Project Assignment 2 Report

DATA MINING

CSE 572: Spring 2018

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1. Introduction

This project is a part of course requirements for Data Mining (CSE 572) Class Spring 2018. The aim of this project is to develop a computing system that can understand human gestures by using the raw data collected from four different sensors which are the accelerometer, gyroscope, orientation and EMG. The entire data consists of 18 data streams which include ten different gestures from American Sign Language (ASL) and for this project, we ignore the Kinnect data.

2. Team Members

Following are the group members for this project

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Abhinethri Tumkur Umesh (atumkuru@asu.edu)
Jay Patel (jkpatel5@asu.edu)

3. Project Phase 1

The first phase of the project is to collect data. The data has been collected in the IMPACT lab with the help of MYO wearable sensors by each team. A total of 10 gestures were enacted (repeated 20 times) with the data being recorded for every 3 seconds with a frequency of 15 Hz.

4. Project Phase 2

In task 1, data of all the groups are annotated into 10 different files based on the gestures(ABOUT, CAN, AND, DEAF, HEARING, GO OUT, FATHER, FIND, COP and DECIDE.) We have read the sensor values column wise for every instance and transposed to have a time series along the columns and sensor values along the rows.

Below is the snippet from Annotation. m:

```
for n=1:numOfElements-1  % sensors
        if (folder==1 && k==1 && n==1)
        flag=0;
```

```
        dlmwrite(strcat('.\op_task1\',output{1,gesture}),(dataArray{1,n})');
        else
        dlmwrite(strcat('.\op_task1\',output{1,gesture}),(dataArray{1,n})','-append');

        end
  end
```

5. Project Phase 3

In phase 3, we have performed the feature extraction and the feature selection tasks. The raw data after annotation from phase 2 forms the input for this phase. Below are the tasks which are performed in phase 3 of this project.

5.1 Task 1: Intuitions

Before making intuitions, it was important to have a clear idea of what information would be captured by each of the sensors.

Accelerometer

- The acceleration force along three different axes X, Y and Z are captured and measured in m/s2 (also includes gravity).
- The reference of this sensor data in the report would be with the use of abbreviations ALX, ALY, ALZ, ARX, ARY and ARZ.
- The first letter signifies that the data corresponds to Accelerometer sensor, second letter signifies the data captured that of Right hand or the Left hand and the third letter captures the acceleration along a different axis.

Gyroscope

- Rate of rotation around three different axes X, Y and Z are captured and measure in rad/sec.
- The reference of this sensor data in the report would be with the use of abbreviations GLX, GLY, GLZ, GRX, GRY and GRZ.
- The first letter signifies that the data corresponds to Gyroscope sensor, second letter signifies the data captured that of Right hand or the Left hand and the third letter captures the rate of rotation around different axis.

Orientation

- The orientation along different axes is captured as: Azimuth angle (angle around Z-axis), Pitch (angle around the X-axis), Roll (angle around the Y-axis) and measured in degrees.
- The reference of this sensor data in the report would be with the use of abbreviations OPL, OPR, ORL, ORR, OYL and OYR.
- The first letter signifies that the data corresponds to Orientation sensor, the second letter signifies the orientation along corresponding axis as mentioned above and the third letter signifies the data captured that of Right hand or the Left hand.

EMG

- Captures the movement/activity of the muscles (electrophysical data) in real-time and this data is measured along 8-different axes (8-axis EMG).
- The reference of this sensor data in the report would be with the use of abbreviations EMG0L, EMG0R, EMG1L, EMG1R, EMG2L, EMG2R, EMG3L, EMG3R, EMG3L, EMG3R, EMG3L, EMG3R, EMG3L, EMG3R, EMG3L, EMG3R, EMG3L, EMG3R.
- The first three letters signifies that the data corresponds to EMG sensor, the fourth letter signifies the muscle movement along corresponding axis as mentioned above and the third letter signifies the data captured that of Right hand or the Left hand.

After having a clear idea of what data was captured by each sensor, we were ready to discover patterns between the actions showing clear distinction between them.

ABOUT, DECIDE and CAN

Out of all the ten actions, ABOUT, DECIDE and CAN actions are significant because they involve movement of the left hands. This is clearly shown in the Figures [1-3] where we can see that the magnitude of ALZ is very much higher these actions compared to others. The magnitude of ALZ for the remaining actions is no greater than 0.3.

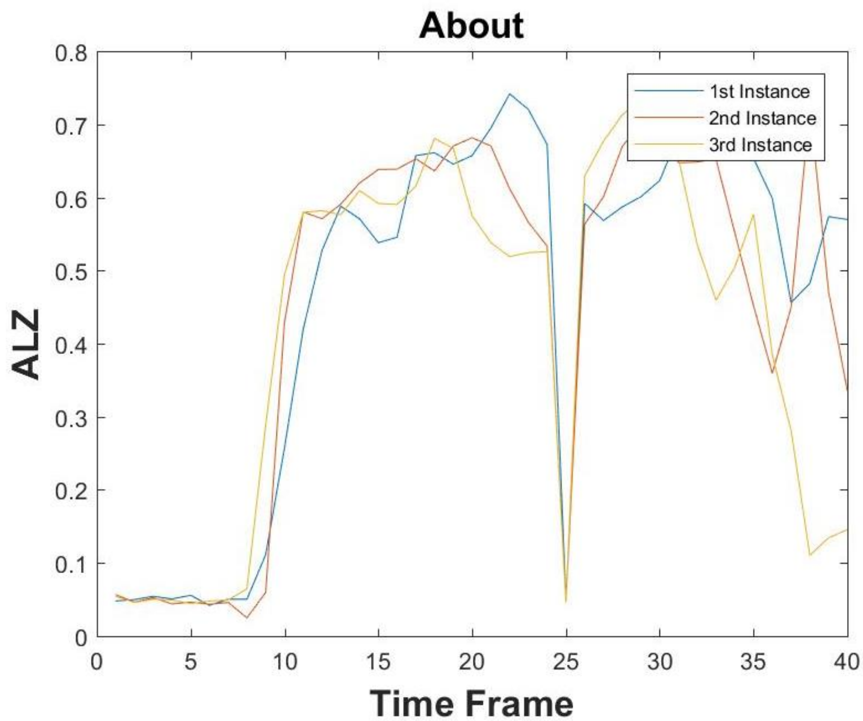


Figure 1: ALZ of About in time

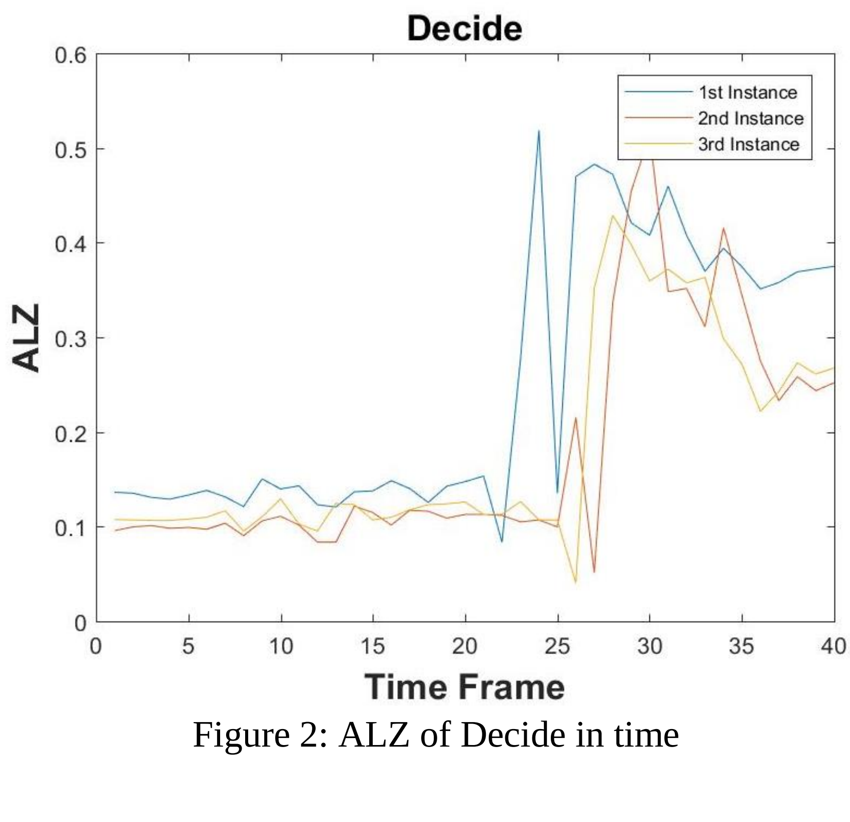


Figure 2: ALZ of Decide in time

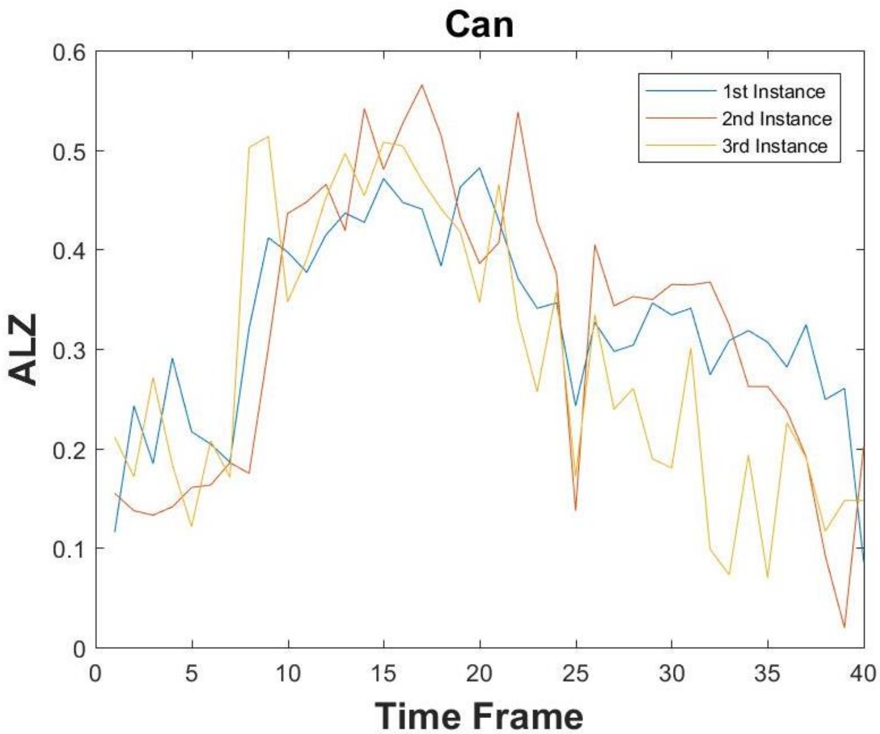


Figure 3: ALZ of Can in time

ABOUT and CAN

For ABOUT, we are well aware of the fact that the left hand stays stable, without any movement and right hand rotates around it. So when the actions ABOUT and CAN are compared, we have found that the magnitude of GLX for ABOUT is always less than that of CAN as shown in Figure[4-5].

