CSE 572 Data Mining, Spring 18

Phase Two Report

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Introduction

The aim of this project is to classify ten different gestures for which time series data have been recorded by using Accelerometer, Gyroscope, Orientation and EMG sensors. In this phase of the project, we segment the raw data into ten different classes, apply five feature extraction methods that will clearly distinguish the ten gestures and apply Principal Component Analysis for selecting features that show the best distinction.

Task 1 - Segmentation of raw data into classes

The first task of this phase is to write a MATLAB code that segments the raw sensor data into 10 different classes, each corresponding to a gesture. Each class data is stored in a separate csv file. Each csv file contains sensor data collected by 37 groups that performed 20 actions for each gesture. The data inside a csv file is stored in such a way that each row corresponds to one sensor of an action. For example, in the above.csv file, the first row contains the data for Accelerometer X for the first action performed by the first group.

Following data is a sample taken from above.csv file:

Action 1-ALX 0.943848 0.95166 0.95459 0.95459 0.949707 0.956543 …

Action 1-ALY -0.27979 -0.25244 -0.2627 -0.26465 -0.2627 -0.23633 …

Action 1-ALZ 0.12207 0.12793 0.12207 0.127441 0.116211 0.122559 …

…….

…….

Action 20-OYR 4.507289 4.366444 4.237298 4.133125 4.027725 4.014144 …

In this segmentation, we have eliminated actions that contained any time series data greater than 45 values or less than 35 values and have zero-padded the time series data with values between 35 and 45. Thus we have ensured that every action was recorded over a time period of 3 seconds thus having having a sampling frequency of 15 hertz.

Task 2 - Feature Extraction

In this task, five feature extraction methods that best discriminate the ten gestures are selected. This section contains, for each of the extracted feature, (a) an explanation of the feature extraction performed, (b) intuition behind selecting such a feature, (c) plots to analyze the extraction and followed by (d) a discussion that evaluates our intuition.

Below are the five extraction methods used in this phase:

1. Power Spectral Density (PSD)
2. Fast Fourier Transform (FFT)
3. Variance
4. Discrete Wavelet Transform (DWT)
5. Root Mean Square (RMS)

Fast Fourier Transform

a) The raw data measured in the time domain of 45 seconds is converted into the frequency domain for EMG, Gyroscope and Accelerometer sensors using the in-built *fft* function of MATLAB. Fast Fourier Transform will help to observe the properties of different muscle movements, such as activation and acceleration, that are measured by these sensors in the frequency domain. For each of these sensors, by comparing the plots, we identify the five best sensors that provide interesting results to differentiate the gestures and from each of these five sensors, three maximum amplitude peaks are identified as features. Thus, we arrive at a set of 15 extracted features through this method.

b) The intuition is that the frequency pattern for the amplitude of the signal must vary significantly for different movements of muscles. Applying FFT on the EMG sensor should provide a clear distinction in the amplitude of sampled frequencies clearly indicating the contraction and relaxation of muscles associated for each gesture. Similarly, FFT on the Accelerometer and Gyroscope should distinguish the gestures based on the different linear accelerations and angular momentums associated with every gesture.

For example, the ‘find’ gesture involves more contraction of muscles when compared to the ‘deaf’ gesture that does not require much activation of muscles. Hence, the amplitude in the fft plot for ‘find’ should be much higher than the amplitude of ‘deaf’.

c) The MATLAB code for this extraction can be found in ‘f .m’

d)

e) From the graphs, it can be seen that our intuition holds good. FFT clearly discriminates certain gestures from the rest based on the muscle movements involved. As predicted, plot(1) discriminates ‘find’ from other gestures like ‘deaf’, ‘father based on the contraction involved in the gestures. Similar logic holds good for other plots.

Variance

a) We computed variance for each action on ‘Gyroscope’ and selected the top best six features from the variance across the classes by performing *‘max’* . This differentiated the classes clearly. The graphs for these are shown below.

b) The intuition here is that we expect to see different levels of variances for each of the different gestures. For eg, we expect to see the variance of linear acceleration for the left hand to be negligible for gestures like ‘And’, ‘Father’,’Can’ etc. that do not involve the movement of the left hand. Similarly, we also expect to witness high variance of linear acceleration in both the hands along Y-axis for the gesture - ‘Can’ which has a fast downward movement.

c) The MATLAB code for this extraction can be found in ‘feature_extracted.m’

d)

e) The graphs for variance on ‘Gyroscope’ for each of the class showed different values. For eg: Gestures like ‘decide’,’go-out’ and ‘can’ have high variances as seen from the graph - variance on ‘GLY’, gestures like ‘and’ and ‘hearing’ have high variance on ‘GRZ’. Our intuition above for variance on ‘Gyroscope’ was most accurate which was supported by our plots.

Discrete Wavelet Transform

a) Discrete Wavelet Transform decomposes the time series data into wavelets by passing through high and low pass frequency filters in order to eliminate noise. As DWT accounts for the abrupt changes in the muscle movements, DWT is applied to EMG sensors by using the *dwt* function of MATLAB. Features are extracted by choosing five low order coefficients after eliminating the first four levels that contribute to noise.

b) When DWT is applied to the EMG sensor, we expect to see the frequency components of a signal along with its corresponding temporal location. This idea, we believe, will provide a good distinction between gestures that have different levels of muscle activations at different points in time.

c)

d)

e)

Power Spectral Density

a) Power Spectral Density helps to describe how power of the time series is distributed over frequency. The underlying idea behind this method is to compare the power of different muscle movements involved with each gesture. For this purpose, we use the *psd* function of MATLAB on the EMG sensors in order to differentiate gestures based on the power of muscle activation.

Features are extracted from this method by finding three maximum power peaks for each EMG sensor.

b) This extraction method is based on the expectation that, when DWT is applied to EMG sensors, gestures with different levels of power for muscle activations will be clearly differentiated from each other.

Root Mean Square Value

a) Root mean square provides most probability amplitude approximation in a non tiring contraction. We computed Root Mean Square value for each action using *rms* function in matlab on 'Gyroscope' and selected the top best five features across the gestures by performing *max* function on the rms values. Again most of the classes were differentiated clearly using this extraction method.

b) The intuition is that we expect to see different values for rms energy function for each of the different gestures. For eg: we expect to see high rms values for gestures like - 'decide', 'and', ‘go-out’ etc and similarly lower rms values for gestures like - ‘deaf’,’cop’ etc , clearly discriminating the classes.

c) The MATLAB code for this extraction can be found in ‘feature_extracted.m’.

d)

e) As seen from the graphs, the values of rms clearly differentiated the classes as expected. Features like ‘decide’. ‘go-out’ had high rms values for ‘GLZ,GLY’ etc. Also as expected the rms values for the ‘cop’ and ’and’ were less.

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Electromyography (EMG) Sensors and Signal Processing

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Understanding Wavelets, Part 1: What Are Wavelets