Project Phase III Report

Data Mining

CSE 572

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Recap of Previous Phases

This section gives us a brief recap as to what had been carried out in the previous two phases, to give a better understanding of what is being carried out in this phase.

Phase I

A set of common gestures from the American Sign Language were enacted several times in front of a Kinect and the corresponding movements were recorded from the wristband sensors – Accelerometer, Gyroscope, Electromyography (EMG) and Orientation – and stored in a comma separated value file.

Phase II

Sensor data collected from Phase I was used to implement feature extraction and feature selection methods to better represent the data of different gesture classes i.e. the ASL signs for about, and, can, cop, deaf, decide, father, go out, find and hearing, in a reduced feature space.

Feature Extraction

Based on the hand movements over time and our intuition, we came up with the following set of features and respective transformations that would best represent each action:

Sensor/Feature	Transformation
Electromyograph (EMG0R)	Root Mean Square (RMS)
Electromyograph (EMG2R)	Root Mean Square (RMS)
Electromyograph (EMG3R)	Root Mean Square (RMS)
Electromyograph (EMG4R)	Root Mean Square (RMS)
Accelerometer (ALY)	Discrete Wavelet Transform (DWT)
Accelerometer (ARX)	Discrete Wavelet Transform (DWT)
Accelerometer (ARZ)	Standard Deviation (STD)
Orientation (OPR)	Discrete Wavelet Transform (DWT)
Orientation (ORR)	Standard Deviation (STD)
Orientation (OPL)	Standard Deviation (STD)

Feature Selection

From the extracted list of features, our aim was to determine the features that could yield the most variance on the data set. This was accomplished by performing Principal Component Analysis (PCA).

The extracted features for all the actions were combined to form a feature matrix to be fed into PCA. The execution of PCA resulted in the top three principal components capturing 90.62% of the variance in the features. The major contributing features to these principal components were from the sensors EMG and Orientation.

Phase III

Goal

The goal of this phase is to develop models to classify the ten selected ASL signs using Decision Tree, Support Vector Machine and a Neural Network model on the features extracted from PCA.

Definitions

This section contains the set of definitions for the concepts we have used to carry out this phase of our project. The definitions are given below:

Decision Tree

A decision support tool which uses a tree-like model of decisions and their possible outcomes. [1] In this phase, we have utilized the ***fitctree*** provided by Matlab. As per Matlab, ***fitctree*** is a fit binary classification decision tree for multiclass classification. [2]

Support Vector Machine

Support Vector Machines (SVM) are supervised learning models with association learning algorithms that analyze data used for classification and regression analysis. [3] In this phase, we have utilized the ***fitcsvm*** provided by Matlab. As per Matlab, ***fitcsvm*** trains or cross-validates a support vector machine (SVM) model for two-class (binary) classification on a low-to-moderate dimensional predictor data set. ***fitcsvm*** supports mapping the predictor data using kernel functions, and supports SMO, ISDA, or L1 soft-margin minimization via quadratic programming for objective-function minimization. [4] We have two different types of SVMs, one class is linear SVM, which separates the points in the space into two categories which are as wide from each other as possible. The other class is the non-linear SVM, which maps the inputs into high dimensional feature space and classifies the points.

Artificial Neural Network

Artificial Neural Networks are computing systems inspired by the biological neural networks like brain networks. It is a collection of artificial neurons, where each neuron can transmit the signal to other connected neurons, the receiving neurons can process the signal and send signals further. In most cases, the signal from a neuron is mostly a number and the output of each neuron either increases or decreases the strength of that real number. [5] In this phase, we have utilized the Neural Network Toolbox functions provided by Matlab. It helps us create, train, and simulate shallow and deep learning neural networks.

True Positives

The True Positives (TP), refer to the positive tuples that were correctly labeled by the classifier. [7]

True Negatives

The True Negatives (TN), refer to the negative tuples that were correctly labeled by the classifier. [7]

False Positives

The False Positives (FP), refer to the positive tuples that were incorrectly labeled by the classifier. [7]

False Negatives

The False Negatives (FN), refer to the negative tuples that were incorrectly labeled by the classifier.

