The approach to detect the waveform by FFT and Wavelet, updated on Oct 8th

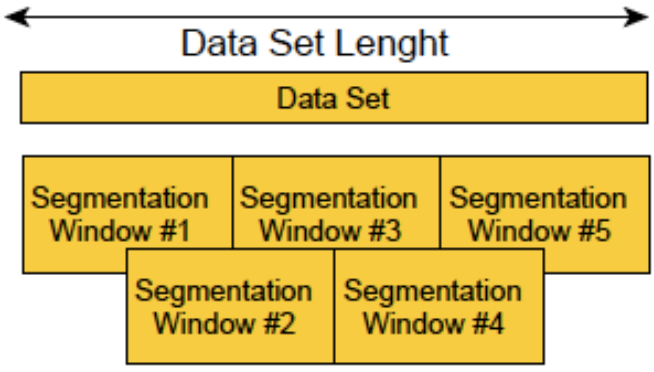
After discussing with Annie-Sophie how to related the magnitude (g) that Paul mentioned on the group wechat, I had done some exploratory research in the direction of using Fourier Transform to decompose the waveform into different formats within the certain energy.

Below is the briefing summary:

Translate the sensor data that collected from the voltage on the 0 and 1 in the digital electronics/digital communication base. If we see the wave form of different features that recorded by the given time and frequency (100HZ= 100 data points/s), then how we transform this wave in a smoother way and make it more variant formatting, here we will use the FFT and Wavelet, the inspiration is from the signal processing for the audio and movement detection (acceleration signal processing) in the medical research. Imagine in the 3-D space, that time, frequency and amplitude (magnitude, also called g) can visualize the different waves by given frequency range in a certain power spectrum, if need the high frequency (small scale), or vice versa.

We will make the advantage of the visualization to understand the process, also use the frequency domain analysis to move the noise so that we can get the higher S/N ratio.
Inspiration: EEG datasets and music/audio signal

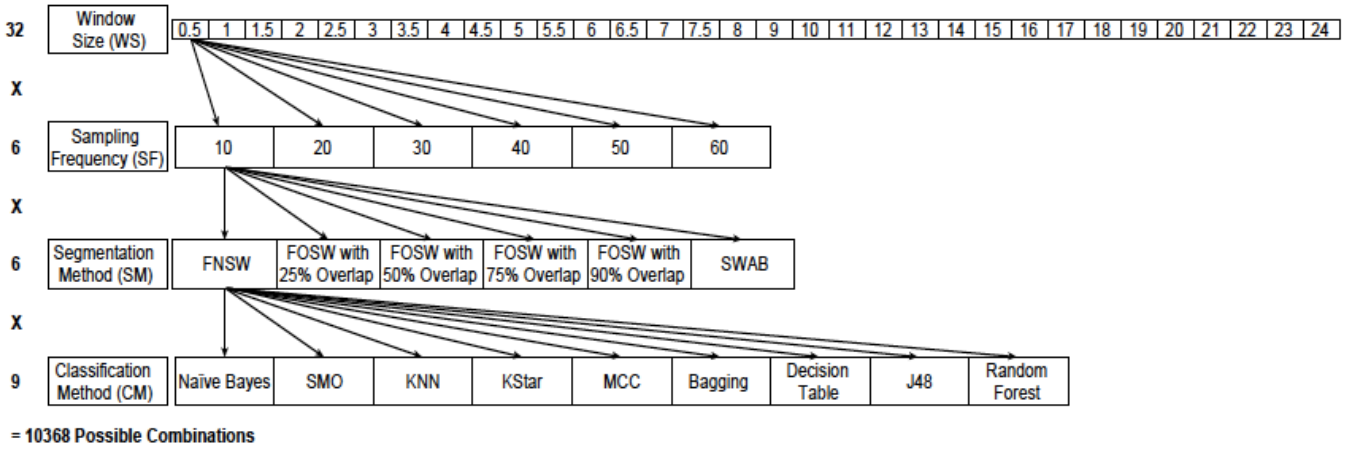
- **Current stage:** Need to cut the window of each movement (it's a successive window and periodically repeating), decide the chunk size, also called window size in this briefing, which will be useful to diff the features, list some segmentation methods (fixed size non overlapping sliding window, fixed size overlapping window), the different methods applied varied in online and offline based, for auto-modeling in real time or opposite. Based on our problem, will try FSOW.



