroscope sensor by utilizing the change in value which is the output of the sensor[2]. The MPU 6050 sensoris an example of a device that has combined these two sensors and the output of this device is anumeric value from the three angles, namely x, y, and z. From the known output, it

ICAE 2023, November 07, Batam, Indonesia

DOI 10.4108/eai.7-11-2023.2342948

is possible todetermine the movement that is taking place by processing this value using data processingmethods[3].

There are many methods that can be used to process the data obtained, some of which are supervised classification methods with predetermined targets or classes, namely the Learning Vector Quantization (LVQ) method[4]. The use of this method is intended to be able to classifya class more easily based on the input that is the result of the sensor[5]. This research will also test the introduction of additional movements, namely the prayer movement. The introduction of prayer movements that will be carried out includes bowing, prostration, and sitting between twoprostrations.

The use of Accelerometer and Gyroscope sensors is the main component to retrieve data where the output will be processed to determine movement[6]. This study also explains the use of Accelerometer and Gyroscope sensors in helping to obtain data that will later be processed using the classification method, and how to conduct training, learning, and testing using the Learning Vector Quantization method.

IMU or inertial measurement unit is an electronic module unit that can collect data from angular acceleration and linear acceleration[7] which will then be sent to the main processing unit. The IMU consists of an Accelerometer which is used to measure the acceleration of an object and a Gyroscope used to measure the rotation of an object[8].

Accelerometer sensor is an electromagnetic device that has the function of measuring the acceleration of an object precisely, acceleration by gravity, detecting and measuring vibrationsthat occur in vehicles, vibrations in machines, or vibrations that occur on Earth[9]. orientation,with the principle of constant angular momentum. The way it works is a rotating wheel with a disc inside which remains stable. A gyroscope is a sensor that can determine the orientation of motion by relying on a wheel or disc that rotates rapidly about an axis[10].

Arduino Nano is a mini-board based on the Arduino Nano Atmega328 microcontroller. Arduino Nano has 14 digital input/output pins (pins 0-13) consisting of 8 analog input pins (pins0-7) which are commonly used to read voltage from sensors and convert them into values 0 and 1023, 6 analog output pins (pin 3, 5, 6, 9, 10, 11) which are used for PWM (Pulse Width Modulation) settings, a 16 MHz Crystal oscillator, a USB connection, an ICSP header, and a resetbutton. Arduino NANO can be operated using a computer USB port, USB charger, or AC-DC adapter with the recommended voltage of 7-12 Volts.

2 Method

2.1 Learning Vector Quantization

Learning Vector Quantization (LVQ) is a training method for conducting supervised learningin a competitive layer with a single-layer network architecture. A competitive layer will automatically learn to classify input vectors or classes. The classes obtained as a result of this layer only depend on the distance between the input vectors where if the 2 input vectors are thesame, then the competitive layer will put the two inputs into the same class and the output unit represents a certain category or class. The **fig. 1** shown an example of the network architecture.

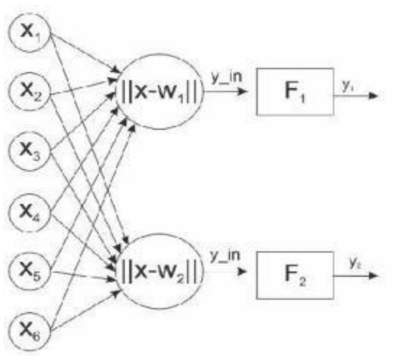

Fig. 1. Learning Vector Quantization Network Achitecture[3]

The algorithm for testing is to calculate the output value or vector class that is closest to the input vector or equated with the classification process. The information used in LVQ is as follows.

X = training or input vector (x1, x2, x3, …, xn).

T = The exact category or class for the input vector.

Wj = Vector weight for the jth output unit (w1j, …, wij, …, wnj).