Precision

The precision (P) is the fraction of records that turn out to be positive in the group the classifier has declared as positive class. Higher precision implies a lower number of false positive errors committed by the classifier. [8] Mathematically it can be represented as: [9]

$$P = \frac{T_p}{T_p + F_p}$$

Recall

Recall computes the fraction of positive examples correctly predicted by the classifier. Higher recall implies very few positive examples are misclassified as the negative class. Recall is equivalent to the true positive rate (TPR). [8] Mathematically it can be represented as: [9]

$$R = \frac{T_p}{T_p + F_n}$$

F1 Score

Precision and Recall can be summarized into another metric, called the F1 Score, which is the harmonic mean of precision and recall. The harmonic mean of two numbers tends to be closer to the smaller of the two numbers. Therefore, a high value of the F1 measure ensures that both precision and recall are high. [8] Mathematically it can be represented as: [9]

$$F1 = 2\frac{P \times R}{P + R}$$

Approach Adopted for Implementation

In this section, we explain the different methods we used in Matlab, to implement the three different models.

Decision Tree (fitctree)

For this phase the default function provided by Matlab was used. Matlab by default sets *PredictorSelection* as *allsplits* by default, and we use this version of decision tree to classify the data. Once the training is complete, the test data is loaded, and the model returns the predicted labels, which are used for the computation of the accuracy metrics.

Support Vector Machine (fitcsvm)

We experimented with three types of kernels: linear, polynomial kernels and RBF kernel. Linear and polynomial kernels didn't perform well for any accuracy measures used, i.e., Precision, Recall and F1 Score. Clearly the gestures are not separable. We found out that the RBF kernel gave us the best results in terms of all the measures we calculate. Hence, we used the RBF kernel.

Neural Network (Neural Network Toolbox)

We used the feedforwardnet implementation provided by Matlab. The network is created using the feedforwardnet() function and the number of hidden layers is set to 15. To train the data, we use the randomly sampled input and the training data labels. We used the net() function and the test data to obtain the predicted results. If the predicted score is less than or equal to 0.5, it is classified as the negative class(0) and for values greater than 0.5, the test sample would be classified as the positive class(1).

Implementation - User Dependent Analysis

Based on our preprocessing analysis of each group's data, we concluded that the data collected by the groups - DM05, DM11, DM16, DM20, DM22, DM24, DM26, DM28, DM32 and DM36 best suited our requirements under the given constraints. For each of the aforementioned groups' sensor data, we combined all the data for all gestures and constructed gesture specific input by labelling a given gesture as 1 and remaining nine as 0. We then randomly selected 60% (random sampling) of the data for training and the remaining 40% was used for testing to report the accuracy metrics such as Precision, Recall and F1 score for each of the three models, which are Decision Trees (fitctree), SVM (fitcsvm) and Neural Network (Neural Network Toolbox).

Results

The following table shows our results for Precision, Recall and F1 score for all the gestures across all users' data:

Group Data	Gesture	Classifier	Precision	Recall	F1 Score
DM 05	About	Decision Tree	0.85714	0.75	0.8
		Support Vector Machine	1	0.875	0.93333
		Neural Network	1	1	1
	And	Decision Tree	0.375	0.375	0.375
		Support Vector Machine	NaN	0	NaN
		Neural Network	0	0	NaN
	Can	Decision Tree	1	1	1
		Support Vector Machine	1	1	1
		Neural Network	0.8	1	0.88889
	Cop	Decision Tree	0.66667	0.54545	0.6
		Support Vector Machine	0.75	0.27273	0.4
		Neural Network	NaN	0	NaN
	Deaf	Decision Tree	1	0.54545	0.70588
		Support Vector Machine	1	0.36364	0.53333
		Neural Network	NaN	0	NaN
	Decide	Decision Tree	0.66667	0.22222	0.33333
		Support Vector Machine	1	0.66667	0.8
		Neural Network	0.71429	0.55556	0.625
	Father	Decision Tree	0.5	0.83333	0.625
		Support Vector Machine	0.75	0.5	0.6
		Neural Network	0.3	0.5	0.375
	Go Out	Decision Tree	1	0.44444	0.61538
		Support Vector Machine	0.8	0.44444	0.57143
		Neural Network	0	0	NaN
	Find	Decision Tree	0.77778	0.77778	0.77778

