전남대학교
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# Implementation of Human Gait Identification

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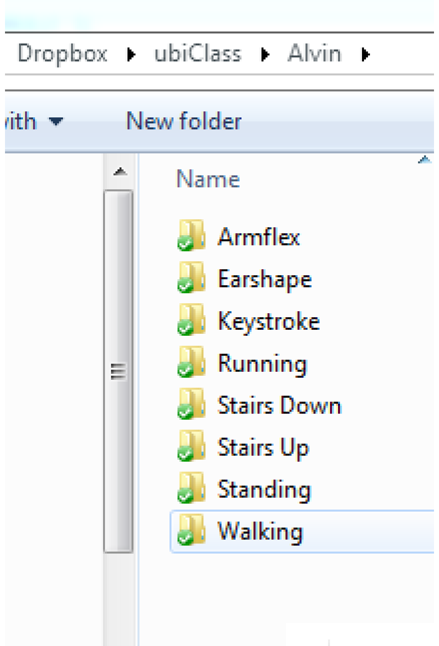
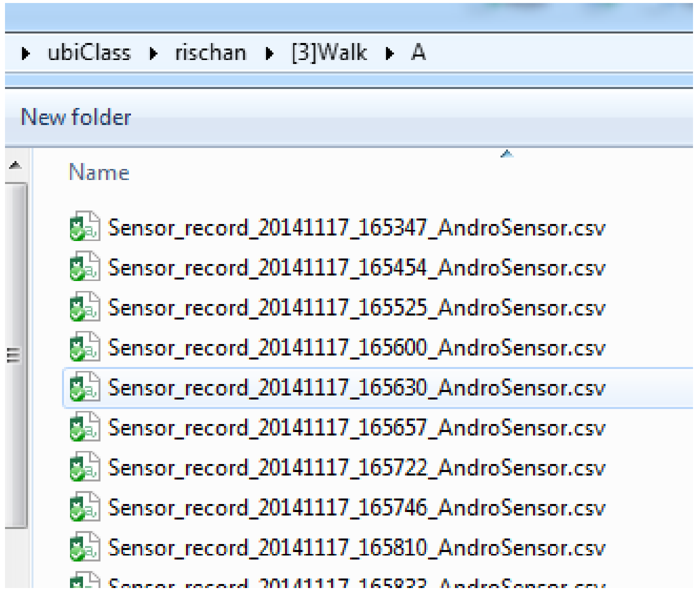
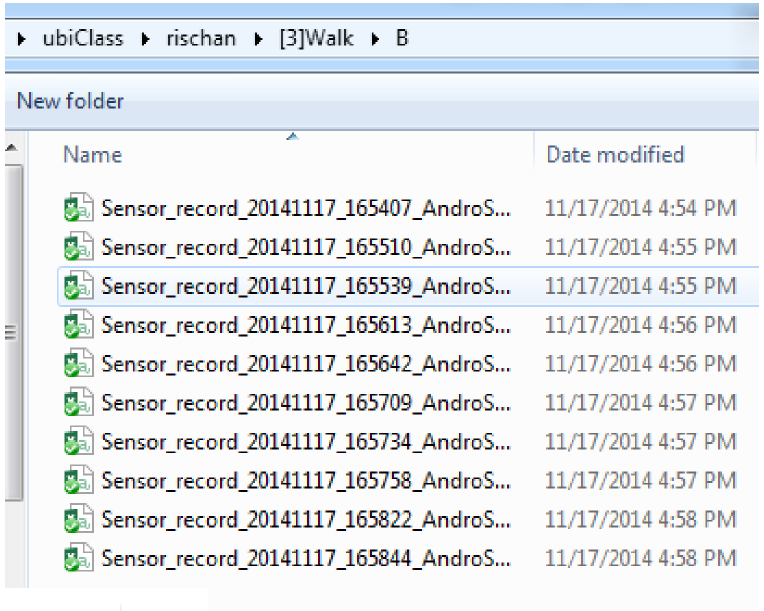
# About Our Dataset



