Development of an Enhanced Threshold-Based Fall Detection System Using Smartphones With Built-In Accelerometers

By

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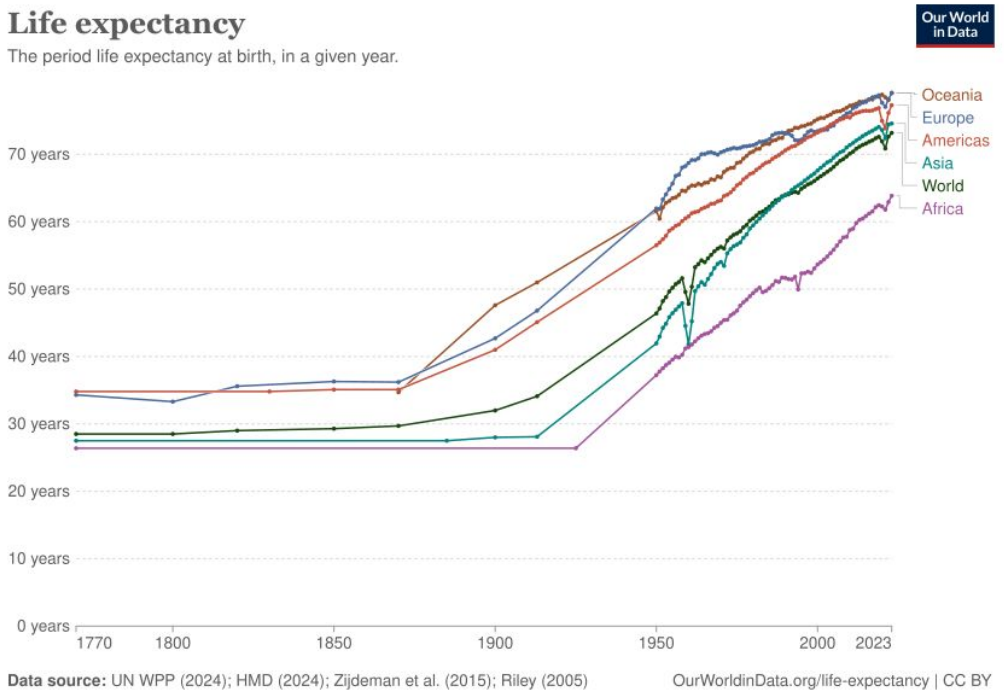
Importance of Fall Detection

- Last decades : huge increase in life expectancy
- Falls are primary accident for elderly people



Fall detection approaches :

- Environmental :
  - Floor vibration -> signal processing + pattern recognition
    -> Problem : with accuracy, specificity, and not all places are good for it (material …)
  - Camera coverage -> pattern recognition
    -> Problem : only works on monitored areas , privacy concerns
- “Wearable” :
  - Shoes -> acceleration + pressure : intrusive (need to always wear specific shoes)
  - Surface electromyography + accelerometer : intrusive (need to wear specific hardware)
  - Smartphone … seems to be the most logical way to do this

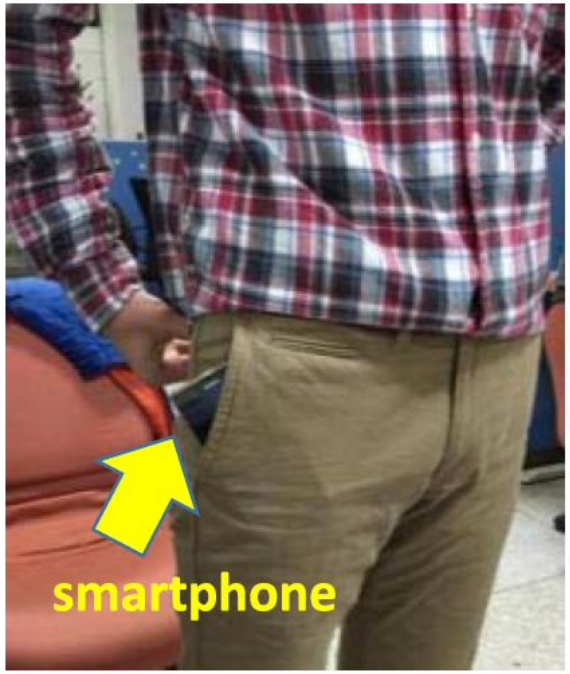
Situation Analysis

- Using android phone -> has accelerometer
- Hypothesis : phone is in (front)pocket

