Air Writing Recognition using Machine Learning Algorithms

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Abstract— Air Writing Recognition is one of the most innovative forms of human and computer interaction. Recognizing Gesture based writing in Air helps in the analysis of hand movements without touchpad or screen to trace and to convert them into written or digital text images. Air writing recognition system is developed using sensors that helps to recognize the characters with the help of accelerometer and gyroscope data. Air written characters face challenges in the writing styles of participants, the articulation speed and thereby exhibits difficulty in effective character writing. Existing research works to recognize air written characters have been carried out using CNN and LSTM with captured images. The proposed methodology suggests an improved Air Writing Recognition system with a smart band worn in the wrist. The data collected using the smart band is wirelessly transferred using the Bluetooth module. Three Machine Learning algorithms like RF, KNN, GBM were trained using the acquired data. The performance of the machine learning model was compared using the metrics like Accuracy, Precision, Sensitivity and Specificity and Recall. The accuracy of the KNN model is found to be better than the other two algorithms for the digits. Simulation results show that the accuracy of the KNN model is .49%, 27.57% higher than RF and GBM model respectively.

Keywords – Air Writing; Accelerometer, Gyroscope, GBM, LSTM, Machine Learning component, Shimmer device.

I. Introduction

Motion gestures are simple to remember and straightforward for people to employ. Recently, significant attempts have been made to create intuitive and natural user interfaces for computer-based systems that are based on human gestures. Both people and computers can interact with one another via gestures.As a result, such gesture-based interfaces can be used to enhance as well as replace the functionality of the standard interface devices.

In the beginning, the only means of communication with a robot was through programming, which required a lot of effort. Gesture Recognition was developed together with science and robotics advancements. The hand or the face are typically where gestures begin, but they can originate from any movement or state of the body. Gesture recognition is one way a computer can understand human body language. The demand for text interfaces and GUIs has decreased as a result. A gesture is an action that must be seen by another person and convey some form of message as a gesture is commonly understood to be a movement of a portion of the body to express an idea or meaning.

A person's motions can be tracked and any gestures they may be making can be recognized using a variety of techniques. Despite much research on image / video-based gesture detection, various implementations employ various methods and environments. Among the conceivable devices are radar, wired gloves, stereo cameras, gesture-based controls, and cameras.

II. Related Works

Human activity recognition involves identifying and understanding human behaviours, actions, and intentions based on sensor data [1]. Air writing recognition contributes to this field by providing a method to recognize gestures and motions performed by individuals in the air.
By integrating air writing recognition with human activities recognition system, it becomes possible to infer users' intentions, preferences, and behaviors more accurately.

A sensor based air writing methodology is suggested with the help of motion of air written characters captured by the sensor . Yaney et al. has suggested text recognition using motion signals that are captured by smart bands that are worn around the wrist [2]. Watanabe et al. [3] proposed alphabet and digit recognition from air writing using web camera. Prasun Roy et al. [4] proposed a CNN based Unistroke numeral recognition for multiple languages using generic video camera aided CNN.

The Inertial sensors which include the accelerometers and gyroscopes, measures the acceleration and angular velocity of the hand or stylus to track its motion in three-dimensional space. Prabhat Gupta [5] proposed a method for collection of datasets using Inertial Measurement Units. Yanay et al. [2] proposed a method of using motion signals with a smart band. Author has developed a user dependent approach with k-NN and Dynamic Time Warping and User independent approach with CNN.Tsai et al. [6] has developed a tier-based arrangement of reverse time ordered algorithm to overcome unnecessary lifting strokes. Bastas et al. [7] explores an Air writing methodology with Leap motion Controller Sensor.

Guo et al [8] suggests a deviceless method to recognize characters based on Wi-Fi signals. Chen et al. [9]

proposes air writing recognition using Acoustic waves. Aradhana et al. [10] demonstrates temporal convolutional network for recognizing 3D characters. Hsieh et al. [11] has carried out 1DCNN and 2DCNN based on trajectory output. Tripathi et al. [12] proposed an approach that outperforms the accuracy in available dataset and proved the same with another dataset. Tripathi et al. [13] in another work combines triplet and cross entropy losses.