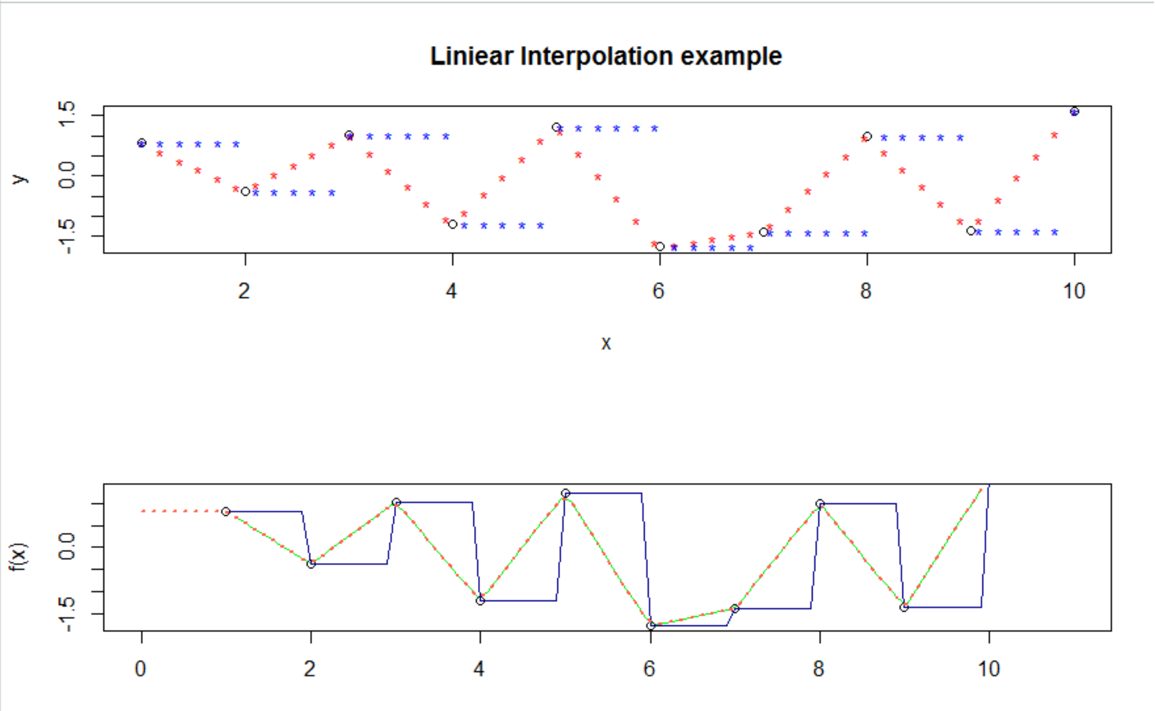

| | A | B | C | AG | AH |
|---|---|---|---|---|---|
| 1 | ACCELEROMETER X (m/s??) | ACCELEROMETER Y (m/s??) | ACCELEROMETER Z (m/s??) | YYYY-MO-DD HH-MI-SS_SSS | |
| 2 | 0.019154 | -9.615114 | 1.455675 | 2014-11-17 16:53:57:173 | |
| 3 | 0.019154 | -9.615114 | 1.455675 | 2014-11-17 16:53:57:223 | |
| 4 | 0.718261 | -9.490616 | 1.168371 | 2014-11-17 16:53:57:276 | |
| 5 | -0.047884 | -9.940724 | 1.158794 | 2014-11-17 16:53:57:327 | |
| 6 | 0.651223 | -9.346964 | 1.580173 | 2014-11-17 16:53:57:381 | |
| 7 | -0.114922 | -9.883264 | 1.934515 | 2014-11-17 16:53:57:437 | |
| 8 | 0.047884 | -9.615114 | 0.871489 | 2014-11-17 16:53:57:500 | |
| 9 | 0.574608 | -9.844956 | 1.063026 | 2014-11-17 16:53:57:560 | |
| 10 | 0.086191 | -9.816226 | 1.254562 | 2014-11-17 16:53:57:624 | |
| 11 | 0.124498 | -9.816226 | 0.593762 | 2014-11-17 16:53:57:675 | |
| 12 | 1.608904 | -9.500192 | 0.986411 | 2014-11-17 16:53:57:738 | |
| 13 | -0.086191 | -10.28549 | 1.312023 | 2014-11-17 16:53:57:793 | |
| 14 | 1.053449 | -8.801084 | 0.6608 | 2014-11-17 16:53:57:862 | |

# Experiment

- Preprocessing
  - Linear Interpolation
  - DB6 Level 1~3 De-noising (Noise Removal)
  - Gait Segmentation
- Features Extraction
- Identification

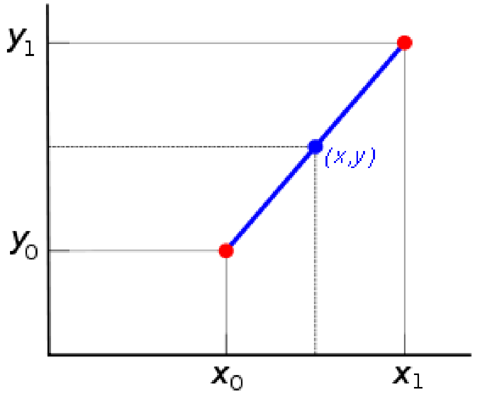
# Linear Interpolation

```r
f <- approxfun(x, y)
curve(f(x), 0, 10, col = "green")
is.function(fc <- approxfun(x, y, method = "const")) # TRUE
curve(fc(x), 0, 10, col = "darkblue", add = TRUE)
```