		Support Vector Machine	0.77778	0.77778	0.77778
		Neural Network	0.69231	1	0.81818
	Hearing	Decision Tree	0.66667	1	0.8
		Support Vector Machine	0.8	0.66667	0.72727
		Neural Network	0.5	1	0.66667
DM 11	About	Decision Tree	1	0.375	0.54545
		Support Vector Machine	NaN	0	NaN
		Neural Network	NaN	0	NaN
	And	Decision Tree	0.85714	1	0.92308
		Support Vector Machine	1	1	1
		Neural Network	1	0.66667	0.8
	Can	Decision Tree	0.57143	0.44444	0.5
		Support Vector Machine	0.5	0.11111	0.18182
		Neural Network	0.33333	0.22222	0.26667
	Cop	Decision Tree	0.090909	0.14286	0.11111
		Support Vector Machine	NaN	0	NaN
		Neural Network	NaN	0	NaN
	Deaf	Decision Tree	0.375	0.42857	0.4
		Support Vector Machine	0.66667	0.28571	0.4
		Neural Network	0.33333	0.57143	0.42105
	Decide	Decision Tree	0.75	0.66667	0.70588
		Support Vector Machine	1	0.11111	0.2
		Neural Network	0.7	0.77778	0.73684
	Father	Decision Tree	0.2	0.2	0.2
		Support Vector Machine	1	0.2	0.33333
		Neural Network	1	0.4	0.57143
	Go Out	Decision Tree	NaN	0	NaN
		Support Vector Machine	NaN	0	NaN
		Neural Network	0	0	NaN
	Find	Decision Tree	0.27273	0.5	0.35294
		Support Vector Machine	0.5	0.16667	0.25
		Neural Network	0.4	0.33333	0.36364
	Hearing	Decision Tree	0.5	0.6	0.54545
		Support Vector Machine	NaN	0	NaN
		Neural Network	0.5	0.6	0.54545
DM 16	About	Decision Tree	0.92308	1	0.96
		Support Vector Machine	1	0.83333	0.90909
		Neural Network	0.91667	0.91667	0.91667
	And	Decision Tree	0.57143	0.57143	0.57143
		Support Vector Machine	0.75	0.42857	0.54545
		Neural Network	0.57143	0.57143	0.57143
	Can	Decision Tree	0.81818	0.69231	0.75
		Support Vector Machine	0.875	0.53846	0.66667
		Neural Network	0.88889	0.61538	0.72727