III. METHODOLOGY

To create a flexible model, data from many different age groups and people with various handwriting styles were collected. A wearable Shimmer 3 IMU unit was used to gather the tri-axial accelerometer and gyroscope data where the volunteers' wrists were secured with the device. Fig.1 displays a volunteer wearing the shimmer gadget as seen in studies.

Fig.1 Volunteer with shimmer device

Shimmer wearable sensor and equipment enables quick and efficient biophysical and kinematic data collection.

Dataset specification

The dataset collected consists of 30 Tamil alphabets and 10numeric digits. Tamil alphabets include the letters அ to ஔ and க் to ன் whereas the numerical values range from 0 to 9.

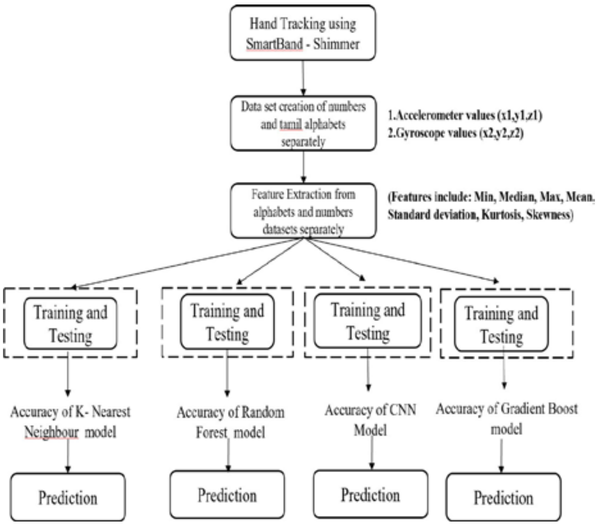

Fig.2 Workflow diagram for Air Writing Recognition

The flow diagram explains the process of recognizing the characters that are air written based on suitable machine learning algorithms.

IV. EXPERIMENTAL RESULTS

Machine Learning model for Air writing recognition is implemented by the following stages as shown in Fig. 3:

Fig.3 Machine Learning model for Air Writing Recognition

4.1Data Acquisition

Data being the crucial requirement for any Machine Learning Algorithm, data acquisition is done by collecting the acquired data from the sensors. The accelerometer data acquired by the device was transferred wirelessly to the laptop using the Bluetooth module embedded in the device. Each volunteer wore the device on the wrist and air wrote the Tamil alphabets/numbers on air 20 times. The process was repeated with 20 people for each alphabet/number.

4.2 Data Preprocessing

The data captured from the sensors are preprocessed which involves eliminating the noisy data. By normalizing the values, they are converted to a format suitable to run in a Machine Learning Algorithm.

4.3 Feature Extraction

Air Writing Recognition involves high dimension of data collected through the MPU 6050 sensor which collects the orientation of the fingers in terms of velocity, acceleration, and position at different instances of time. This results in large amount of data resulting in good number of features from the datasets. Seven Time domain features namely Min, Max, Mean, Median, Standard Deviation, Kurtosis and Skewness are computed from the collected data.

1.The smallest observed value in the data set is the Minimum value.

2. The largest observed value in the data set is the Maximum value.

3.The middle value of the dataset when it is ordered is the median.

4.Taking s as the inertial data along the three axes {s = x,y,z}, the Mean (μ_s) of the inertial signal is given as

$$\mu_s = \frac{1}{N}\sum_{i=0}^{N-1} s_i \qquad (i)$$

Where

$s_i = \{s_0, \ldots\ldots, s_{N-1}\}$ representing inertial signal of size N.