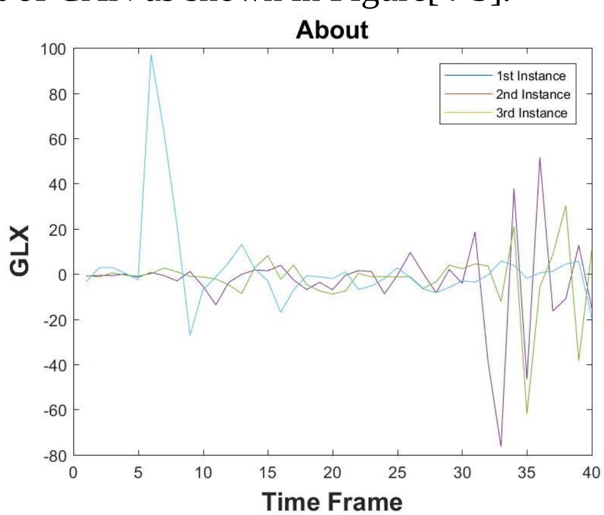


Figure 4: GLX of About in time

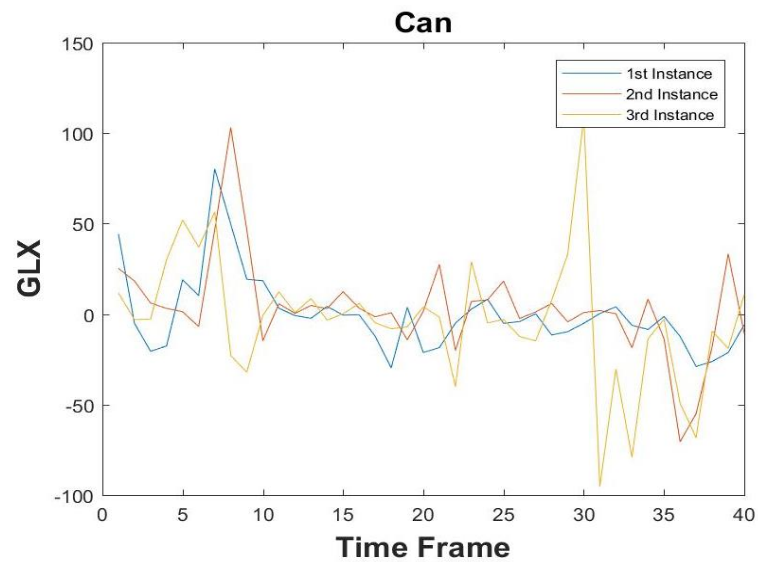
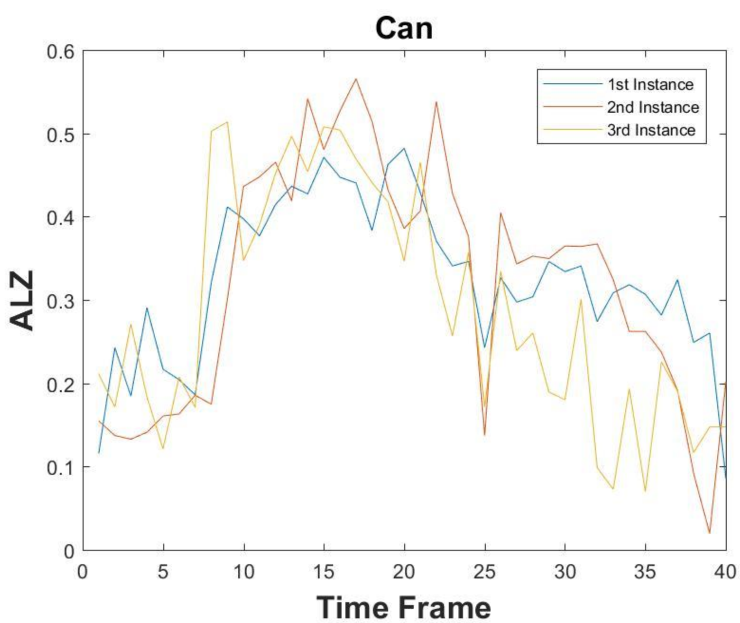
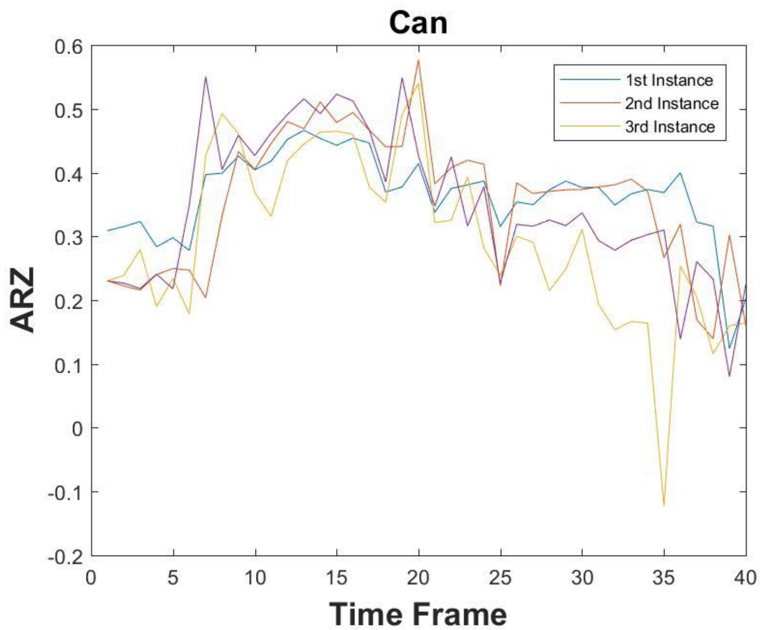


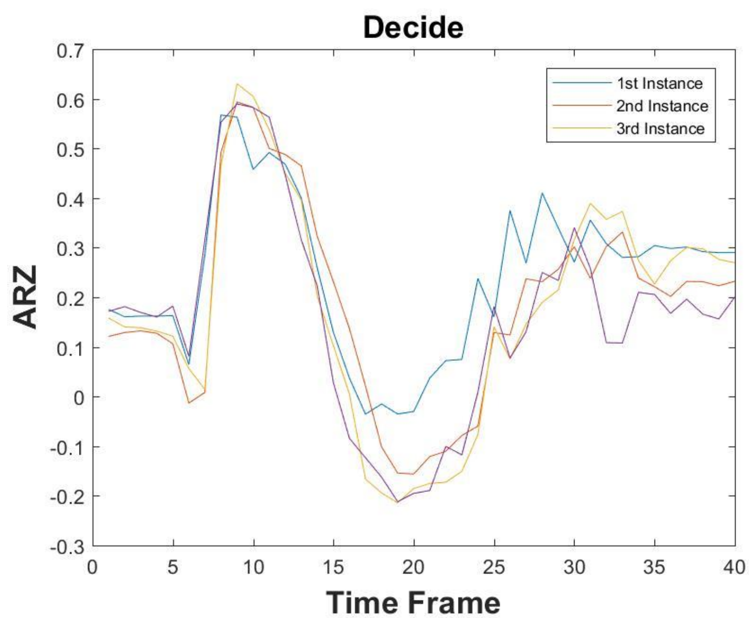
Figure 5: GLX of Can in time

CAN and DECIDE

These two actions can be differentiated using both ALZ and ARZ. The ALZ and ARZ patterns of CAN are very similar when compared to that of DECIDE, which are different. CAN is the only action with same movement in right and left hand.This can help us differentiate CAN from DECIDE as shown in Figure 6.




Can
1st Instance
2nd Instance
3rd Instance
ARZ
Time Frame


Decide
1st Instance
2nd Instance
3rd Instance
ARZ
Time Frame

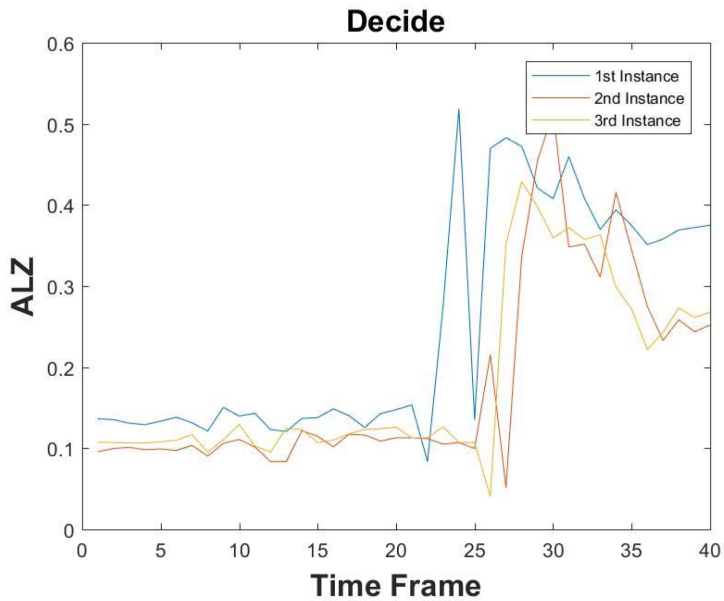


Figure 6: ALZ and ARZ of Can and Decide in time

HEARING

This action imitates brushing of a person's teeth and since brushing involves repetitive and cyclic patterns, these kind of patterns are recorded with OYR which resembles a sine wave pattern as shown in the Figure 7.