The linear interpolation is calculated by:

$$s' = s_0 + \frac{(s_1 - s_0)(t' - t_0)}{t_1 - t_0} \qquad (2)$$

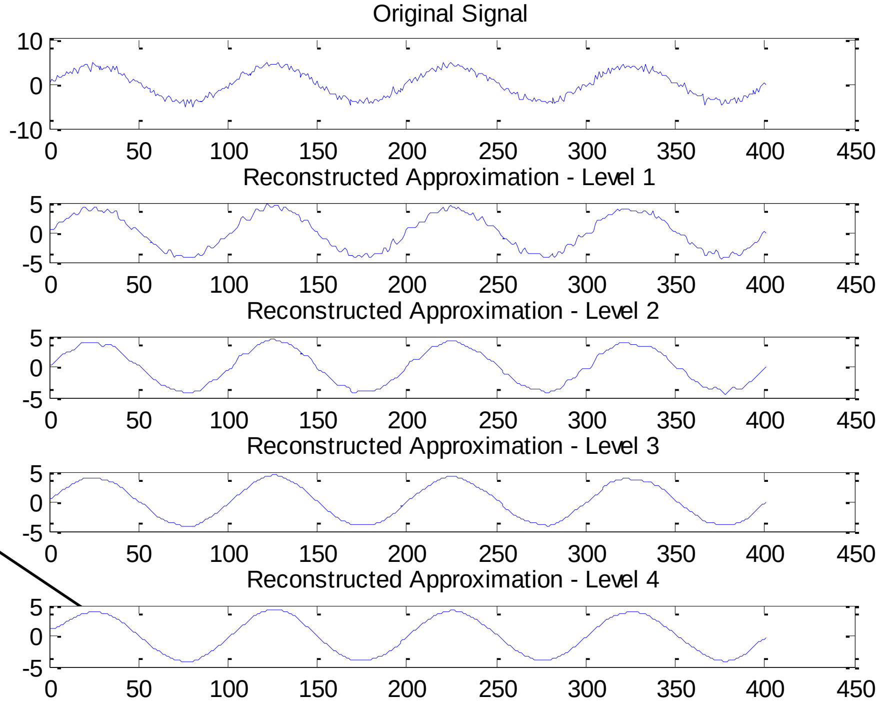



where $s_o, s_1$ represents two samples collected at times $t_o$ and $t_1$, respectively, $(s', t')$ is the new generated point that lies between $(s_0, t_0)$ and $(s_1, t_1)$.

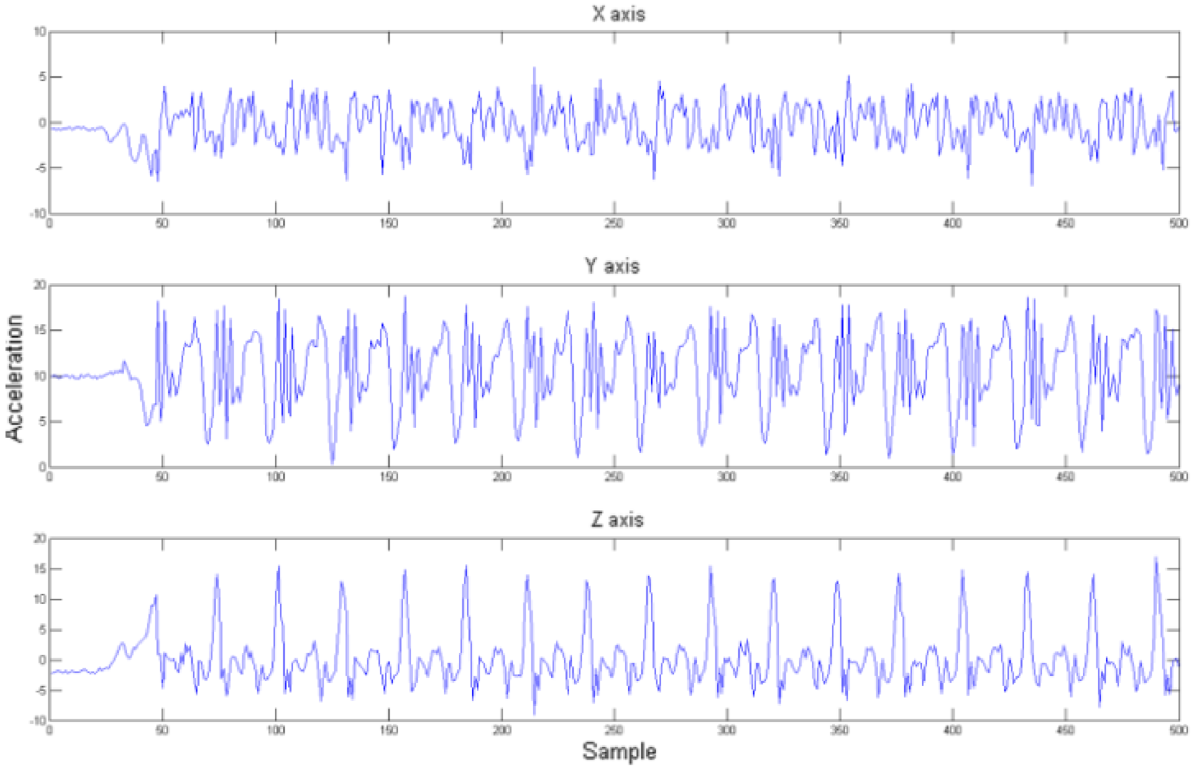
# De-Noising a Signal with Multilevel Wavelet Decomposition