Cj = category or class displayed by the jth output unit ||x-wj|| the Euclidean distancebetween the input vector and the vector weight for the jth output layer

The steps of the artificial neural network learning algorithm with the learning vector quantization method consist of:

1. Initialize Wj weights and learning degrees α (0).
2. As long as the stop condition is still wrong, do steps 2 to 6.
3. For each training input vector x, do steps 3 – 4.
4. Find j to ||x-Wj|| minimum.
5. Update Wj as follows[3].

   If T = Cj, then
   Wj(latest) = Wj(before) + α[x-Wj(before) (1)

   If T ≠ Cj, then (2)
   Wj(latest) = Wj(before) - α[x-Wj(before)

6. Reduce the training rating.

Test the stop condition, if the condition may determine a fixed number of iterations or the learning rating reaches a small enough value.

2.2 Motion Recognition Testing

Testing was carried out to know whether the device made was as expected. In this study, experiments were also carried out which aimed to adjust the output results from the sensor whether it was by the provisions. The experiment was carried out in 2 ways, namely an experiment in a stationary position with a motion detection device attached and an experiment with a device attached to the body and this experiment will be carried out by placing the deviceand seeing the output.

Movement recognition device testing is carried out to obtain values from the Accelerometer and Gyroscope sensor outputs. The device is placed horizontally in the bag, then attached to thewaist of the test object.

Motion testing is performed on a subject using the device. The experiment will be carried outby 10 subjects with 6 trials, namely 6 movements with a time period of 10 seconds for each movement to be tested. The device is turned on when the subject is in a predetermined positionand movement as shown in the **fig. 2**.

Fig. 2 Tested moves. (a) Stand up. (b) Sit. (c) Lay down. (d) Bow. (e) Prostration. (f) Sit between 2 prostrations

When testing the movement, the device in the bag will follow the position of the object for each movement being tested. So that it will affect the values generated by the x, y, and z axes andthe slope at the output of the accelerometer and gyroscope sensors. Based on the picture of oneparticipant as an example for testing the movement. These movements can be seen in the picture, namely part (a) standing movement, part (b) sitting movement, part (c) lying down, part (d) bowing movement, part (e) prostration movement, and part (f) sitting movement between 2 prostrate.

3 Results and Discussion

After testing and collecting data, we proceed to the motion recognition process using Learning vector quantization. Each move has 6 input variables and 12 additional features. The total data that has been received is 60 data with 6 classes and from all this data will be further divided into 2 data sets, namely training data as much as 70% of the normalized data set with atotal of 42 training data and testing data as much as 30% of the data set which has been normalized with a total of 18 testing data. The introduction is done with iterations 10000, 20000, 30000 and40000.

The selection of weights is done randomly and the distribution of weights is done using Nearest Neighbor Interpolation in the sklearn library which is used in processing training data and data testing. The sklearn used in the learning vector quantization method is sklearn_lvq whichcan be a sklearn for this method. Nearest Neighbor Interpolation is used to estimate the value of a point based on known values at the surrounding points and in the context of classification, nearest interpolation is used as a classification method that works based on the majority of the nearest neighbor class. The weights obtained are trained on the training data set and after that arealso used to train the data set on the testing data. The following is the result of motion recognitionor class classification using the Learning Vector Quantization method with the best iteration which is 40000.

Table 1. Data Training LVQ With 40000 Iteration

Actual	**Prediction**						**Recall**
	Sit	Stand	Lie Down	Ruku’	Prostrate	Sitting during Prayer	
Sit	4						100%
Stand		8					100%
Lie down			8				100%
Ruku’				6			100%
Prostrate					8		100%
Sitting during Prayer						8	100%
Precision	100%	100%	100%	100%	100%	100%	
Accuracy				100%			

After the training data set is trained with 40000 iterations to produce an accuracy level of 100% with all the actual trained data being read according to predictions. Next is testing the testdata or testing data where the test results are as follows.