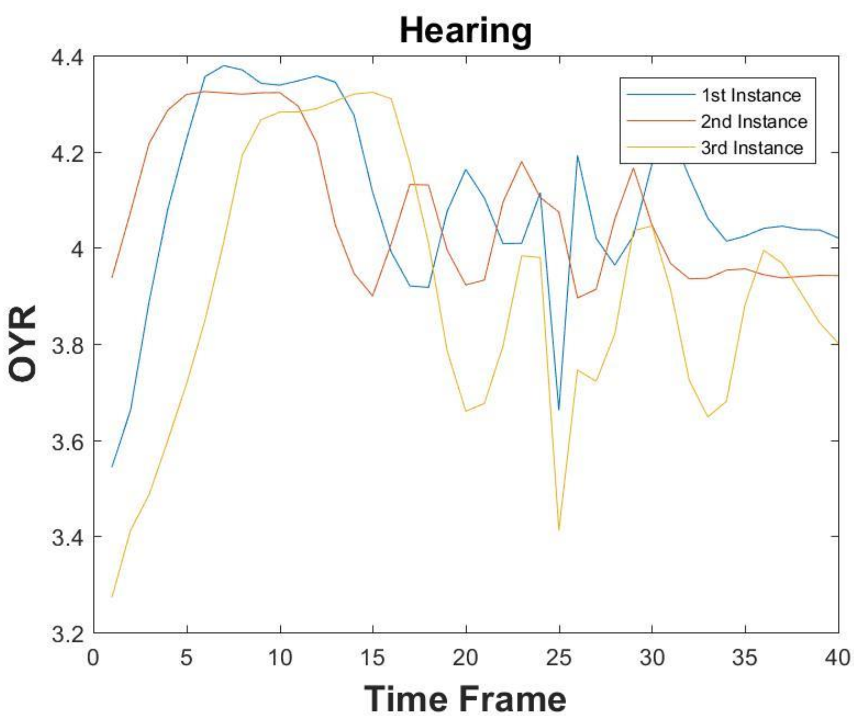


Figure 7: OYR of Hearing in time

COP and FATHER

These actions can be compared to have the same kind of pattern with respect to OPR as shown in Figure 8, which signifies the same orientation in the direction of pitch for these actions because both the actions involve tapping two times on the body with the person’s right hand. Another significance is that the magnitude of OPR for FATHER is always greater than that of COP as shown in Figure 8.
We can also differentiate these two actions using ORR. The maximum value of father in ORR is greater than that of COP. However, the value is greater when compared to all other actions since FATHER is the only action where the right hand goes over to the top of the person’s body so as to perform the corresponding ASL gesture.

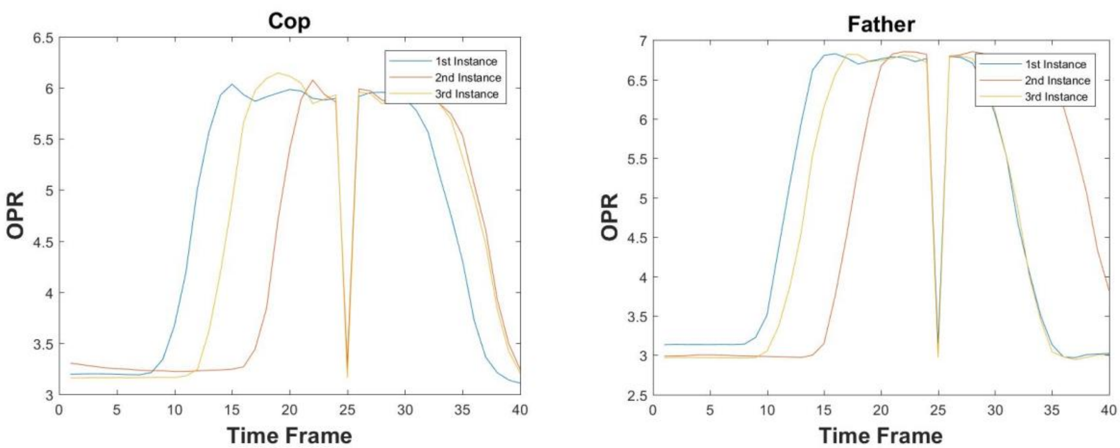


Figure 8: OPR of Cop and Father in time

FIND

We can differentiate FIND from all other gestures when we look at OYR. The magnitude of the difference between the maximum and the minimum of OYR is very less when compared to that of the other actions as shown in Figure 9. This is because of the fact that FIND has very low orientation in that particular direction when compared to other gestures.

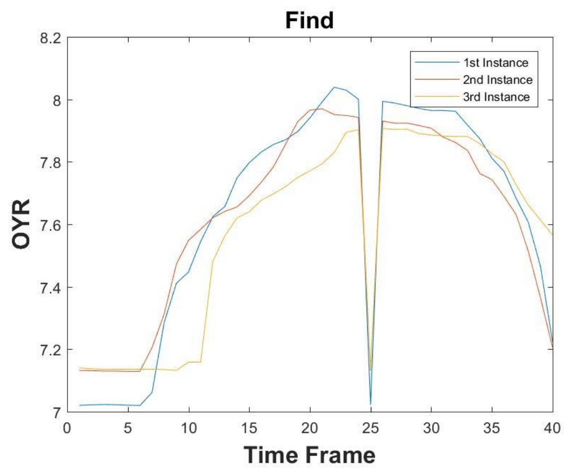


Figure 9: OYR of Find in time

DEAF

We can distinguish DEAF from other gestures using OPR since we can find the same pattern with respect to DEAF in OPR as shown in Figure 10. This depicts the orientation along the pitch.

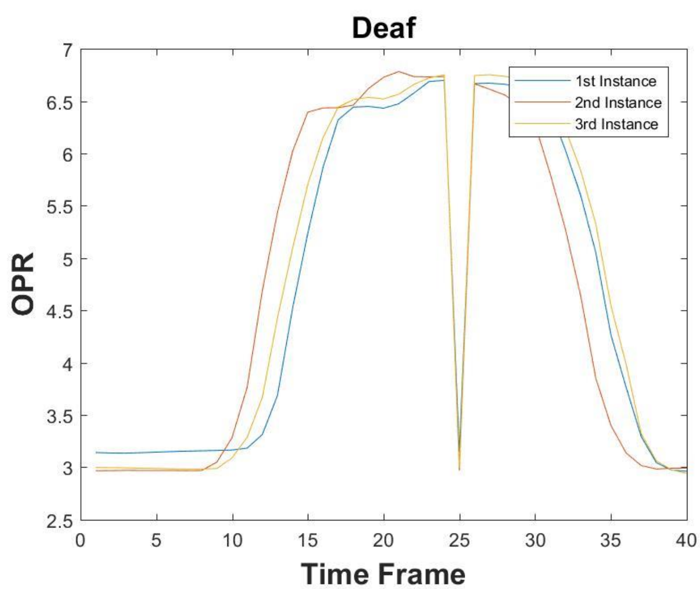


Figure 10: OPR of Deaf in time

AND

We can distinguish AND from other gestures using OYR since AND always shows a clear depiction of the same kind of pattern as shown in Figure 11, even though there exists some scaling factor in terms of magnitude.

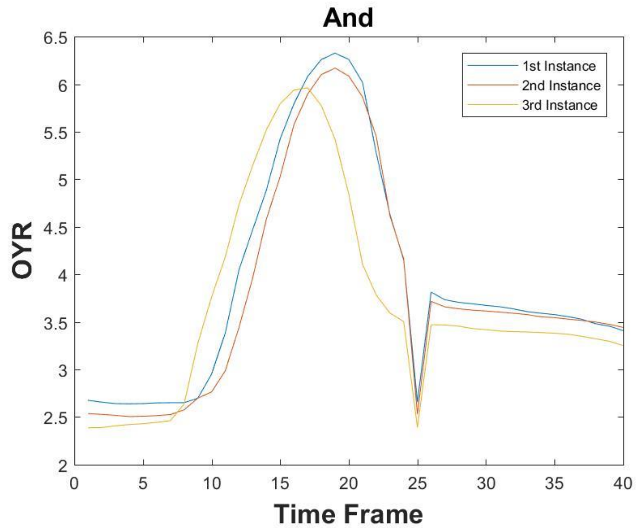


Figure 11: OYR of And in time

GO OUT

We can distinguish GO OUT from other gestures using OPR since an elephant back pattern is always observed as shown in Figure 12

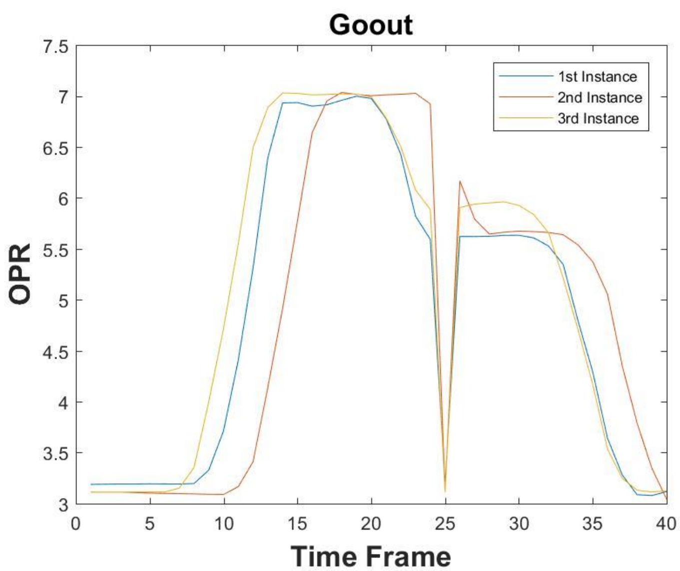


Figure 12: OPR of Go out in time

5.2 Task 2 : Feature Extraction

For this task, the following feature extraction methods were selected. The explanation, intuition, analysis and discussion for each method is contained in this section.

Ignoring the groups with incorrect data - Before extracting the features, we have ignored some group's data to be considered for further steps as they turned out to be noisy due to the following reasons:

1. Exchange of sensor bands (right and left hand)
2. Very less number of repetitions (<15)
3. Greater number of instances due to incorrect sensor calibration
4. Incorrect file names

a) write an explanation on how the feature is extracted.

