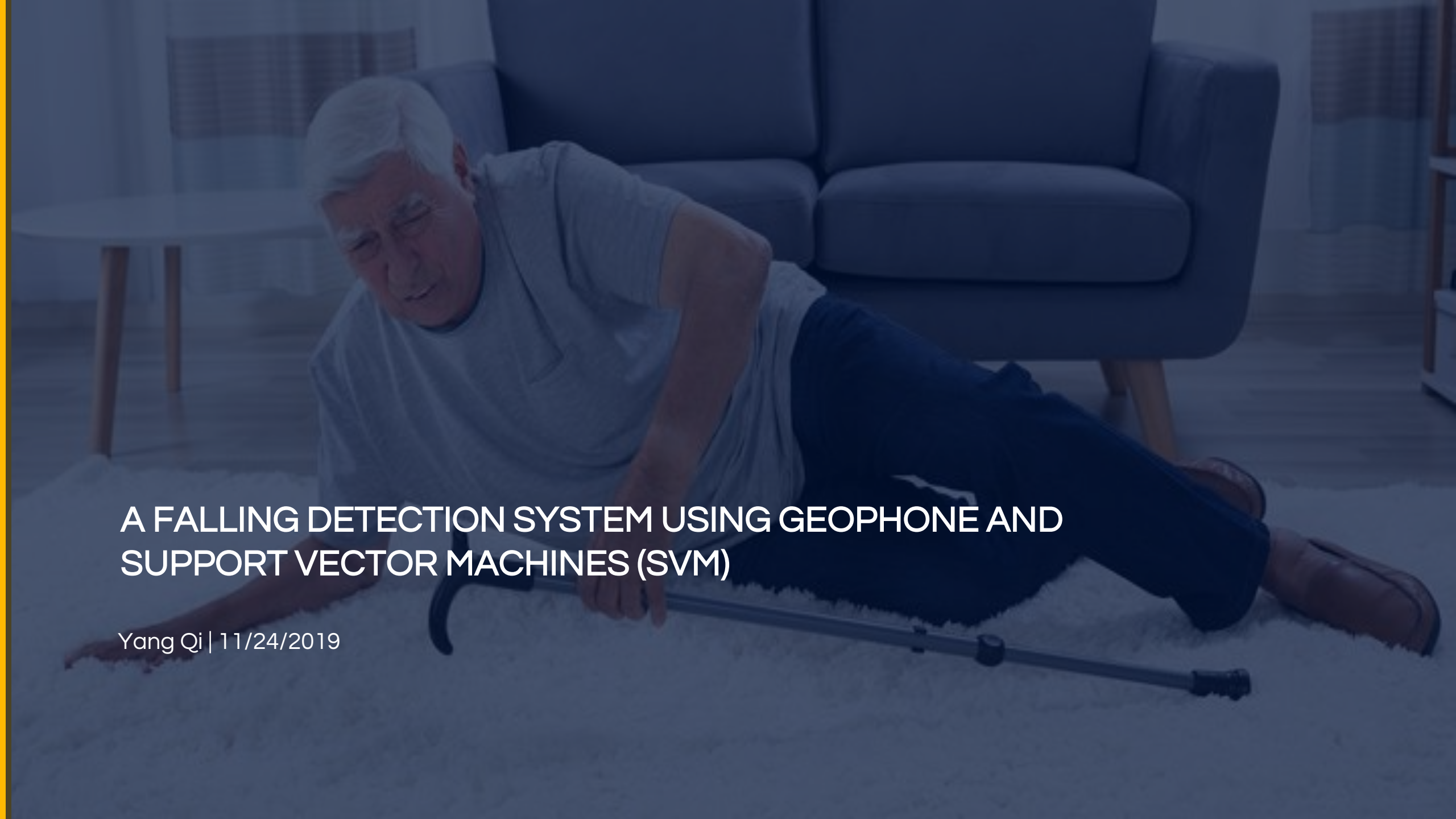


A FALLING DETECTION SYSTEM USING GEOPHONE AND SUPPORT VECTOR MACHINES (SVM)

Yang Qi | 11/24/2019

Facts.