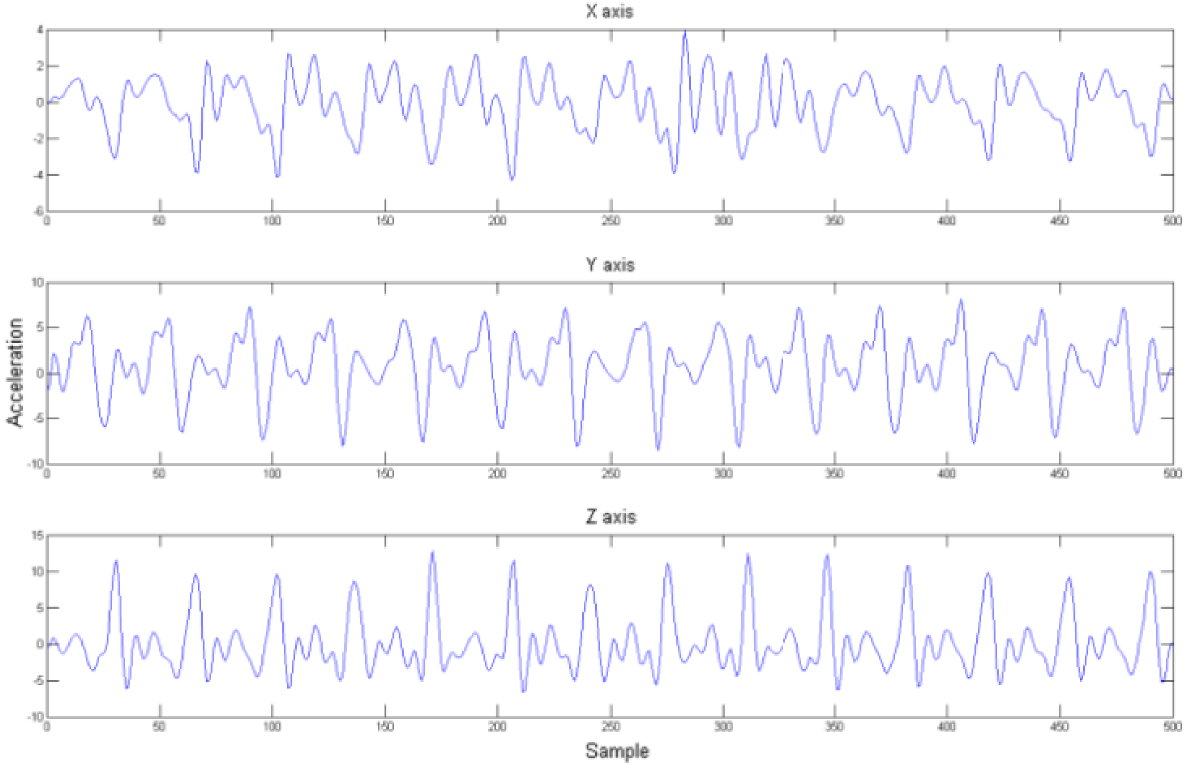
```
[C,L] = wavedec(xn,4,'db6') #do a multi-level analysis to four levels with the Daubechies-6  wavelet
A1 = wrcoef('a',C,L,'db6',1) # Reconstruct the approximations at various levels
A2 = wrcoef('a',C,L,'db6',2)
A3 = wrcoef('a',C,L,'db6',3)
A4 = wrcoef('a',C,L,'db6',4)

subplot(5,1,1),plot(xn),title('Original Signal')
subplot(5,1,2),plot(A1),title('Reconstructed Approximation - Level 1')
subplot(5,1,3),plot(A2),title(' Reconstructed Approximation - Level 2')
subplot(5,1,4),plot(A3),title(' Reconstructed Approximation - Level 3')
subplot(5,1,5),plot(A4),title(' Reconstructed Approximation - Level 4')
```

Significant de-noising occurs with the level-4 approximation coefficients (Daubechies wavelets)