Feature we would be extracting are listed below:

1. Max of ALZ - The maximum value among set of ALZ values
2. Max of ARZ - The maximum value among set of ARZ values
3. Standard Deviation of GLX - The amount of deviation for the set of GLX sensor values
4. FFT of OPR - Transfers the signal into frequency components.
5. Variance of OPR - Indicates how the OPR values (data) have been spread out.
6. FFT of variance of OYR - Calculate the variance for OYR and then apply FFT to find the frequency components having high values

b) Write an intuition on why you use such a feature

1. Max of ALZ - To extract the maximum values of the gestures using left hand (which are CAN, DECIDE, ABOUT only).
2. Max of ARZ - To differentiate between CAN and other gestures using left hand (DECIDE & ABOUT) as only CAN has symmetric left and right movements.
3. Standard Deviation of GLX - To differentiate between rate of rotation(angular velocity) between different actions.

4. FFT of OPR - To find the similarity in the orientation in terms of pitch for actions FATHER, DEAF and COP.
5. Variance of OPR - To extract gestures having less variance in pitch (FATHER and COP- nearly constant between 15th and 35th time instance).
6. FFT of variance of OYR - For identifying the gesture having specific pattern (HEARING - repeated circular motion).

e) Discuss whether your initial intuition about the features that you selected holds true or not.

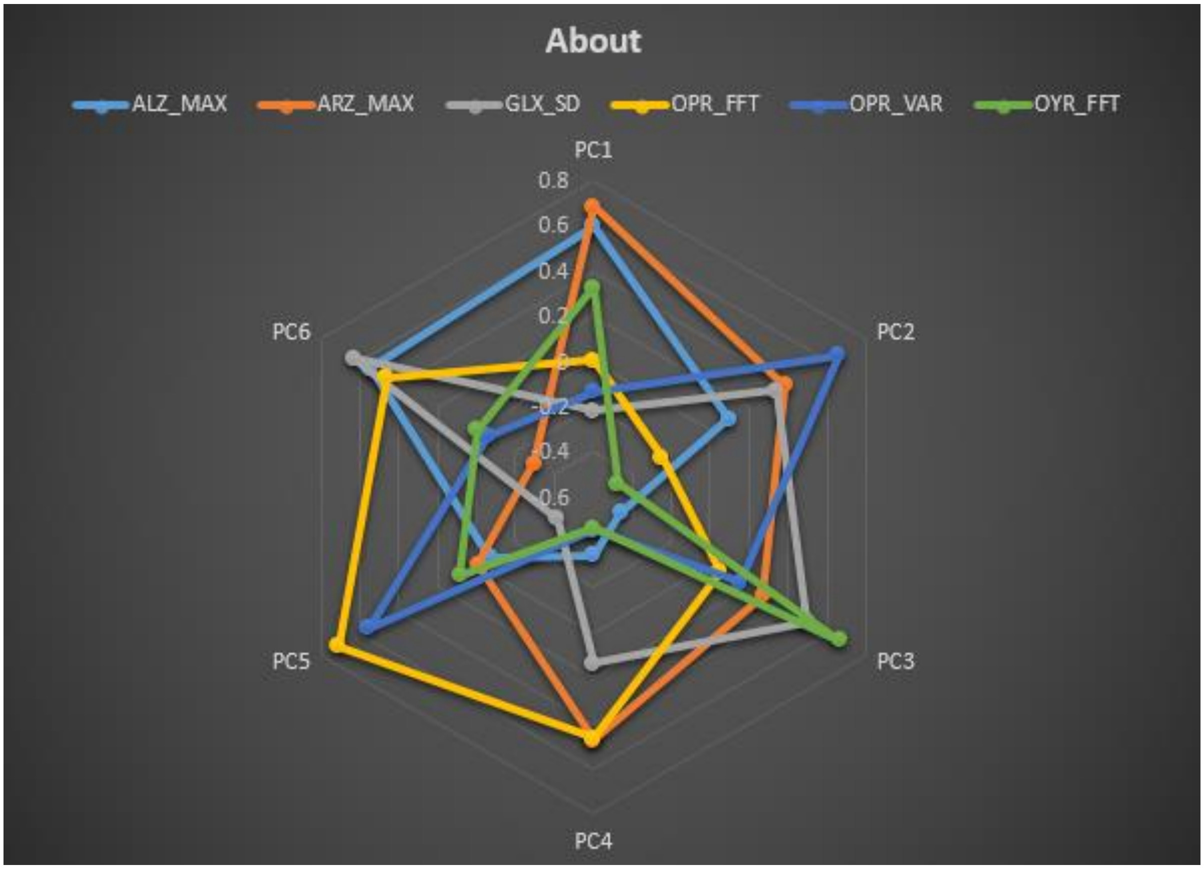
Initially we were thinking of using the features like mean and median for clear distinction between actions. But when we plotted the graphs, the graphs did not seem like good features to achieve clear distinction between all the actions. But after exploring through different features plotted against the data, we were able to come up with a good set of features which clearly distinguishes different actions from each other as mentioned above in the report.

<u>6. Project Phase 4 - Principal Component Analysis</u>

In this task, we analyze the feature extraction methods we picked in Task 2 and identify which features are responsible for the highest variance in the data set, according to the Principal Component Analysis (PCA).

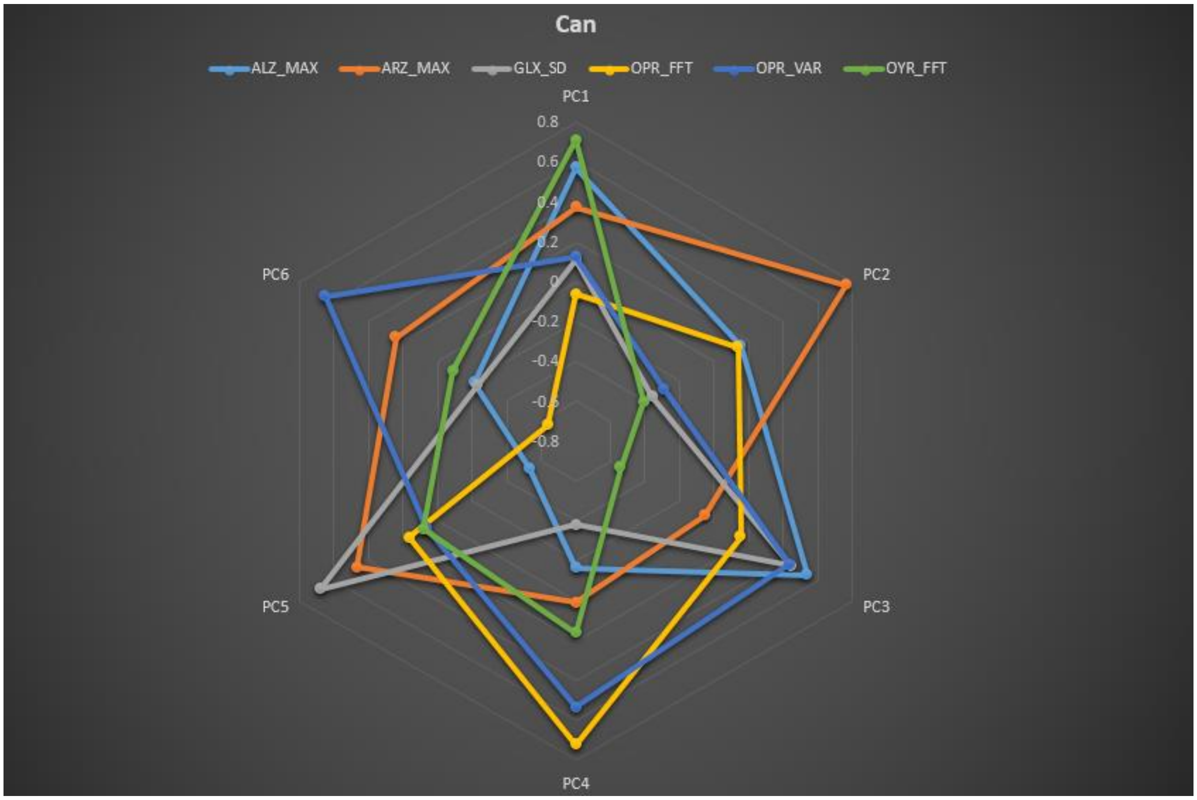
Subtask 3: Making sense of PCA Eigenvectors
Below is the discussion of the eigen vectors with respect to the spider plots for each gesture.

ABOUT



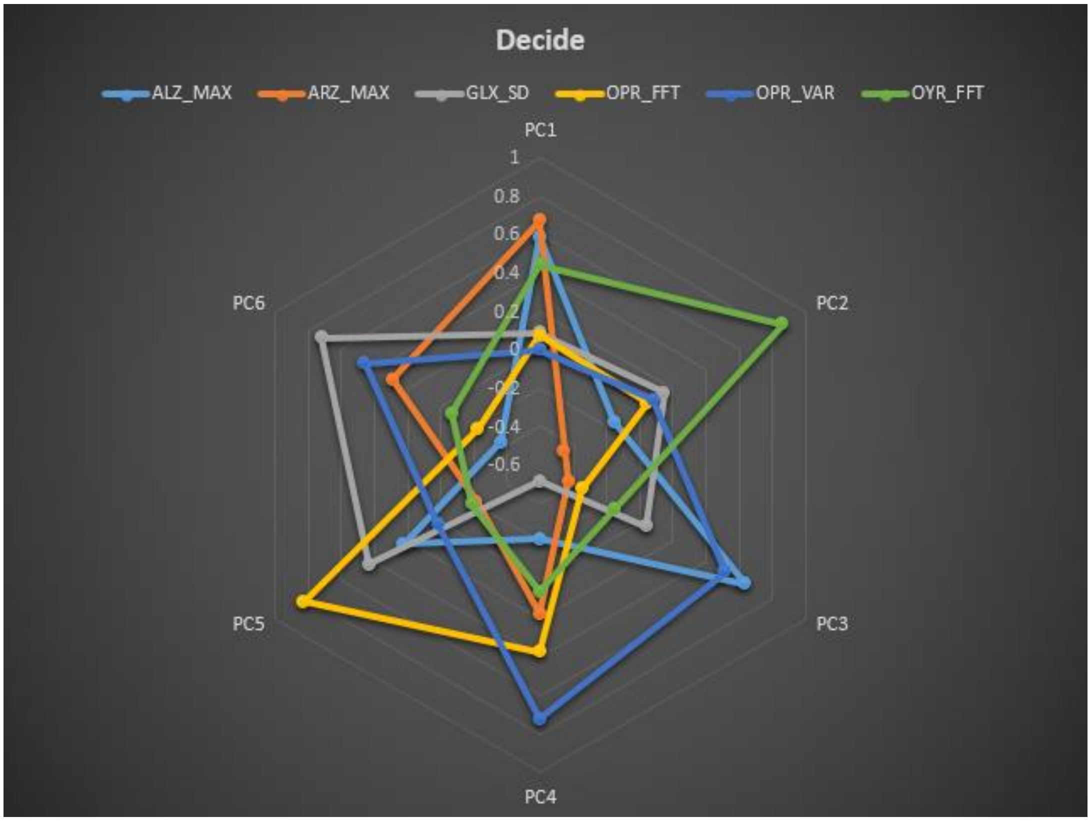
- ARZ_max has the higher contribution towards PCA1 because there is good movement in the direction of Z axis.
- ALZ_max has a greater coefficient because ABOUT is one of the gestures (others being CAN and DECIDE) where the left hand is active.
- Since the right hand has a rotatory motion, there is a considerable change in the Yaw and Pitch (OYR and OPR) making it a better feature.
- GLX_SD contributes the least as the left hand is quite stable for most actions.