	Cop	Decision Tree	0	0	NaN
		Support Vector Machine	0	0	NaN
		Neural Network	0.44444	0.66667	0.53333
	Deaf	Decision Tree	0.5	0.57143	0.53333
		Support Vector Machine	0.5	0.28571	0.36364
		Neural Network	0.6	0.42857	0.5
	Decide	Decision Tree	0.38889	0.875	0.53846
		Support Vector Machine	0.8	0.5	0.61538
		Neural Network	0.4	0.5	0.44444
	Father	Decision Tree	0.88889	0.8	0.84211
		Support Vector Machine	0.5	0.1	0.16667
		Neural Network	0.7	0.7	0.7
	Go Out	Decision Tree	0.71429	0.5	0.58824
		Support Vector Machine	0.875	0.7	0.77778
		Neural Network	1	0.8	0.88889
	Find	Decision Tree	1	0.875	0.93333
		Support Vector Machine	0.875	0.875	0.875
		Neural Network	0.85714	0.75	0.8
	Hearing	Decision Tree	0.57143	0.8	0.66667
		Support Vector Machine	1	0.1	0.18182
		Neural Network	0.4	0.4	0.4
DM 20	About	Decision Tree	1	0.75	0.85714
		Support Vector Machine	1	0.75	0.85714
		Neural Network	0.63636	0.875	0.73684
	And	Decision Tree	1	1	1
		Support Vector Machine	1	1	1
		Neural Network	1	1	1
	Can	Decision Tree	0.5	0.33333	0.4
		Support Vector Machine	1	0.83333	0.90909
		Neural Network	0.81818	0.75	0.78261
	Cop	Decision Tree	0.14286	0.25	0.18182
		Support Vector Machine	0.4	0.5	0.44444
		Neural Network	NaN	0	NaN
	Deaf	Decision Tree	0.75	1	0.85714
		Support Vector Machine	1	1	1
		Neural Network	0.6	0.5	0.54545
	Decide	Decision Tree	0.66667	0.5	0.57143
		Support Vector Machine	0.77778	0.875	0.82353
		Neural Network	0.63636	0.875	0.73684
	Father	Decision Tree	0.66667	0.57143	0.61538
		Support Vector Machine	0.75	0.42857	0.54545
		Neural Network	0.57143	0.57143	0.57143
	Go Out	Decision Tree	0.63636	0.7	0.66667
		Support Vector Machine	1	0.6	0.75

		Neural Network	NaN	0	NaN
	Find	Decision Tree	0.625	0.83333	0.71429
		Support Vector Machine	NaN	0	NaN
		Neural Network	0.75	0.5	0.6
	Hearing	Decision Tree	0.83333	1	0.90909
		Support Vector Machine	0.90909	1	0.95238
		Neural Network	0	0	NaN
DM 22	About	Decision Tree	0.71429	0.625	0.66667
		Support Vector Machine	0.66667	0.5	0.57143
		Neural Network	0	0	NaN
	And	Decision Tree	1	0.375	0.54545
		Support Vector Machine	1	0.25	0.4
		Neural Network	0.44444	0.5	0.47059
	Can	Decision Tree	0.58333	0.77778	0.66667
		Support Vector Machine	1	0.55556	0.71429
		Neural Network	1	0.55556	0.71429
	Cop	Decision Tree	1	0.44444	0.61538
		Support Vector Machine	1	0.33333	0.5
		Neural Network	0.85714	0.66667	0.75
	Deaf	Decision Tree	1	0.66667	0.8
		Support Vector Machine	1	0.5	0.66667
		Neural Network	0.85714	1	0.92308
	Decide	Decision Tree	0	0	NaN
		Support Vector Machine	NaN	0	NaN
		Neural Network	1	0.16667	0.28571
	Father	Decision Tree	0.16667	0.2	0.18182
		Support Vector Machine	1	0.1	0.18182
		Neural Network	0.71429	1	0.83333
	Go Out	Decision Tree	0	0	NaN
		Support Vector Machine	NaN	0	NaN
		Neural Network	NaN	0	NaN
	Find	Decision Tree	0.66667	0.66667	0.66667
		Support Vector Machine	1	0.16667	0.28571
		Neural Network	1	0.33333	0.5
	Hearing	Decision Tree	0.71429	0.5	0.58824
		Support Vector Machine	1	0.1	0.18182
		Neural Network	1	0.2	0.33333
DM 24	About	Decision Tree	0.875	0.7	0.77778
		Support Vector Machine	1	0.9	0.94737
		Neural Network	1	1	1
	And	Decision Tree	0.61538	0.72727	0.66667
		Support Vector Machine	0.85714	0.54545	0.66667
		Neural Network	0.64286	0.81818	0.72
	Can	Decision Tree	1	0.6	0.75