$$Segmentation_{Windows} = \frac{S}{L_i - L_i * \frac{P_j}{100}}$$

- The window size some choose like 2s, or 2.56s and overlapping such as 50% is most used case when discussed with Annie-Sophie on last week.
- Further research on algorithm, the window size should be chosen based on the event types, suggested by paper that intending to achieve the good accuracy, the different features should be extracted varied different window cutting (see example below for some classic case)

Authors	Sampling Frequency [Hz]	Segmentation Window [s]	Segmentation Method	Testsubject Information	ADLs
Huynh [5]	512	0.25, 0.5, 1, 2, 4	FNSW, FOSW 50%, FOSW 75%, FOSW 80.5%, FOSW 93.75%		Walking, Standing, Jogging, Skipping, Hopping Riding Bus
Sekine [6]	256			Subjects 11; Age 69.3 ± 5.6 years; Height 1.54 ± 0.078 m; Weight 50.4 ± 9.6 kg	Walking
Bao [7]	76.25	6.7	FOSW 50%	Subjects: 13 male, 7 female; Age 17–48 years	Walking, Sitting & Relaxing, Standing Stil, Watching TV, Running, Stretching, Scrubbing, Folding Laundry, Brushing teeth, Riding Elevator, Walking Carrying items, Working on Computer, Eating or Driniking, Reading, Bicycling Strength Training, Vacuuming, Lying Down & Relaxing, Climbing Stairs, Riding Escalator



*How to select different parameters for classification accuracy testing

From the already tested algorithm, the Random forest, KNN and SVM has the relatively highest model accuracy, so can used one of them as the baseline. For the model testing, tuning the parameter such as window size, frequency to test the model accuracy, there will be huge work in the pre-processing part.

Kindly note there is always no algorithm is perfect enough to be able to classify all the movement in the reality, so we should have much more algorithm to test with different

movements, here I suggest some algorithm as the toolbox, peak detector, signal power calculation and frequency domain analysis (FFT and Wavelet)

Summarized based on previous statement, this is no fixed good size, or models, depending on the event types and the streaming data we can get by far.

- The relationship between the frequency (HZ) and magnitude (g) to detect the noise and signal range, can set the maximum acceleration (between which g range) to filter the noise under that g range, one method is use the Fourier domain analysis to do the movement analysis, because different exercise has the different frequency spectrum, need to choose sampling frequency, so we can visualize and compare the waveform of movements

- Using the Fourier transform decompose the signal into consistent complex exponentials (use this one because the time complexity based on the computer running cost, check the big –O algorithm)

- Will explain the mathematics theory in the meeting session by plot. The equation of Fourier transform and Wavelet will explained but the model will implemented by the fft module from Numpy and Scipy library.

Reference:

1. Wavelets and wavelet convolution, author Dr. Frederike Petzschner, Translation Neuromodeling Unit, 06.03.2015 http://www.translationalneuromodeling.org/uploads/TNU_SpringSeminar2015_EEG-Signal-Processing_Week03_Petzschner_2015_Wavelets.pdf
2. Understand FFT from Jake VanderPlas http://nbviewer.jupyter.org/url/jakevdp.github.io/downloads/notebooks/UnderstandingTheFFT.ipynb
3. Algorithms for processing accelerator sensor data, author Gabor Paller http://pallergabor.uw.hu/common/acceleration_processing.pdf
4. Qualitative features extraction from sensor data using short-time Fourier Transform, author Abolfazl M.Amini, Department of Electronics Engineering Technology, Southern University, Baton Rouge, LA 70813; Fernando Figueroa, NASA Stennis Space Center, Technology Development and Transfer, HA30, MS 39529 https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20050041772.pdf
5. Frequency Domain Analysis of Sensor Data for Event Classification in Real-Time Robot Assisted Deburring, author Bobby K Pappachan, Wahyu Caesarendra, Tegoeh Tjahjowidodo and Tomi Wijaya https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5492292/#B6-sensors-17-01247