Fact #1

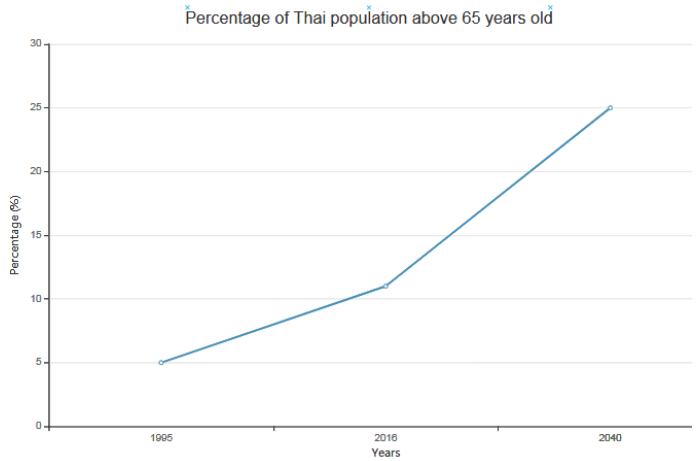


Figure 1: Growth of Thai aging population [1]

Fact #2

As the 2nd leading factor to death in the world, falls cause around 646,000 cases that lead to deaths every year, especially for individuals over 65 years of age in developing countries[2]

Fact #3

Approximately 28 percent of the senior population live alone [3]

Fact #4

In Bangkok, the average monthly cost of long-term care for elders was $464.45 per person, $406 in the northern areas and $638 in the southern areas [4]

Problem Statement

A fall detection system is designed to detect falls in the room from item falls and daily activities of lives.

Performance	User Interaction	Adaptability	Cost
Accurate	User behavior	Assembly condition	$100 per unit
Sensitive	Privacy	Line-of-Sight condition	$10 - $ 15 per month
Real-time	Safety	Noises	

Proposed Approach.

- Sensing Module
- Feature Extraction Module
- Classification Module

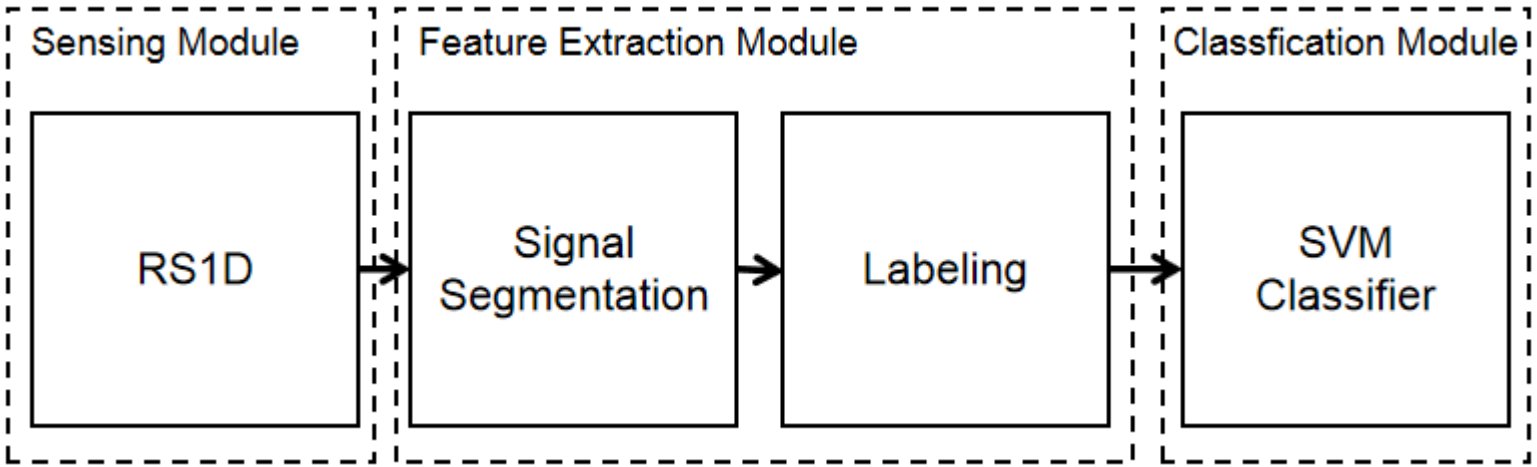


Figure 2: System Overview[1]

Hardware.

- Raspberry Shake RS1D v7
- Sampling rate: 100 Hz; Effective bits: 21 bits (126dB) [5]

Figure 3: Raspberry Shake RS1D Module

Data Segmentation.