# Before and After Linear Interpolation and DB6 noise reduction



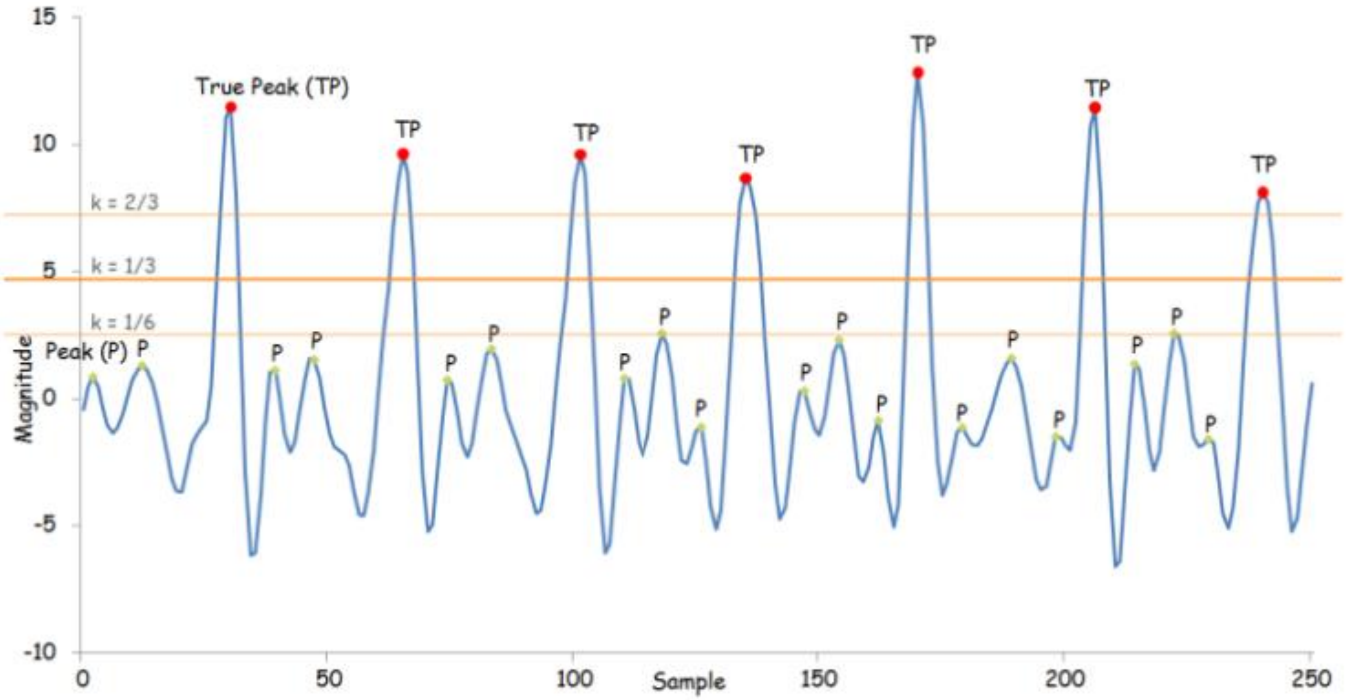
# Gait Segmentation

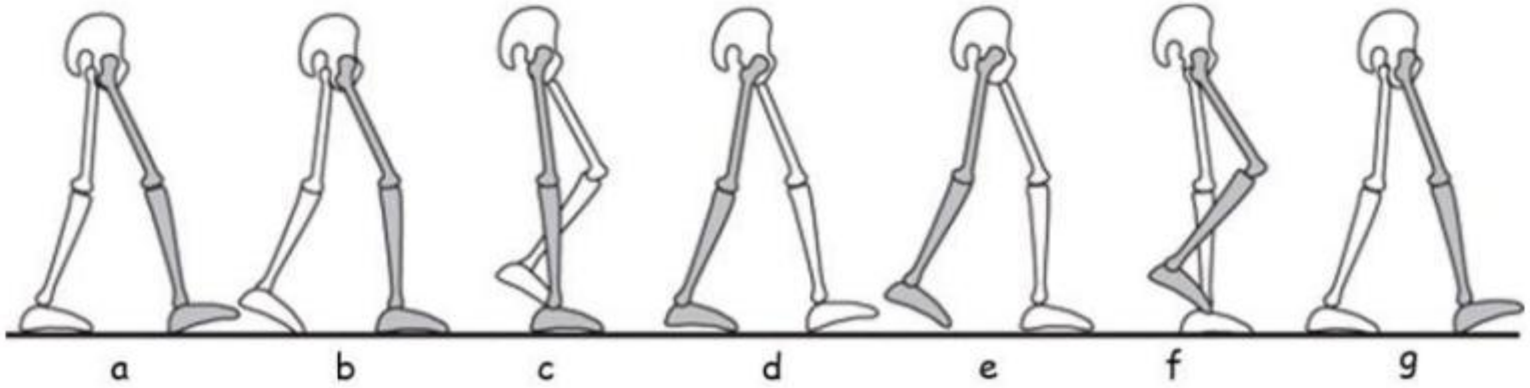
Use **Z** value of Accelerometer to define gait cycle