5. The Standard Deviation can be calculated as

$$\sigma_s = \sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(s_i - \mu_s)^2} \qquad (ii)$$

The RMS value can be determined by using the equation

$$RMS_s = \sqrt{\frac{1}{N}\sum_{i=0}^{N-1} s_i^2} \qquad (iii)$$

6. Skewness measures the asymmetry of the probability didtribution of a real valued random variable.

$$SK_s = \frac{1}{N\sigma_s^3}\sum_{i=0}^{N-1}(S_i - \mu_s)^3 \qquad (iv)$$

7. Kurtosis provides information about the tails and peakedness of the distribution when compared to a normal distribution. Kurtosis

$$\sum_{i=1}^{N}\frac{(S_i-\mu_s)^4/N}{s^4} \qquad (v)$$

4.4 Classification

Presence of large number of features lead to High dimensionality in the Air Writing Recognition which requires an appropriate model like Random Forest, K-Nearest Neighbor, Gradient Boosting Algorithm in Machine Learning Algorithm. K-Nearest Neighbor is an instance-based learning text classifier. Islam et al. [14] reveals that the similarity function in kNN is determined using the proximity distance and the closeness function of data. Prabhadevi et al [15] compared different models of machine learning algorithm and suggests SVM to give better accuracy comparatively SVM, RF.

4.5 Prediction

The trained model was used to make predictions using real time data. To test the machine learning model, one of the subjects was asked to write the character in air swiftly and accurately categorize new data. Being a non- extracted from the sensor data and applied as an input to the machine learning model. The model predicts the alphabet.

by wearing the IMU sensor unit in wrist. Features were The algorithm logs every piece of information that is accessible and groups new information according to commonalities. Thisshows that the KNN technique can

IV EXPERIMENTAL RESULTS

5.1 K-Nearest Neighbours

From the simulations, we obtain an average accuracy of 80.25% for numbers. The performance of the KNN model for numbers has been depicted in Fig 3 in the form of a confusion matrix.

5.2 Random Forest

From the simulations, we obtain an Average Accuracy of 77.50% for numbers. The performance of the random forest model for has been depicted for numbers in Fig 4.10 as a confusion matrix

5.3 Gradient Boosting Algorithm

Simulations were performed by Yasaswy MK Manimegalai T & Somasundaram,J (2022), an Average Accuracy of 78% is obtained for numbers dataset. The performance of the gradient boosting model for has been depicted in the fig.7

TABLE I PERFORMANCE ANALYSIS OF CLASSIFIER ALGORITHMS

Algorithms	KNN		Random Forest		GBM	
Performance	Digit	Alphabet	Digit	Alphabet	Digit	Alphabet
Accuracy (%)	80.25	67.50	77.50	71.60	78	70
Precision (%)	80	72	77	74	79	71
Recall (%)	79	69	77	73	78	70

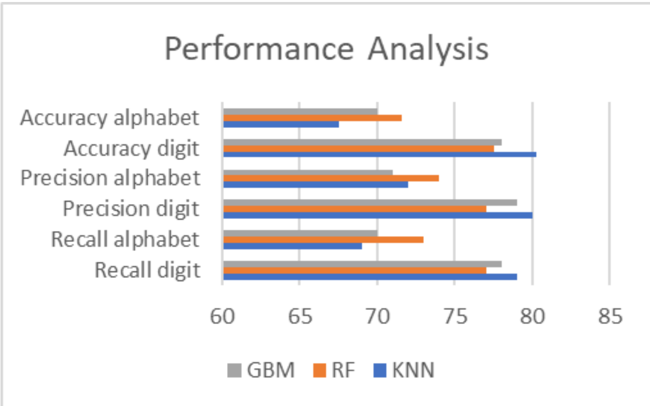

Fig.4.Performance of the Classisfier Algorithms

V. CONCLUSION

Datasets for Tamil alphabets and numbers have been created and 21 features are extracted. Classification of the characters was done with the help of KNN, RF, and GBM and the accuracy was noted and compared. Recognizing characters may be carried out using sensor, computer vision, acoustic waves, radar or millimeter wave [16]. The proposed work acquires real time data set from the sensor output. The Experimental results were analyzed for Different Machine Learning Classification Methods. The results show that the accuracy of the k-NN model is comparatively better than the other two algorithms. Further enhancement of this work is carried out in Deep Learning algorithms.

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