- Time Window: 0.25s, to extract signal energy for event detection [6]
- Threshold: obtained by environmental noise feature

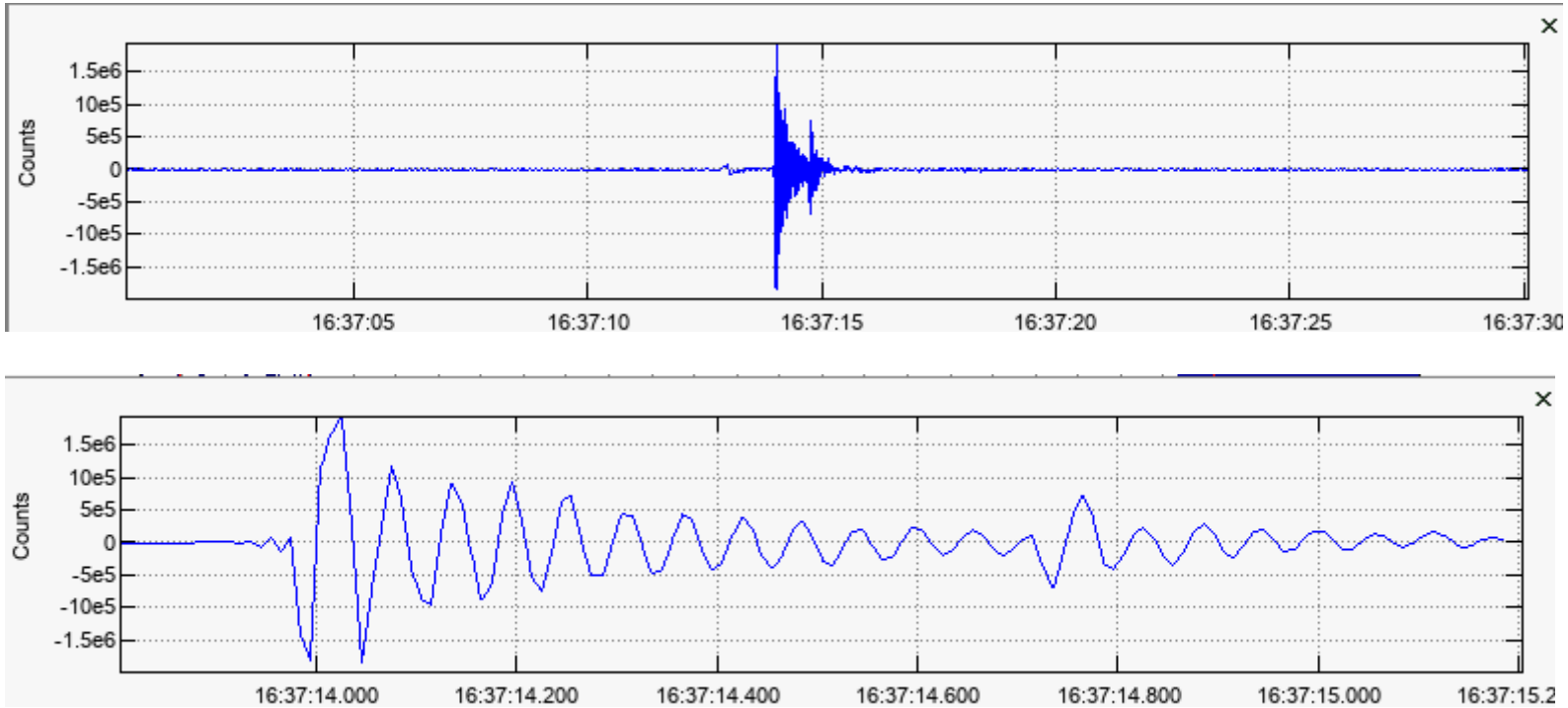


Figure 4: Sample Data Segmentation

Baseline detection.

- Environment configuration:

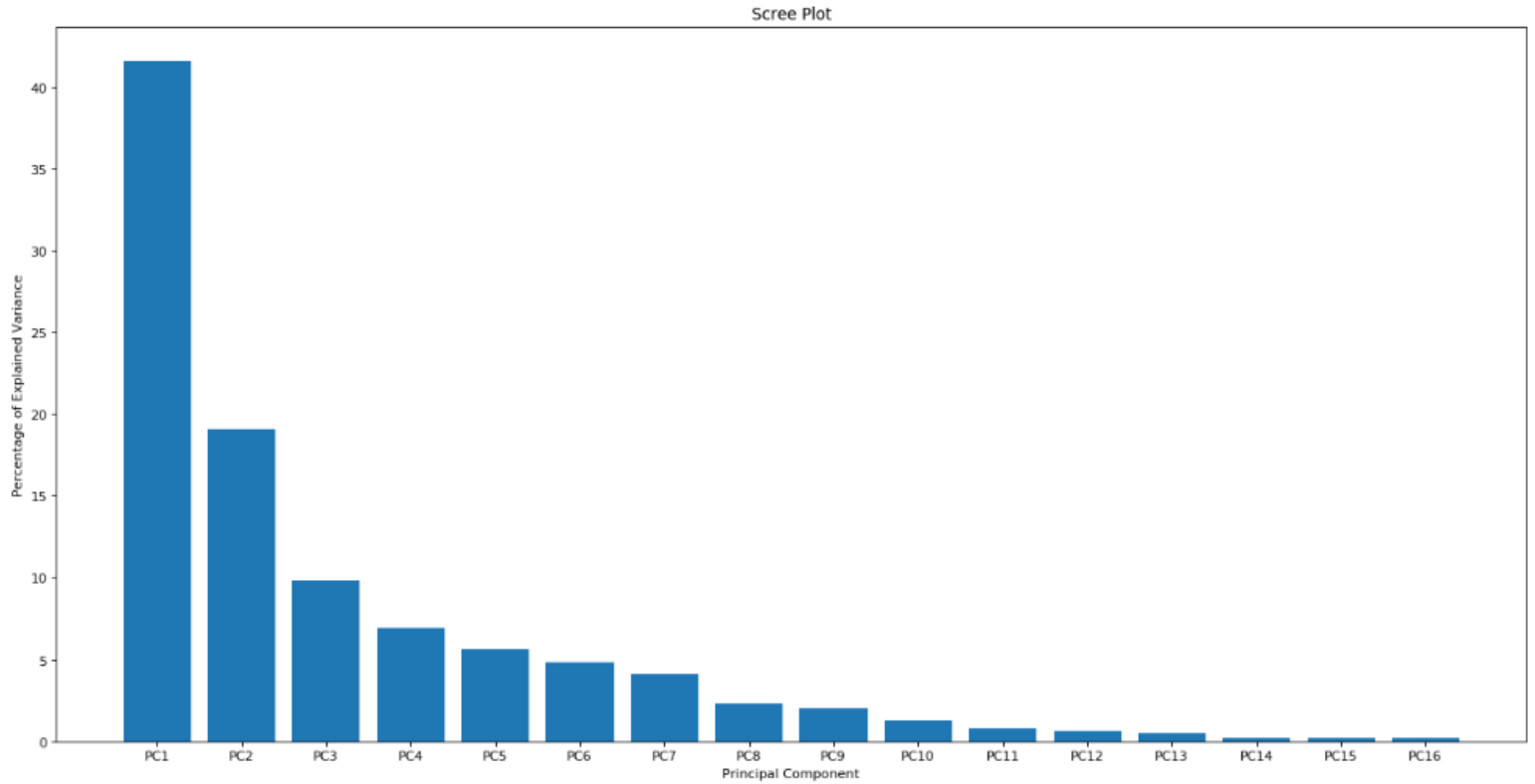
Environmental noise:	6.8E+9 average
	8E+9 max
item fall:	1.17E+10 max
	8.41E+9 min
Daily Activity:	1.20E+10 max
	8.7E+10 min
dummy fall:	3.54E+10 max
	1.03E+9 min
Activity near sensor:	2.8E+10 max
	9.8E+9 min
Threshold:	**Trigger: 2E+10**
	Segment: 1E+10

List of Features.

Time Domain	Description
Duration	Length of the vibration event
Maximum Amplitude Difference	The maximum difference between two consecutive points
Maximum Amplitude Difference Ratio(MADr)	The closer the MADr is to 1.0, the sharper the change between consecutive points
Rate of Dispersion	Variance of the signal
Shannon Entropy	A measure of the possible information expected from the distribution [7]
Maximum Approximation Coefficient	Maximum 1st level approximation coefficient using wavelet transform [8]
Maximum Approximation Coefficient index	Location of the peak value from the wavelet transform
Frequency Domain	**Description**
Maximum frequency spectra	The maximum amplitude of spectrum using Welch approach[9]
Maximum frequency spectra index	Frequency spectrum with maximum amplitude
Spectrum centroid	Where the center of mass of the spectrum is located using numpy.fft [10]
Low frequency range (1 - 20 Hz)	Min, Max, Average Spectra Amplitude (dB)
Medium frequency range (20 - 80Hz)	Min, Max, Average Spectra Amplitude (dB)