CAN



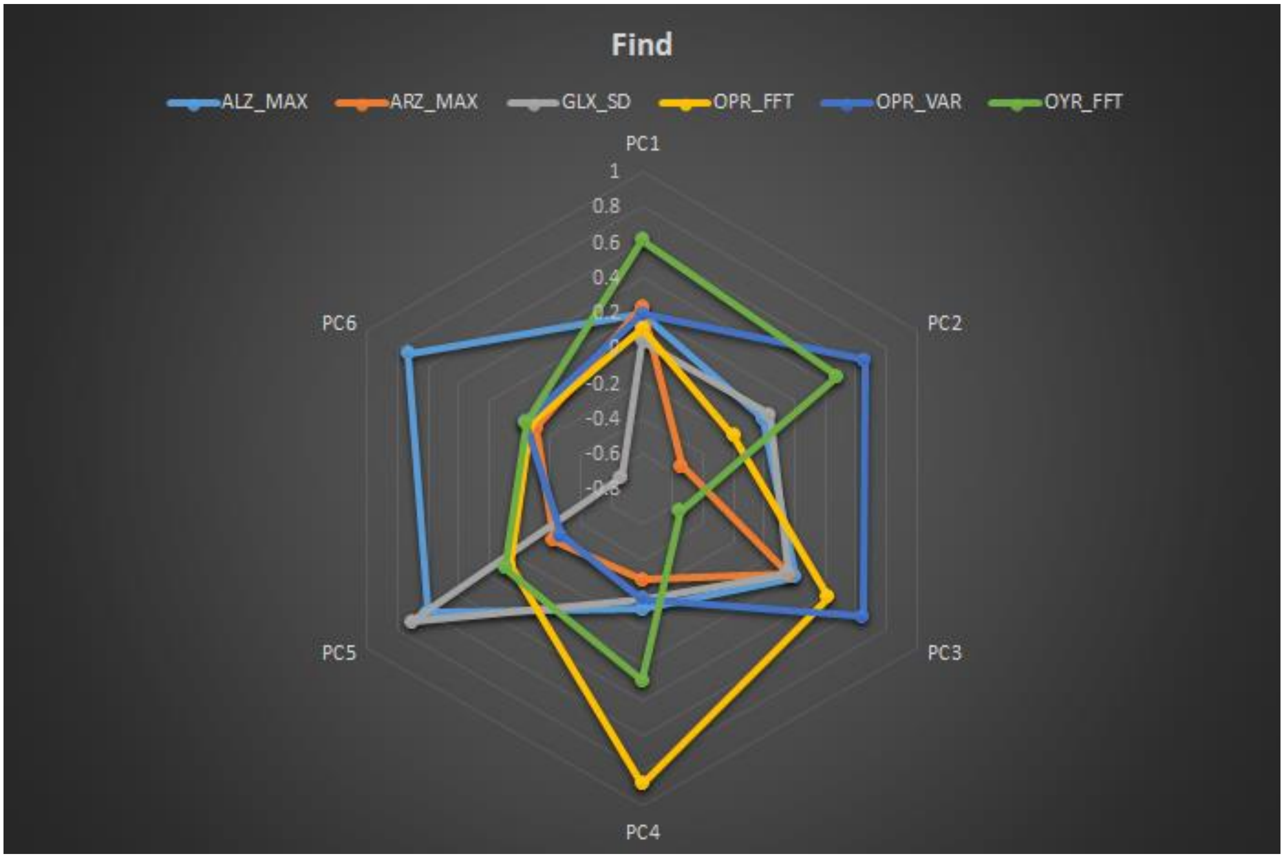
- Here ALZ and ARZ contribute the most because CAN is the only gesture where left and right hand have the similar actions
- OYR_FFT has a good coefficient because there is a considerable movement in the Yaw direction (change in sensor orientation).
- OPR_FFT has least contribution because there is no movement in the direction of Pitch similar to most of the gestures.

DECIDE



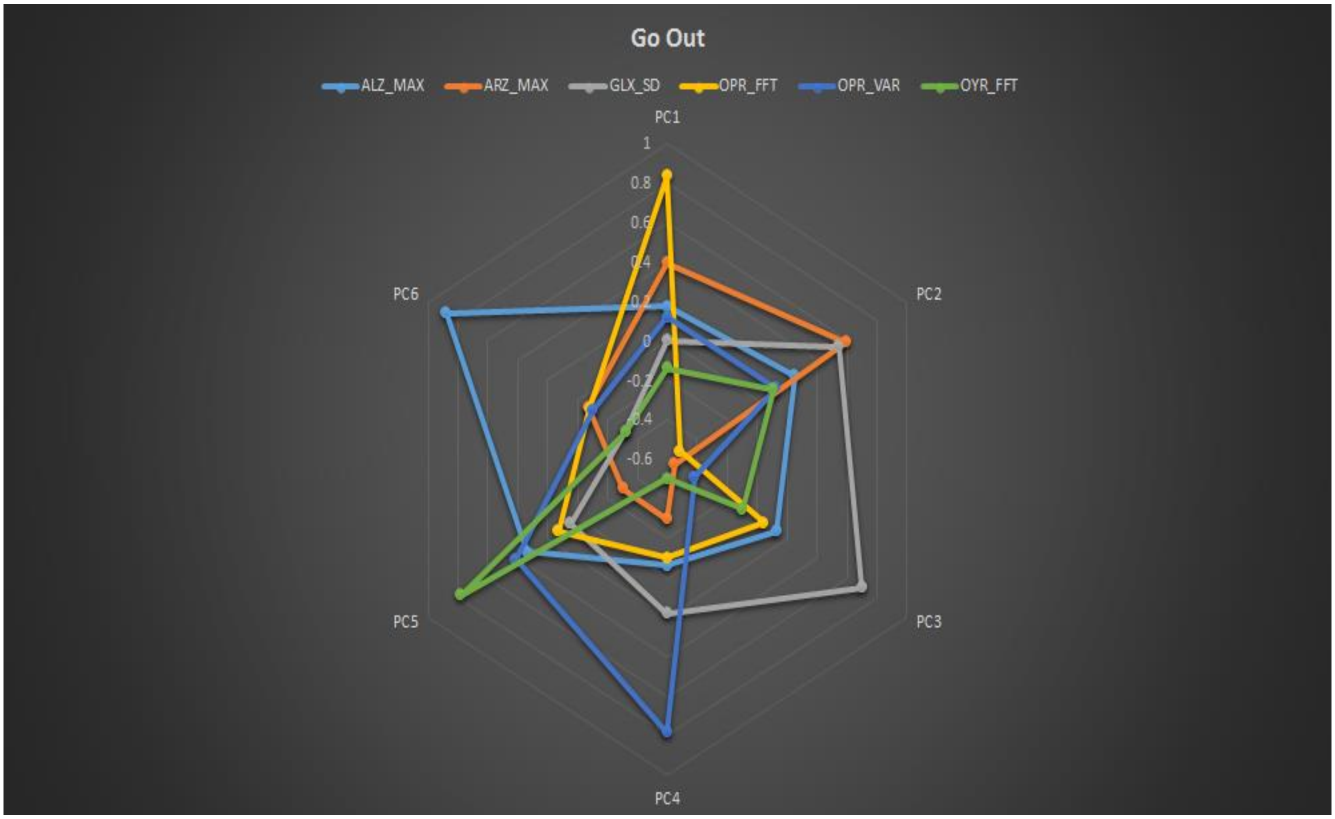
- Decide is a gesture which has the active left hand movement. It can be differentiated from CAN as the values for ALZ and ARZ are different. This difference makes these sensors the major contributor towards the Principal Component 1.
- OYR_FFT has a good coefficient because there is a considerable movement in the Yaw direction (change in sensor orientation).
- OPR_FFT has least contribution because there is no movement in the direction of Pitch similar to most of the gestures.