		Support Vector Machine	1	0.9	0.94737
		Neural Network	1	0.9	0.94737
	Cop	Decision Tree	0.625	0.71429	0.66667
		Support Vector Machine	0.83333	0.71429	0.76923
		Neural Network	0.85714	0.85714	0.85714
	Deaf	Decision Tree	1	0.85714	0.92308
		Support Vector Machine	1	0.85714	0.92308
		Neural Network	1	0.85714	0.92308
	Decide	Decision Tree	1	1	1
		Support Vector Machine	1	1	1
		Neural Network	1	1	1
	Father	Decision Tree	0.7	1	0.82353
		Support Vector Machine	0.77778	1	0.875
		Neural Network	0.58333	1	0.73684
	Go Out	Decision Tree	0.66667	0.75	0.70588
		Support Vector Machine	1	0.625	0.76923
		Neural Network	0.33333	0.25	0.28571
	Find	Decision Tree	1	1	1
		Support Vector Machine	1	1	1
		Neural Network	1	1	1
	Hearing	Decision Tree	0.8	0.88889	0.84211
		Support Vector Machine	1	0.88889	0.94118
		Neural Network	0.9	1	0.94737
DM 26	About	Decision Tree	1	0.77778	0.875
		Support Vector Machine	1	0.77778	0.875
		Neural Network	0.72727	0.88889	0.8
	And	Decision Tree	0.83333	1	0.90909
		Support Vector Machine	0.83333	0.5	0.625
		Neural Network	0.83333	1	0.90909
	Can	Decision Tree	0.4	0.44444	0.42105
		Support Vector Machine	1	0.11111	0.2
		Neural Network	0.7	0.77778	0.73684
	Cop	Decision Tree	0.5	0.33333	0.4
		Support Vector Machine	NaN	0	NaN
		Neural Network	0.33333	0.33333	0.33333
	Deaf	Decision Tree	0.5	0.28571	0.36364
		Support Vector Machine	NaN	0	NaN
		Neural Network	0	0	NaN
	Decide	Decision Tree	0.23077	0.42857	0.3
		Support Vector Machine	1	0.14286	0.25
		Neural Network	0.33333	0.42857	0.375
	Father	Decision Tree	0.33333	0.33333	0.33333
		Support Vector Machine	1	0.16667	0.28571
		Neural Network	0.33333	0.16667	0.22222

	Go Out	Decision Tree	0.33333	0.5	0.4
		Support Vector Machine	NaN	0	NaN
		Neural Network	1	0.5	0.66667
	Find	Decision Tree	1	0.5	0.66667
		Support Vector Machine	1	0.5	0.66667
		Neural Network	0.8	0.66667	0.72727
	Hearing	Decision Tree	0.25	0.33333	0.28571
		Support Vector Machine	NaN	0	NaN
		Neural Network	0.33333	0.16667	0.22222
DM 28	About	Decision Tree	1	0.83333	0.90909
		Support Vector Machine	1	0.83333	0.90909
		Neural Network	1	0.83333	0.90909
	And	Decision Tree	1	0.72727	0.84211
		Support Vector Machine	1	0.72727	0.84211
		Neural Network	1	0.72727	0.84211
	Can	Decision Tree	0.9	1	0.94737
		Support Vector Machine	1	1	1
		Neural Network	0.81818	1	0.9
	Cop	Decision Tree	0.58333	1	0.73684
		Support Vector Machine	0.83333	0.71429	0.76923
		Neural Network	0.29412	0.71429	0.41667
	Deaf	Decision Tree	0.71429	0.625	0.66667
		Support Vector Machine	1	0.625	0.76923
		Neural Network	NaN	0	NaN
	Decide	Decision Tree	1	1	1
		Support Vector Machine	1	1	1
		Neural Network	0.83333	0.83333	0.83333
	Father	Decision Tree	0.76471	1	0.86667
		Support Vector Machine	1	0.69231	0.81818
		Neural Network	0.86667	1	0.92857
	Go Out	Decision Tree	0.25	0.14286	0.18182
		Support Vector Machine	1	0.42857	0.6
		Neural Network	0.57143	0.57143	0.57143
	Find	Decision Tree	1	0.85714	0.92308
		Support Vector Machine	1	1	1
		Neural Network	1	1	1
	Hearing	Decision Tree	0.5	0.42857	0.46154
		Support Vector Machine	1	0.57143	0.72727
		Neural Network	NaN	0	NaN
DM 32	About	Decision Tree	0.5	0.5	0.5
		Support Vector Machine	1	0.5	0.66667
		Neural Network	1	0.5	0.66667
	And	Decision Tree	0.77778	0.7	0.73684
		Support Vector Machine	1	0.2	0.33333