$$P = \{ d_i \mid d_i > d_{i+1} \land d_i > d_{i-1} \} \text{ with } i \in [1 \ldots n] \quad (1)$$

$$T = \mu + k\sigma \quad (2)$$

$$R = \{ d_i \in P \mid d_i \geq T \} \quad (3)$$



# Features Extraction

## *Time domain feature:*

1. Mean from each gait signal (X,Y,Z,M signals)
2. Average maximum acceleration from (X,Y,Z,M signals)
3. Average minimum acceleration from (X,Y,Z,M signals)
4. Average absolute different from (X,Y,Z,M signals)
5. Standard deviation
6. RMS (Root Mean Square)

## *Frequency domain features:*

The first 40 FFT coefficients form a feature vector

# Features

## Time domain Features

Mean, Max, Min, Sd, Abs, Rms (6 features) with 4 signals (X,Y,Z, and M), total features from time domain features are 24 features.

## FFT Features

FFT features is the 40 first FFT coefficient from each gait signal. In this experiment we use 4 accelerometer signals (X,Y,Z, and M) so total FFT features are 160 features.

## All Features

Combine between time domain features and FFT features. Total : 24+160 = 184 features

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MeanX | SdX | MaxX | MinX | AbsX | RmsX | MeanY | SdY | MaxY | MinY | AbsY | RmsY |
| 2 | 0.555395 | 1.098373 | 2.585991 | -1.08811 | 1.252715 | 1.215395 | -9.51746 | 2.921483 | -3.84992 | -13.631 | 2.110561 | 9.94235 |
| 3 | 0.589866 | 1.674695 | 2.342881 | -1.7251 | 1.877133 | 1.702228 | -9.53034 | 4.4986 | -2.73963 | -17.1231 | 4.310039 | 10.4510 |
| 4 | -0.57362 | 1.973134 | 5.313475 | -5.58799 | 1.535156 | 2.029057 | -9.0482 | 3.819357 | 0.18906 | -17.1231 | 1.998044 | 9.80118 |
| 5 | 0.046401 | 1.333856 | 1.680272 | -3.22602 | 0.503896 | 1.31431 | -10.4238 | 4.875651 | -4.62248 | -16.5488 | 7.807723 | 11.4763 |
| 6 | 0.59743 | 2.15929 | 5.780469 | -4.10599 | 1.58677 | 2.216083 | -10.9544 | 2.195639 | -6.95364 | -17.8585 | 1.775844 | 11.1672 |
| 7 | 0.460256 | 1.466863 | 2.977381 | -3.45786 | 1.272482 | 1.513052 | -9.79361 | 4.176959 | -4.37038 | -14.5361 | 6.159178 | 10.6188 |
| 8 | 0.076862 | 3.499743 | 7.005158 | -9.98727 | 2.63952 | 3.447166 | -9.5194 | 3.639357 | -0.46927 | -14.8035 | 3.37587 | 10.1716 |
| 9 | -1.3334 | 1.008193 | 0.501548 | -2.83548 | 0.983463 | 1.65126 | -11.7156 | 1.578985 | -9.67843 | -14.4889 | 2.100525 | 11.8144 |
| 10 | 0.391567 | 1.444585 | 2.786917 | -2.83548 | 1.855781 | 1.474053 | -10.1042 | 4.67004 | -3.88231 | -15.2468 | 6.137039 | 11.0995 |
| 11 | 1.08488 | 1.408252 | 3.484808 | -0.94153 | 2.044802 | 1.758338 | -8.74339 | 4.155428 | -1.59603 | -17.1275 | 3.769392 | 9.64982 |
| 12 | -0.51043 | 0.674269 | 0.81719 | -1.22429 | 0.539701 | 0.832133 | -10.8278 | 1.174787 | -8.95463 | -12.4584 | 1.475132 | 10.8882 |
| 13 | 0.35861 | 2.336641 | 3.258774 | -4.91309 | 1.075629 | 2.327632 | -10.0079 | 4.256948 | -3.78951 | -15.8723 | 6.268378 | 10.8495 |
| 14 | 1.831153 | 1.013319 | 3.485867 | 0.699891 | 1.053489 | 2.057486 | -10.2371 | 2.13004 | -7.52693 | -13.2058 | 2.795151 | 10.4252 |
| 15 | 4.595901 | 1.188852 | 6.851176 | 3.485867 | 0.66244 | 4.725861 | -8.49996 | 4.635166 | -4.2969 | -17.5652 | 2.126148 | 9.52180 |
| 16 | 0.92104 | 3.355269 | 6.851176 | -2.75926 | 2.460915 | 3.27092 | -9.52298 | 7.088065 | 0.304573 | -17.5652 | 7.028253 | 11.6037 |
| 17 | -0.6693 | 0.38319 | -0.15324 | -1.31823 | 0.431065 | 0.76058 | -10.409 | 2.502866 | -8.06672 | -16.0147 | 0.89282 | 10.6731 |
| 18 | -0.26855 | 0.202324 | 0.097024 | -0.47175 | 0.177996 | 0.328536 | -9.49025 | 0.221543 | -9.29248 | -9.90878 | 0.185577 | 9.49251 |
| 19 | 0.172826 | 0.432426 | 0.547773 | -0.68017 | 0.335536 | 0.43606 | -9.75276 | 0.130861 | -9.60609 | -9.91369 | 0.160027 | 9.75350 |
| 20 | -0.54613 | 0.552443 | 0.421373 | -1.29695 | 0.674968 | 0.765833 | -9.49886 | 0.210116 | -9.08911 | -9.91369 | 0.193713 | 9.50105 |
| 21 | 0.334047 | 0.269243 | 0.537492 | -0.04947 | 0.143337 | 0.407377 | -9.402 | 0.090068 | -9.29508 | -9.4855 | 0.092643 | 9.40232 |
| 22 | 0.17121 | 0.200362 | 0.344133 | -0.13422 | 0.151396 | 0.247848 | -9.45391 | 0.020268 | -9.41957 | -9.4669 | 0.001635 | 9.45392 |
| 23 | 0.312653 | 0.269433 | 0.681938 | -0.13422 | 0.310558 | 0.404657 | -9.37638 | 0.020055 | -9.34769 | -9.41957 | 0.017913 | 9.37640 |
| 24 | 0.249499 | 0.096882 | 0.360068 | 0.101849 | 0.08727 | 0.265132 | -9.34003 | 0.018024 | -9.314 | -9.36328 | 0.022763 | 9.34004 |
| 25 | 0.249998 | 0.028222 | 0.27626 | 0.220157 | 0.033632 | 0.251058 | -9.30377 | 0.010308 | -9.29338 | -9.314 | 0.01492 | 9.30377 |
| 26 | 0.312859 | 0.035744 | 0.34651 | 0.220157 | 0.018518 | 0.314824 | -9.34379 | 0.050858 | -9.29256 | -9.43376 | 0.026749 | 9.34392 |
| 27 | 0.330673 | 0.807715 | 2.625555 | -2.01434 | 0.452796 | 0.864246 | -10.0095 | 1.208931 | -8.99344 | -13.322 | 0.267905 | 10.0806 |
| 28 | -0.12814 | 2.019406 | 1.901591 | -4.67069 | 1.104262 | 1.99361 | -9.55233 | 3.856989 | -3.54766 | -13.9149 | 4.207983 | 10.2803 |