FIND



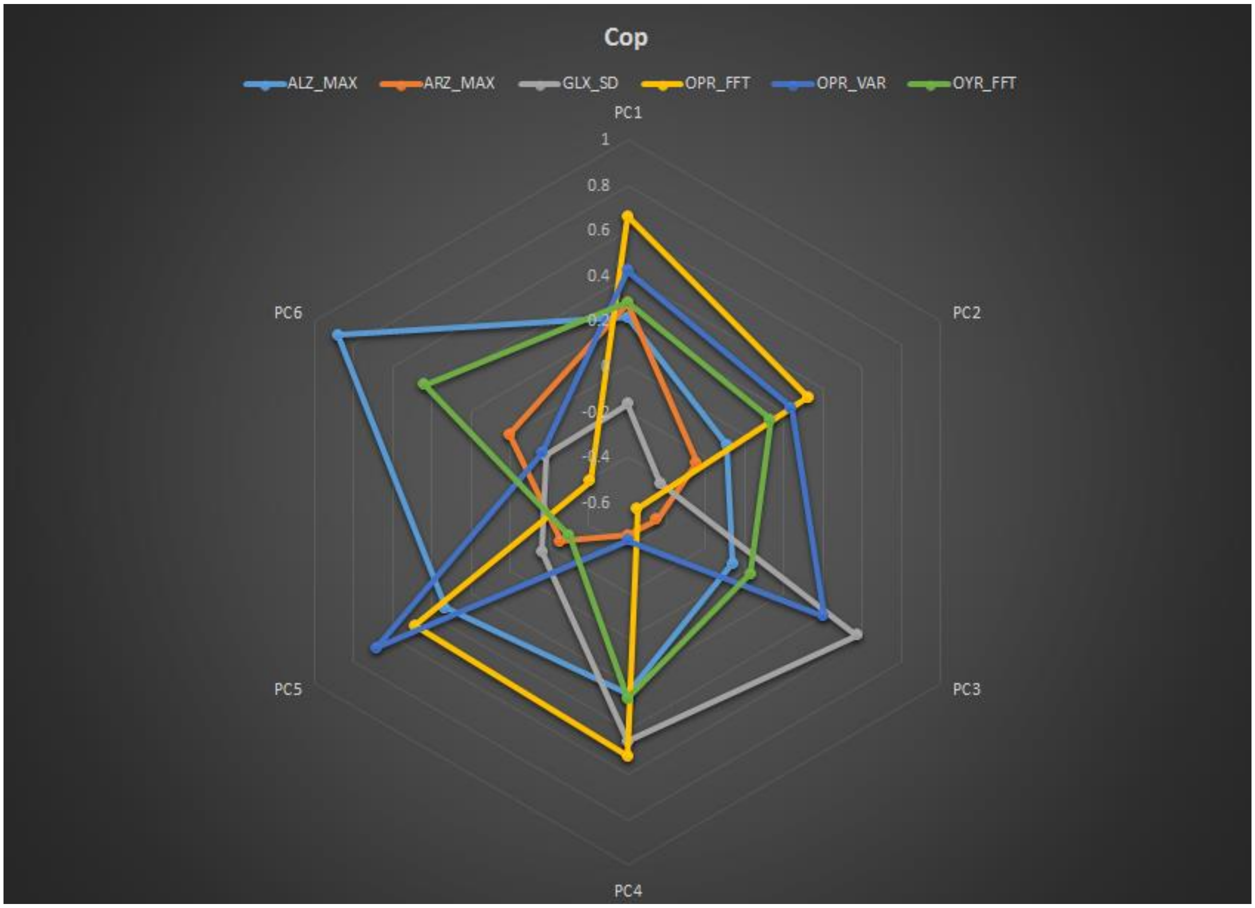
- OYR_FFT for FIND is nearly constant unlike other gestures and hence become a good differentiating feature.

GO OUT



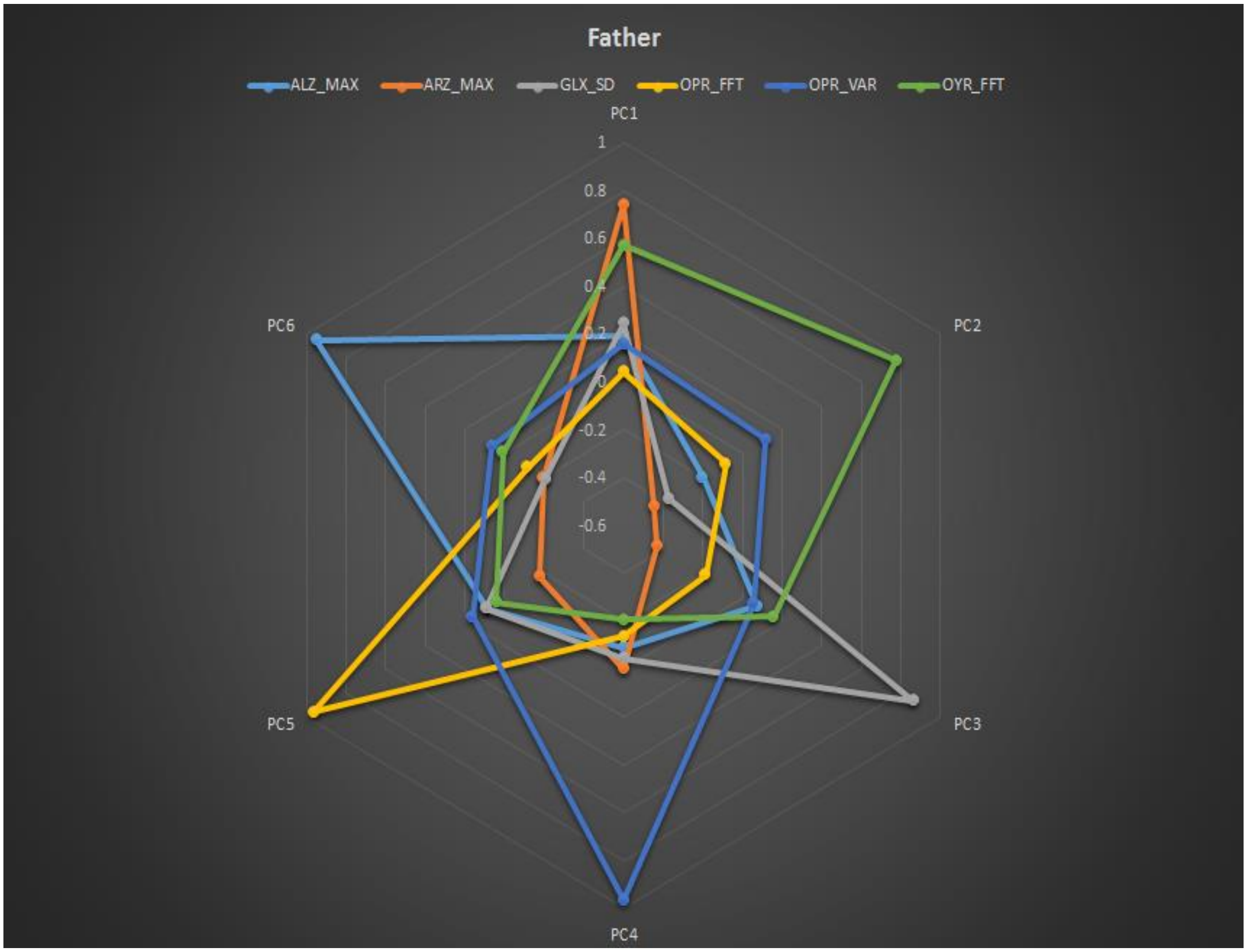
- OPR_FFT is a best differentiator for Go Out as there is good movement in a pitch direction.
- ARZ also contributes more towards the principal component as there is good acceleration in Z direction unlike other actions.
- There is less movement in yaw direction like most of the gestures and hence this feature(OYR_FFT) contributes the least.

COP



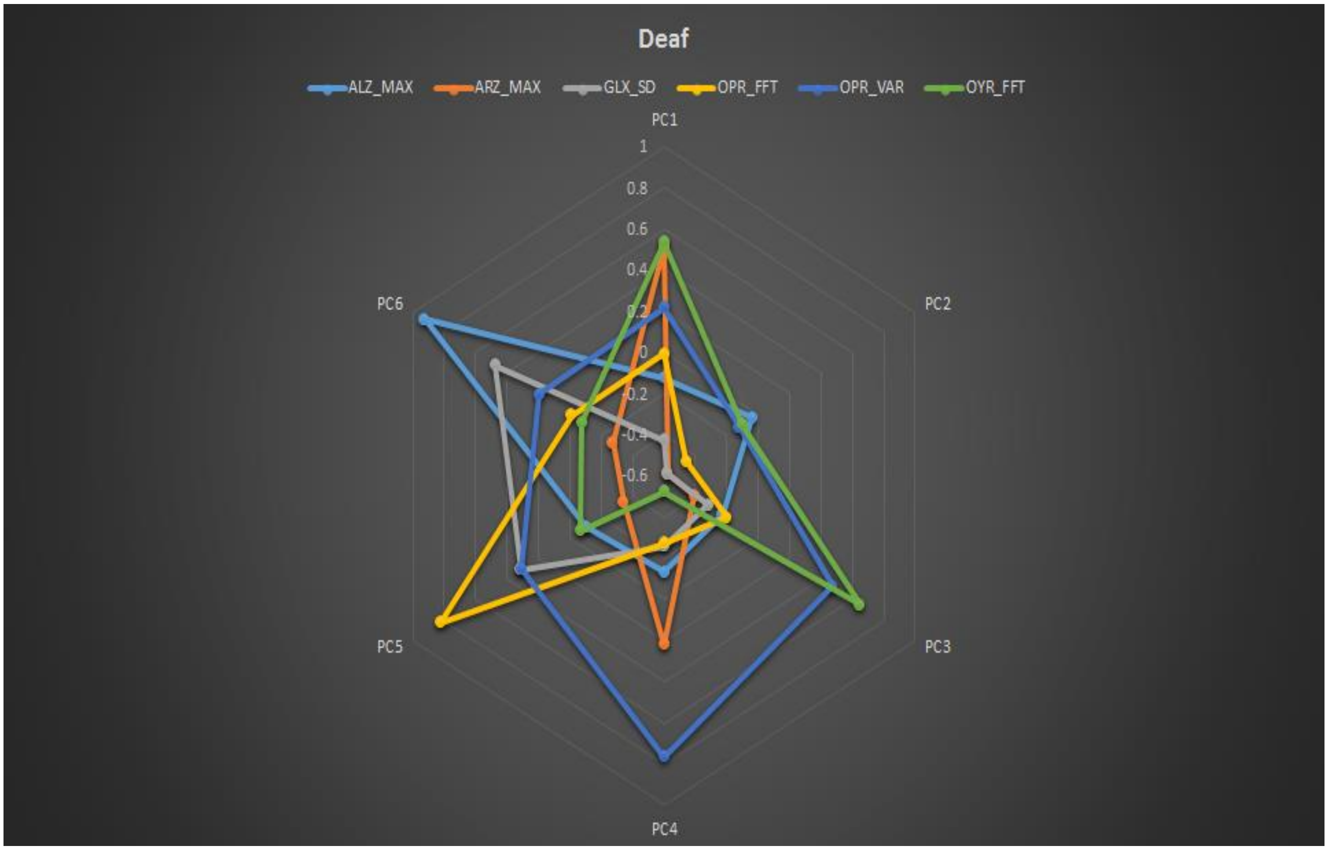
- OPR_FFT has a significant contribution as the right hand is tapped twice in the pitch direction (forming a pattern).
- GLX contributes the least as the left hand is quite stable for most actions.