		Neural Network	0.66667	0.2	0.30769
	Can	Decision Tree	0.73333	0.91667	0.81481
		Support Vector Machine	1	0.58333	0.73684
		Neural Network	0.9	0.75	0.81818
	Cop	Decision Tree	0.8	1	0.88889
		Support Vector Machine	1	1	1
		Neural Network	0.8	1	0.88889
	Deaf	Decision Tree	0.5	0.44444	0.47059
		Support Vector Machine	1	1	1
		Neural Network	0.9	1	0.94737
	Decide	Decision Tree	0.4	0.66667	0.5
		Support Vector Machine	1	0.66667	0.8
		Neural Network	0.5	0.66667	0.57143
	Father	Decision Tree	0.88889	1	0.94118
		Support Vector Machine	0.85714	0.75	0.8
		Neural Network	0.77778	0.875	0.82353
	Go Out	Decision Tree	0.5	0.375	0.42857
		Support Vector Machine	1	0.875	0.93333
		Neural Network	1	0.75	0.85714
	Find	Decision Tree	1	1	1
		Support Vector Machine	1	0.875	0.93333
		Neural Network	0.8	1	0.88889
	Hearing	Decision Tree	0.625	0.71429	0.66667
		Support Vector Machine	0.71429	0.71429	0.71429
		Neural Network	0.53846	1	0.7
DM 36	About	Decision Tree	1	0.57143	0.72727
		Support Vector Machine	1	0.71429	0.83333
		Neural Network	1	0.85714	0.92308
	And	Decision Tree	0.47059	0.88889	0.61538
		Support Vector Machine	1	0.77778	0.875
		Neural Network	0.63636	0.77778	0.7
	Can	Decision Tree	0.66667	0.8	0.72727
		Support Vector Machine	0.66667	0.8	0.72727
		Neural Network	1	0.8	0.88889
	Cop	Decision Tree	1	1	1
		Support Vector Machine	1	0.77778	0.875
		Neural Network	0.77778	0.77778	0.77778
	Deaf	Decision Tree	0.63636	1	0.77778
		Support Vector Machine	1	1	1
		Neural Network	NaN	0	NaN
	Decide	Decision Tree	0.875	0.875	0.875
		Support Vector Machine	1	0.875	0.93333
		Neural Network	0.72727	1	0.84211
	Father	Decision Tree	1	1	1

		Support Vector Machine	0.81818	1	0.9
		Neural Network	0.69231	1	0.81818
	Go Out	Decision Tree	1	0.44444	0.61538
		Support Vector Machine	1	0.55556	0.71429
		Neural Network	0.71429	0.55556	0.625
	Find	Decision Tree	1	1	1
		Support Vector Machine	0.83333	1	0.90909
		Neural Network	1	1	1
	Hearing	Decision Tree	1	0.71429	0.83333
		Support Vector Machine	1	0.71429	0.83333
		Neural Network	1	0.71429	0.83333

As seen in the results, some of the records contain NaNs and 0s. This is because for feature extraction we performed user independent analysis and some of these features may not work well with user specific data.

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