Table 1: List of Features

PCA Analysis.




```
[0.41615536 0.1907458  0.09771615 0.06876536 0.05649867 0.04759699
 0.04138007 0.02290409 0.01955664 0.01300259 0.0079934  0.00634422
 0.0049988  0.002467   0.00214151 0.00173336]
```

Figure 5: PCA Scree Plot

```
max_f[0]            0.228460
x_fft_min_low       0.227917
duration            0.224217
Entropy             0.221752
x_fft_max_mid       0.221108
MAD                 0.220155
x_fft_ave_mid       0.217780
x_fft_ave_low       0.216210
ROD                 0.213720
x_fft_max_low       0.208530
max_cA_index        0.206088
max_pxx             0.204197
spectral_centroid   0.202131
max_cA              0.197491
x_fft_min_mid       0.162219
MADr                0.160190
dtype: float64
```

Figure 6: Features' explained variance ratios

PCA Analysis.

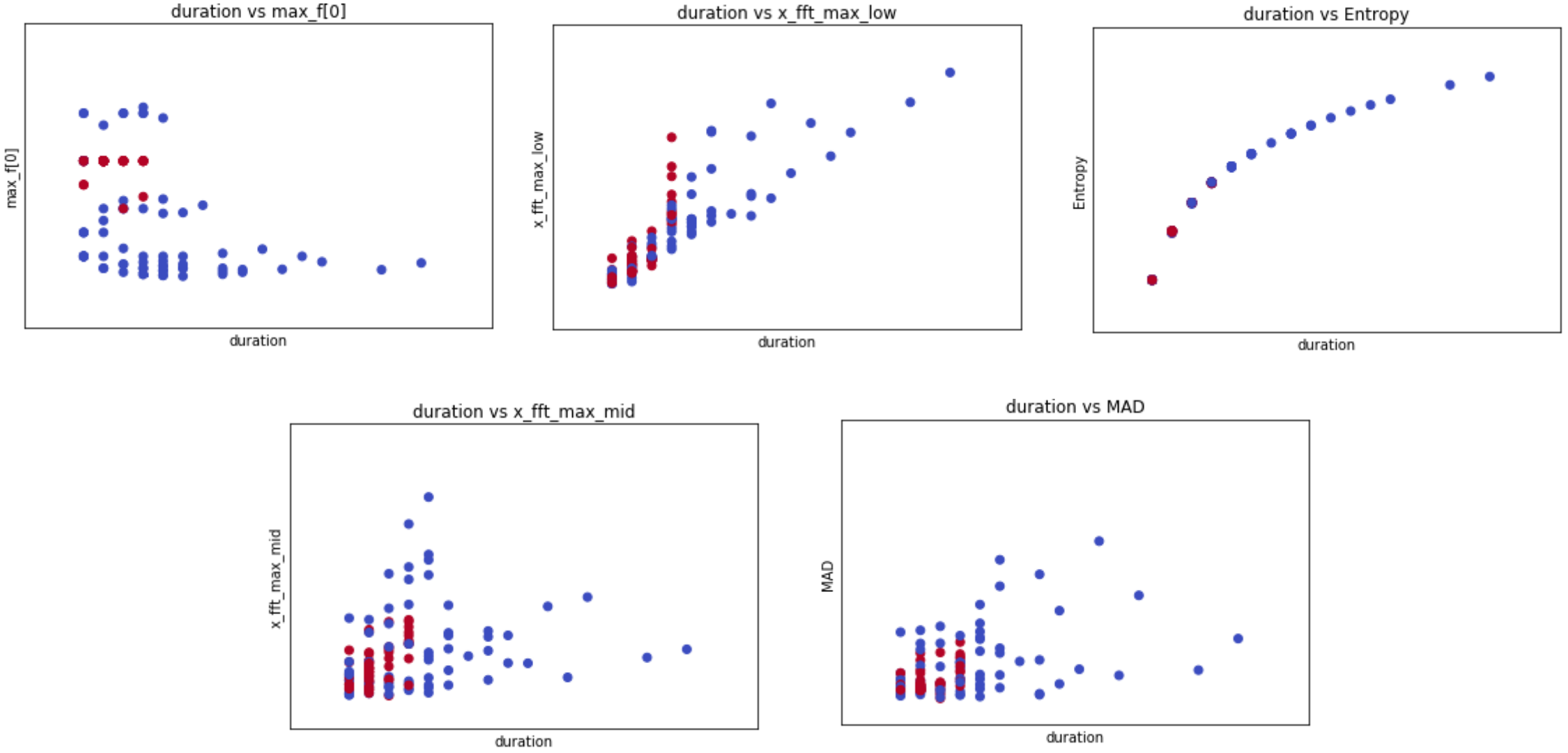


Figure 6: Plots of top-6 featuresd

Data collection.