FATHER



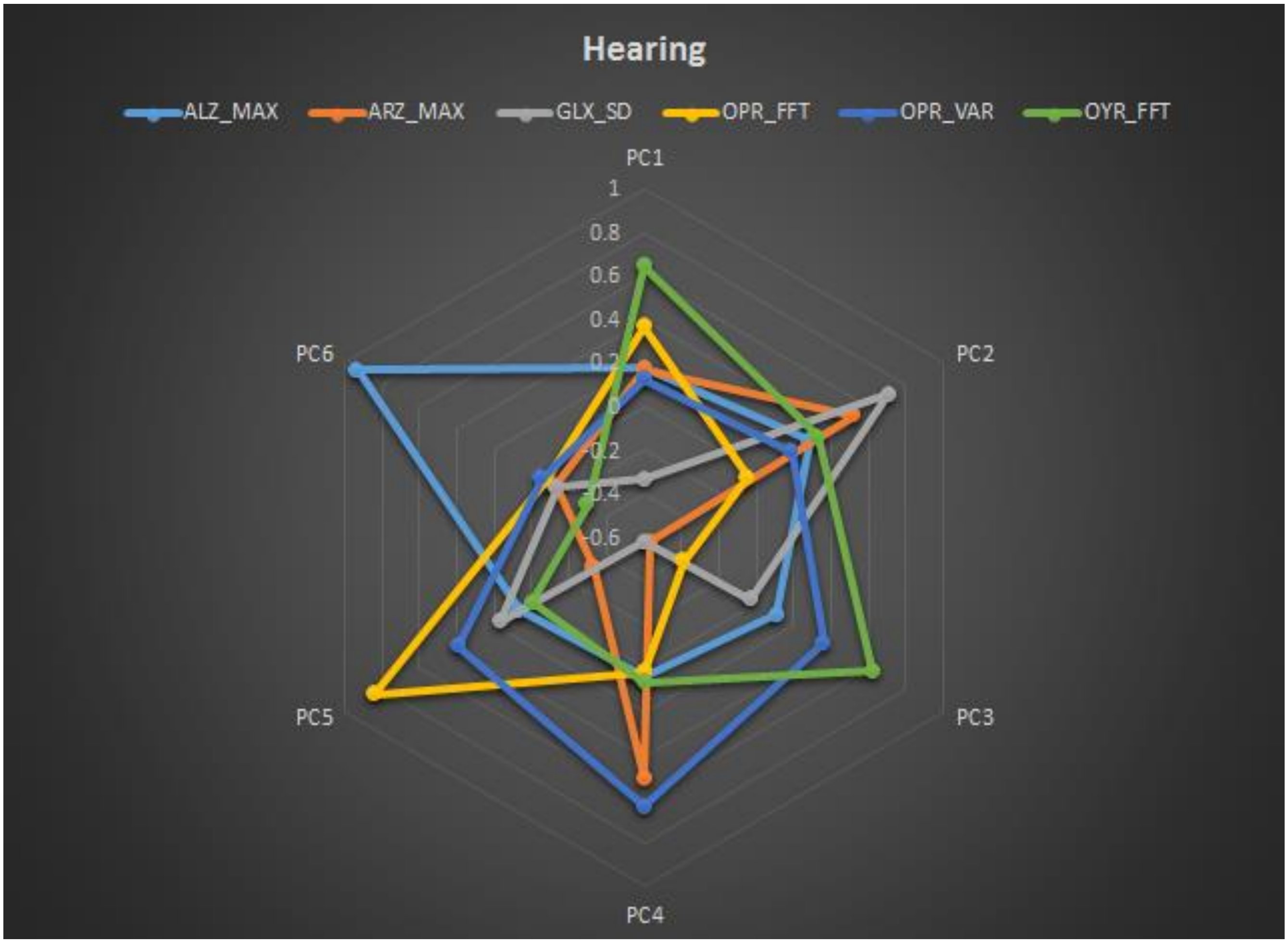
- For this gesture, ARZ is the highest because only in this gesture the hand goes to the top of the head to perform the gesture.
- The next significant feature is the direction of Yaw(OYR_FFT) since there is movement involved in the direction.
- The least contributor is OPR_FFT since there is no movement in the direction of Pitch.

DEAF



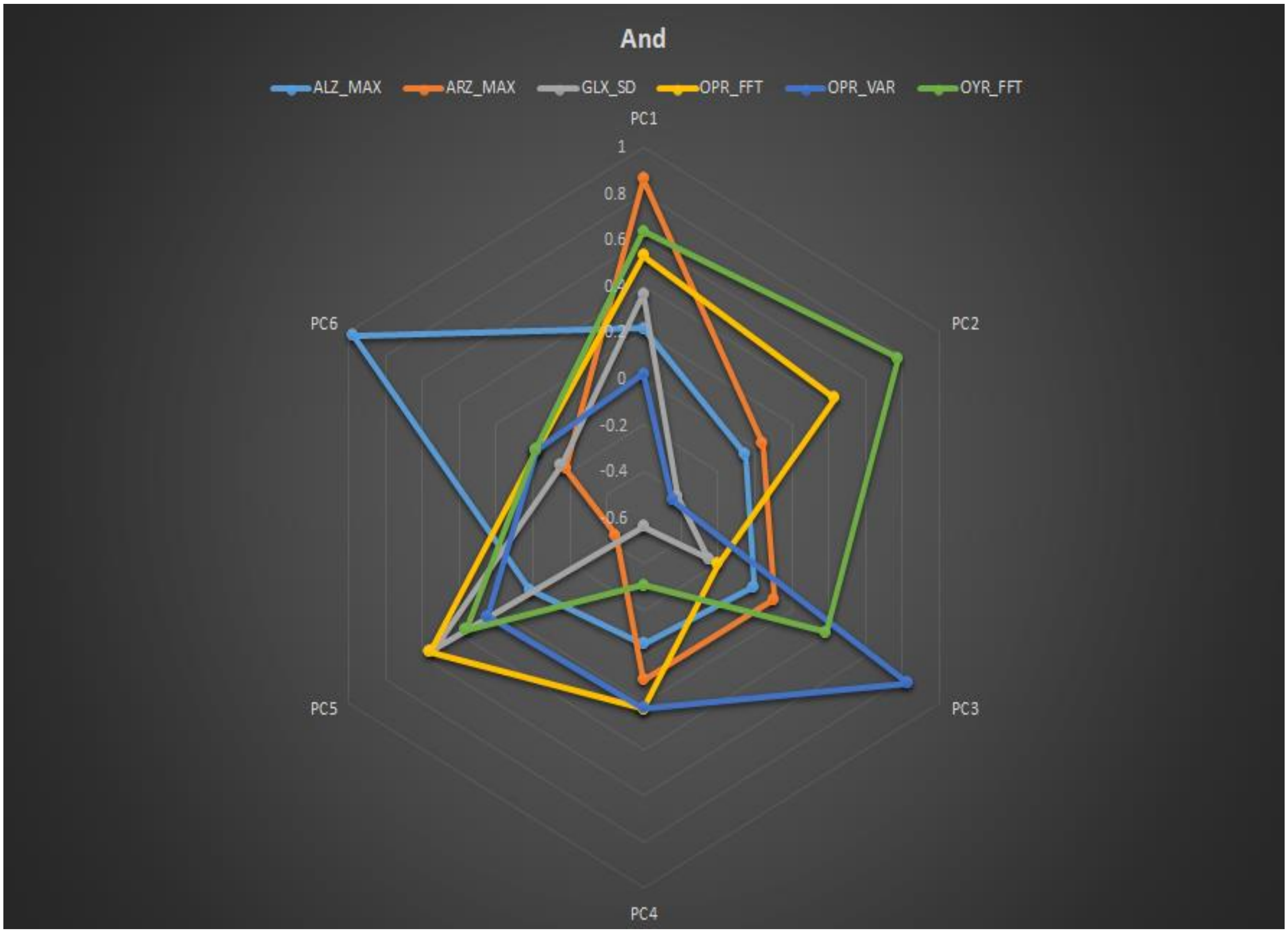
- OYR_FFT is the highest contributor because there is movement in the direction of Yaw according to ASL as shown in the Figure.
- ARZ is a good contributor because DEAF is the action where the right hand has a significant movement in Z direction following FATHER which has the highest value.
- And because of slight movement in the direction of Pitch, OPR _VAR is also a good contributor.

HEARING



- Hearing is a combination of movement in the direction of Yaw and Pitch. As it is clearly reflected in the plot.
- And since there is acceleration in the right hand in the direction of Z-axis, ARZ also forms a good feature.

AND



- Since there is a significant motion in the direction of Z axis, ARZ is the highest contributor.
- And due to the motion in the direction of Pitch and Yaw, OPR_FFT and OYR_FFT are good contributors as well.