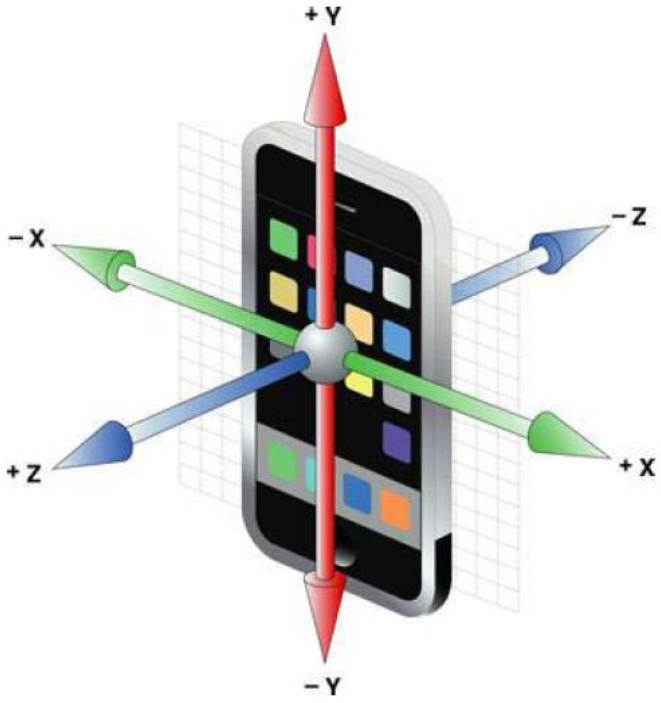
Data :

- X acceleration -> lateral fall
- Z acceleration -> backwards/forwards fall

Sampling 50Hz == once every 20ms (target)



(a)



(b)

Detection Plan

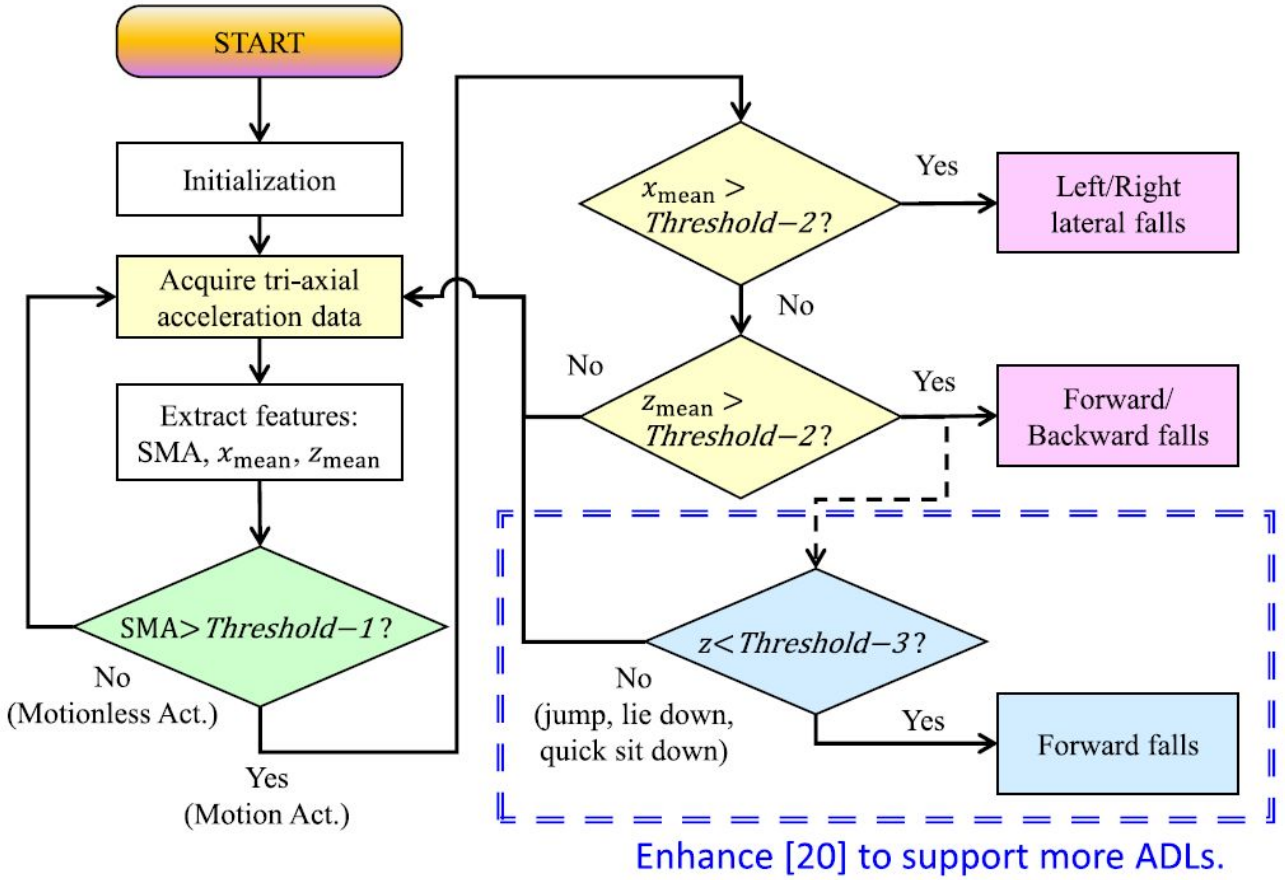
- First : need to distinguish if “noticeable” motion event
- Second : is it fall ? / what kind of fall ?