- Fall 97; non-fall 106
- Primary mechanisms of falling Slipping (52.8%) tripping (26.4%) [11]
- Saved as json file, read into panda.DataFrame

Categories	Number
Forward fall near door	16
Backward fall near door	16
Forward fall near window	15
Backward fall near window	18
Forward fall next table	17
Backward fall next table	15
Falls	97
Walk	30
Run	16
Jump	35
item fall	25
non-falls	106
total	203

Table 2: List of Experiment events

	duration	MAD	MADr	ROD	Entropy
0	125	259610	0.488596	1.043465e-14	6.965784
1	50	29689	0.227883	2.423460e-13	5.643856
2	50	31310	0.248666	2.484697e-13	5.643856
3	50	32271	0.171696	1.147336e-13	5.643856
4	75	17720	0.126841	8.173034e-14	6.228819
...	...	...	...	...	...
101	150	16680	0.148026	1.090722e-14	7.228819
102	50	28458	0.290566	4.345275e-13	5.643856
103	100	47702	0.185753	9.686971e-15	6.643856
104	25	46502	0.362758	8.085954e-13	4.643856
105	25	30927	0.282508	1.001109e-12	4.643856

203 rows × 16 columns

Figure 7: Part of dataset

SVM classifier.

- Data preprocessing
- SVM classifier predict and evaluation

```
[[34  4]
 [ 2 21]]
              precision    recall  f1-score   support

         0.0       0.94      0.89      0.92        38
         1.0       0.84      0.91      0.87        23

    accuracy                           0.90        61
   macro avg       0.89      0.90      0.90        61
weighted avg       0.91      0.90      0.90        61
```

Figure 8: Evaluation of SVM classifier

Demonstration.

Constraints and Future Developments.

- Limited resources
  - From Dummy fall to Human fall
  - More data to train the SVM classifier
- Implementation across different scenarios
  - Adjustable environmental parameters
  - Self-adjusting progress
- Activities of Daily living detection
  - Activity habit observation
  - e.g. Footstep detection [12]

References.

[1]World Bank. Thailand economic monitor - aging society and economy, 2016.
[2]World Health Organization. Falls.
[3] Fabio Bagal, Clemens Becker, Angelo Cappello, Lorenzo Chiari, Kamiar Aminian, Jeffrey M. Hausdorff, Wiebren Zijlstra, and Jochen Klenk. Evaluation of Accelerometer-Based Fall Detection Algorithms on Real-World Falls. PLoS ONE, 7(5):e37062, May 2012.
[4] Yueng Santiago Delahoz and Miguel Angel Labrador. Survey on Fall Detection and Fall Prevention Using Wearable and External Sensors. Sensors, 14(10):19806–19842, October 2014.
[5] Rasbpberry Shake. Specifications for: The original (1d), 2016.
[6] Shijia Pan, Amelie Bonde, Jie Jing, Lin Zhang, Pei Zhang, and Hae Young Noh. BOES: Building Occupancy Estimation System using sparse ambient vibration monitoring. page 90611O, San Diego, California, USA, April 2014.
[7]https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.entropy.html
[8] Gregory R. Lee, Ralf Gommers, Filip Wasilewski, Kai Wohlfahrt, Aaron O'Leary (2019). PyWavelets: A Python package for wavelet analysis. Journal of Open Source Software, 4(36), 1237, https://doi.org/10.21105/joss.01237.
[9] P. Welch, "The use of the fast Fourier transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms", IEEE Trans. Audio Electroacoust. vol. 15, pp. 70-73, 1967.
[10] https://docs.scipy.org/doc/numpy/reference/routines.fft.html
[11]Lausawatchai P, Sirapo-ngam Y, Putwatana P; Related factors and outcome of fall in the elderly. J Gerontol Geriatr Med, 2000, I: 16-23
[12]S. Pan, N. Wang, Y. Qian, I. Velibeyoglu, H. Y. Noh, and P. Zhang, "Indoor Person Identification through Footstep Induced Structural Vibration," Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications - HotMobile 15, 2015.


Q & A

Thank you!