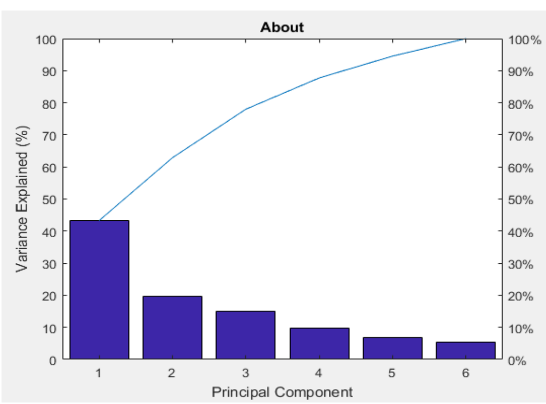
Results of PCA

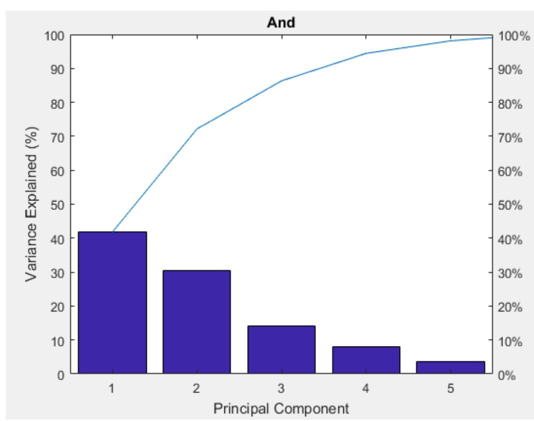
PCA is a procedure to convert set of correlated variables into principal components. This conversion is done in such a way that first principal component has the largest variance and next component has the next largest possible variance.

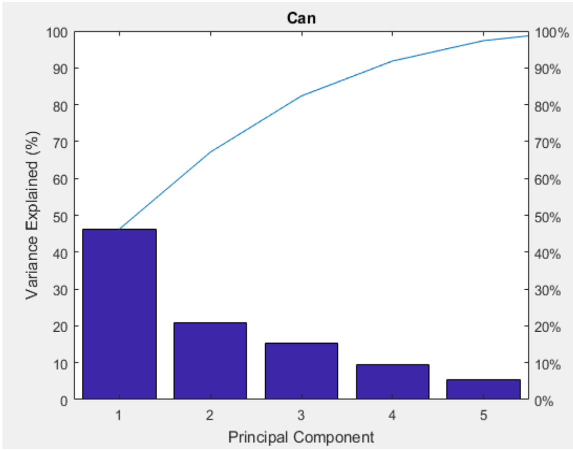
The PCA function returns the following

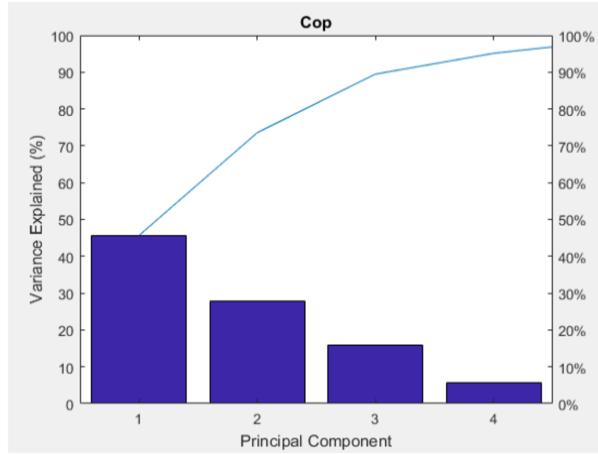
1. wcoeff - the corresponding principal component coefficients are contained in this parameter
2. score - The position of the actual data is contained in this parameter which is reflected on a new transformed coordinate system (Principal components are defined in this new coordinate system)
3. latent - This parameter can be said as a vector which contains the variance (depicted by the respective principal component).
4. explained - The percentage of the variance (depicted by the principal component) is contained in this parameter.

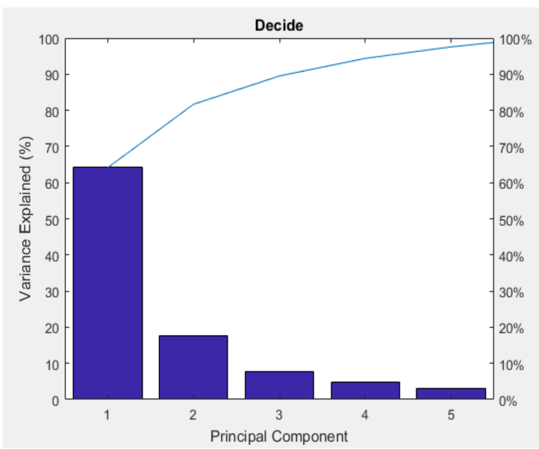
We have plotted the explained output parameter of PCA to show the degree of variance expressed by each principal component for every gesture. Its observed that a good percentage of variance (above 40 %) is exhibited by the first Principal component for all actions. So we have decided to reduce the dimensions to THREE (from six initial features) for the next step of classification.

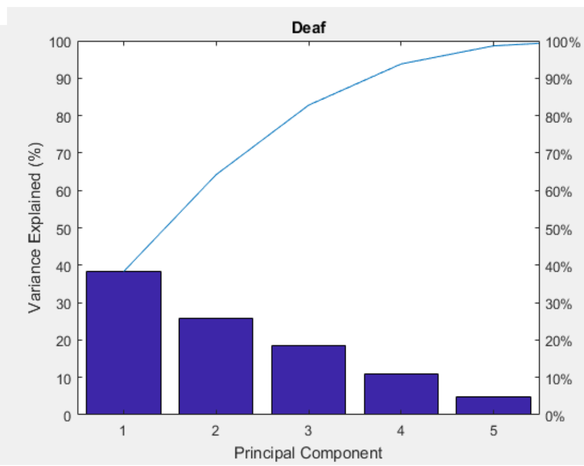


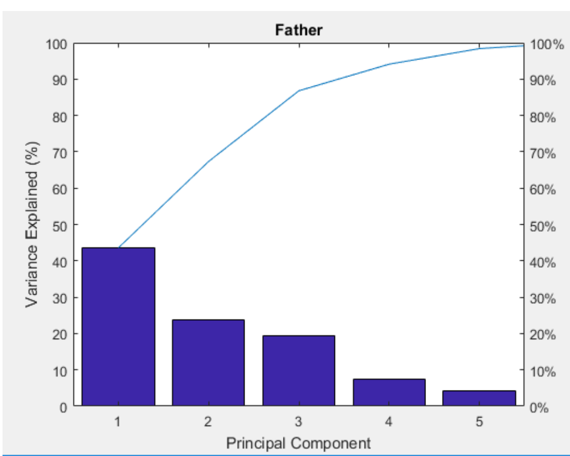


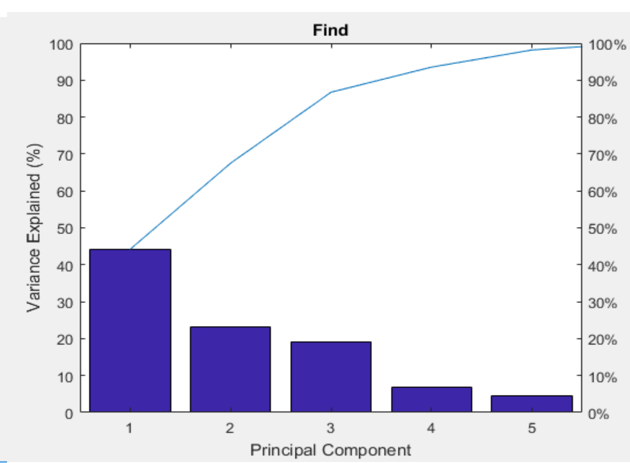

Can
Variance Explained (%)
Principal Component
0 10 20 30 40 50 60 70 80 90 100
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
1 2 3 4 5

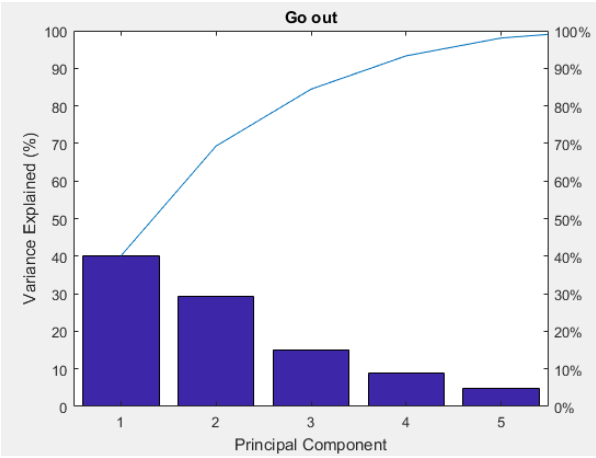

Cop
Variance Explained (%)
Principal Component
0 10 20 30 40 50 60 70 80 90 100
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
1 2 3 4

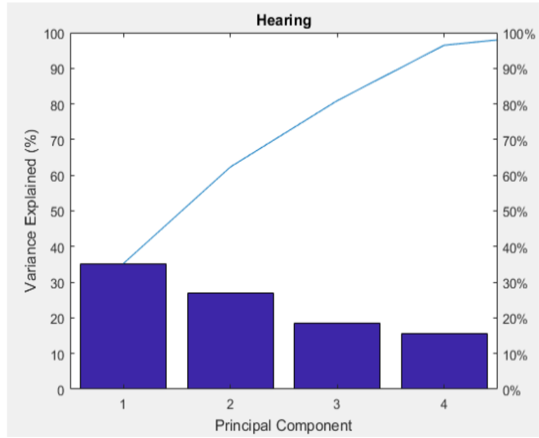

Decide
Variance Explained (%)
Principal Component
0 10 20 30 40 50 60 70 80 90 100
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
1 2 3 4 5


Deaf
Variance Explained (%)
Principal Component
0 10 20 30 40 50 60 70 80 90 100
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
1 2 3 4 5


Father
Variance Explained (%)
Principal Component
0 10 20 30 40 50 60 70 80 90 100
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
1 2 3 4 5


Find
Variance Explained (%)
Principal Component
0 10 20 30 40 50 60 70 80 90 100
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
1 2 3 4 5





Whether doing PCA was helpful or not.

- **Yes.** PCA results are helpful as it helped to drill down the list of candidate sensors for specific gestures based on the principal component results.
- It also geared us in the right direction with respect to certain wrong intuitions, made in the initial steps (explained below).

1. Based on our intuitions for ABOUT, GLX was a good differentiator between gesture ABOUT and CAN, but according to PCA results, GLX seemed to be least contributor as GLX has similar values across most gestures.
2. For our initial intuitions, OPR seemed to be a good differentiating candidate sensor but for some gestures (CAN and DECIDE) PCA results favoured OYR as there is a change in orientation(Yaw and Pitch directions change) when the hands face each other.

- As shown by the plots, PCA results aligned with the logical intuitions we came up with during task 2 and also helped filter top features for the next steps.