Table 2. Data Testing LVQ With 40000 Iteration

Actual	**Prediction**						**Recall**
	Sit	Stand	Lie Down	Ruku’	Prostrate	Sitting during Prayer	
Sit	2			1		3	33.33%
Stand		2					100%
Lie down			2				100%
Ruku’				3	1		75.00%
Prostrate					2		100%
Sitting during Prayer						2	100%
Precision	100%	100%	100%	75.00%	66.67%	40.00%	
Accuracy				72.22%			

The results of the test data at 40000 iterations can be seen to show an accuracy rate of 72.22% with 5 actual readable data not in accordance with predictions. Comparison of reading results andaccuracy levels of training data and test data can be seen in table 3.

Table 3. Result Of Data Training and Testing with 40000 Iteration

Motion	Amount Of Data and Accuracy					
	Training Data	Classification Results	Accuracy Percentage	Testing Data	Classification Results	Accuracy Percentage
Sit	4	4	100%	6	2	33.33%
Stand	8	8	100%	2	2	100%
Lie down	8	8	100%	2	2	100%
Ruku'	6	6	100%	4	3	75.00%
Prostrate	8	8	100%	2	2	100%
Sitting during prayer	8	8	100%	2	2	100%
Total	42	42	100%	18	13	72.22%
	Error Rate		0%	Error Rate		27.78%

From the table 3 it is known that at 40,000 iterations, the training data and test data show an accuracy rate of 100% for training data with 42 data that have been identified successfully fromthe 42 data that were trained and 72% for test data with 13 data that have been identified from the 18 data that have been identified. on test. The error rate for the training data is 0% and 27.78%for the test data. After testing the data from the training results, table 4 is obtained which containsthe results of calculating the True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN) values of each data that is trained and tested using different iterations with confusion matrix.

Table 4. Confusion Matrix LVQ

Iteration	Data	TP	FP	TN	FN
10000	Training	41	1	205	1
	Testing	11	4	56	7
20000	Training	41	1	205	1
	Testing	11	7	55	7
30000	Training	41	1	205	1
	Testing	12	6	60	6
40000	Training	42	0	210	0
	Testing	13	5	65	5

Based on Table 5, it can be observed that the LVQ algorithm with 40000 iterations gets better precision, specification, sensitivity and accuracy for the Training data and Testing data comparedto the other iterations by showing the level of accuracy of readings on the training data, namely 100% and 72.22% for reading the training data. Precision, specification, sensitivity and accuracyare important parameters because it contains information and results. Different iterations are required to create more accurate results of training and testing data when using Learning Vector Quantization. Table 5 shown the results of Learning Vector quantization.

Table 5. Results Of Learning Vector Quantization

Iteration	Data	Precision	Specification	Sensitivity	Accuracy
10000	Training	97.62%	99.51%	97.62%	99.19%
	Testing	73.33%	93.33%	61.11%	85.90%
20000	Training	97.62%	99.51%	97.62%	99.19%
	Testing	61.11%	88.71%	61.11%	82.50%
30000	Training	97.62%	99.51%	97.62%	99.19%
	Testing	66.67%	90.91%	66.67%	85.71%
40000	Training	100.00%	100.00%	100.00%	100.00%
	Testing	72.22%	92.86%	72.22%	88.64%

4 Conclusion

Based on the tests that have been carried out, it can be seen how the Learning Vector Quantization (LVQ) classification method works in class classification. The level of accuracy in recognition depends on how much data is used as input, in this test there are 60 classification data, 42 class classification data for training data, and 18 class classification data for testing datawith an unequal distribution of each class.

The results of the classification using the Learning Vector Quantization (LVQ) algorithm with several iteration experiments, namely 10000, 2000, 30000, and 40000, which was found thatthe 40000 iterations had the best level of accuracy in classifying data on training data and testingdata. Judging from the results of the introduction or classification, the Learning Vector Quantization (LVQ) method has an accuracy rate of 100% for training data and for data testinghas an LVQ accuracy rate of 72.22%.

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