| FU | FV | FW | FX | FY | FZ | GA | GB | GC |
|---|---|---|---|---|---|---|---|---|
| FFT153 | FFT154 | FFT155 | FFT156 | FFT157 | FFT158 | FFT159 | FFT160 | label |
| -0.60934 | 0.144611 | -0.405 | -0.88437 | -0.67508 | -0.40843 | -0.55527 | -0.59382 | agung |
| -2.61995 | -2.79797 | -2.47035 | -2.78383 | -2.50306 | -2.71729 | -2.16354 | -2.44152 | agung |
| 2.700932 | 1.954585 | 2.055435 | 1.902533 | 1.679828 | 2.059306 | 2.190261 | 2.336578 | agung |
| -0.95285 | -0.17715 | -0.38109 | 0.241818 | -0.72403 | -0.65203 | -1.93696 | -1.98026 | agung |
| 4.808676 | 2.777703 | 4.670166 | 6.669613 | 3.334803 | 0.89254 | 2.977633 | 2.611604 | agung |
| -1.17916 | -2.04098 | -2.44121 | -3.28289 | -3.10196 | -3.18561 | -2.60327 | -2.40219 | agung |
| 5.966523 | 5.999911 | 7.502656 | 6.85634 | 6.760834 | 4.302868 | 5.591767 | 6.273775 | agung |
| -2.77245 | -2.62142 | -2.8757 | -2.84504 | -2.84814 | -2.64578 | -2.8176 | -2.83888 | agung |
| -0.542 | -0.30119 | -1.41766 | -0.92355 | -1.59163 | -1.09617 | -1.03317 | -0.8322 | agung |
| 4.431904 | 5.628292 | 3.171458 | 3.831947 | 3.641558 | 4.807209 | 3.801818 | 4.083849 | agung |
| -2.17362 | -2.24252 | -2.24948 | -2.14989 | -2.24958 | -2.38743 | -2.40747 | -2.3552 | agung |
| -2.25839 | -2.31592 | -1.74282 | -1.40156 | -1.70077 | -2.06582 | -3.03182 | -3.14669 | agung |
| 5.516083 | 5.465489 | 5.449561 | 5.577563 | 5.453935 | 5.588735 | 5.49983 | 5.456692 | agung |
| -7.31496 | -7.15132 | -7.27213 | -7.14189 | -7.50581 | -7.05846 | -7.38461 | -7.2666 | agung |
| 4.172495 | 4.292497 | 4.836977 | 4.363838 | 4.718246 | 4.136125 | 4.193529 | 4.255587 | agung |
| 3.404821 | 3.567294 | 3.555427 | 3.487997 | 3.510887 | 3.555237 | 3.485073 | 3.577724 | agung |
| -1.13499 | -1.17272 | -1.15514 | -1.20356 | -1.15912 | -1.17396 | -1.15804 | -1.15923 | agung |
| 0.86713 | 0.803363 | 0.846054 | 0.860618 | 0.813731 | 0.868544 | 0.851388 | 0.805035 | agung |
| 0.482515 | 0.404696 | 0.39354 | 0.415888 | 0.438225 | 0.346379 | 0.415751 | 0.453539 | agung |
| 0.062353 | 0.048932 | 0.058648 | 0.060265 | 0.048935 | 0.05705 | 0.058647 | 0.048939 | agung |
| 0.02446 | 0.026294 | 0.024354 | 0.026032 | 0.02446 | 0.025875 | 0.024375 | 0.025682 | agung |
| -0.03734 | -0.03736 | -0.03715 | -0.03729 | -0.03725 | -0.03737 | -0.03759 | -0.03747 | agung |
| -0.06281 | -0.06267 | -0.06287 | -0.06285 | -0.06306 | -0.06288 | -0.06288 | -0.06279 | agung |
| -0.02659 | -0.02656 | -0.02659 | -0.02657 | -0.02659 | -0.02657 | -0.02659 | -0.02657 | agung |
| 0.042131 | 0.043772 | 0.042679 | 0.034298 | 0.04193 | 0.040868 | 0.040933 | 0.040135 | agung |
| -4.05089 | -4.31722 | -3.92748 | -3.66853 | -3.67108 | -3.95814 | -4.09392 | -3.91254 | agung |
| 1.044144 | 1.04149 | 1.479194 | 1.546559 | 1.572899 | 1.5814 | 1.246371 | 1.176803 | agung |

# Result

**Time Domain Features**

List Features after SFFS:

"MeanX", "AbsX", "MeanY", "MinY", "MeanZ", "SdZ"

Best SVM Parameters: gamma = 0.5, cost = 10

| | Original | SFFS |
|---|---|---|
| Time Loading | 0.48 | 0.37 |
| Time Prediction | 0.11 | 0.02 |
| Accuracy | 0.7614 | 0.8267 |

**FFT Features**

List Features after SFFS:

"FFT1", "FFT13", "FFT71", "FFT81", "FFT82", "FFT121"

Best SVM Parameters: cost=1, gamma=1

| | Original | SFFS |
|---|---|---|
| Time Loading | 1.73 | 0.87 |
| Time Prediction | 0.45 | 0.03 |
| Accuracy | 0.4821 | 0.7178 |

*SFS (Sequential Forward Selection)*

*SFFS (Sequential Floating Forward Selection)*

**All Features**

List Features after SFFS:

"MeanX", "AbsX", "MeanY", "MinY", "MeanZ", "SdZ"

Best SVM Parameters: gamma = 0.5, cost = 10

| | Original | SFFS |
|---|---|---|
| Time Loading | 2.45 | 0.37 |
| Time Prediction | 0.55 | 0.02 |
| Accuracy | 0.4155 | 0.8267 |

# Naïve Bayes and Random Forest

| | SVM SFFS | Naïve Bayes | Naïve Bayes with SFFS |
|---|---|---|---|
| Time Loading | 0.37 | 91.36 | 4.09 |
| Time Prediction | 0.02 | 8.58 | 0.31 |
| Accuracy | 0.8267 | 0.5297 | 0.6287 |

| | SVM SFFS | Random Forest | Random Forest with SFFS |
|---|---|---|---|
| Time Loading | 0.37 | 2.53 | 0.62 |
| Time Prediction | 0.02 | 0.36 | 0.23 |
| Accuracy | 0.8267 | 0.848 | 0.7966 |

# Conclusion

- If we want to play with sensor data, we have to consider deeply about sampling rate.
- Features selection is very useful method, we can use it to find which is the best features.
- Many features does **not** mean good accuracy, but many features means take more time to load and predict.

Thank you,