Problem : many false positives at any stage

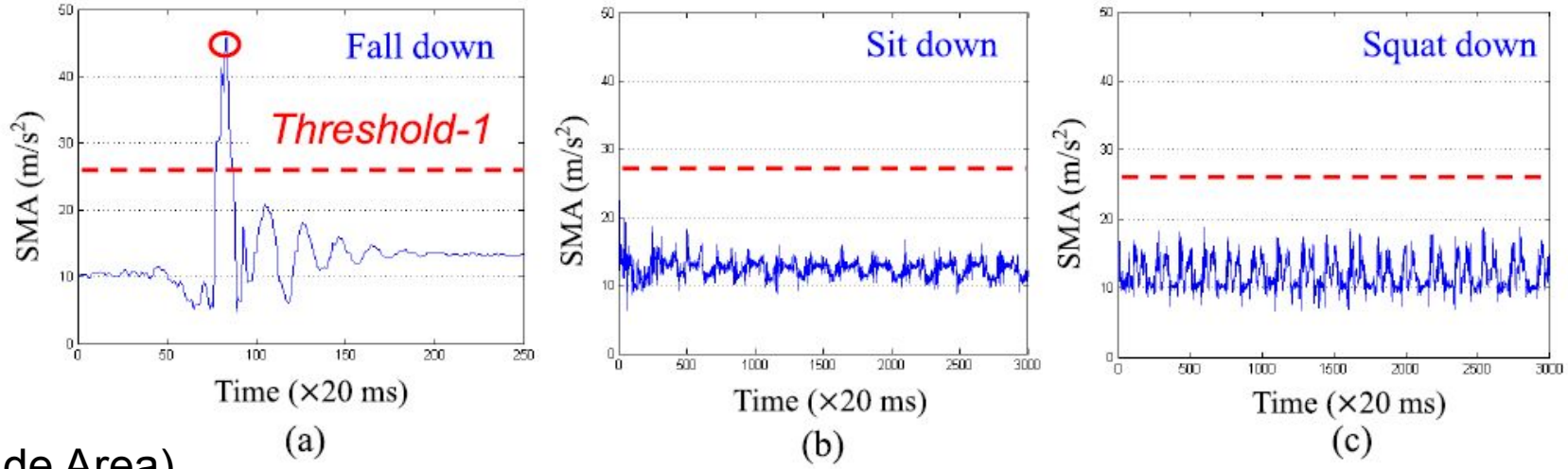
Solution : experimentally calibrated Thresholds

Note : any movement can be a fall, or dangerous …

-> Experimental analysis that covers most cases



Motion Act ?



Calculate SMA (Signal Magnitude Area)

$$\mathrm{SMA}[n] = \frac{1}{N} \sum_{i=n-N+1}^{n} (|x[i]| + |y[i]| + |z[i]|)$$

If SMA less than 27 m/s^2, then it is not a fall .

. SMA VALUES OF NINE HUMAN ACTIVITIES

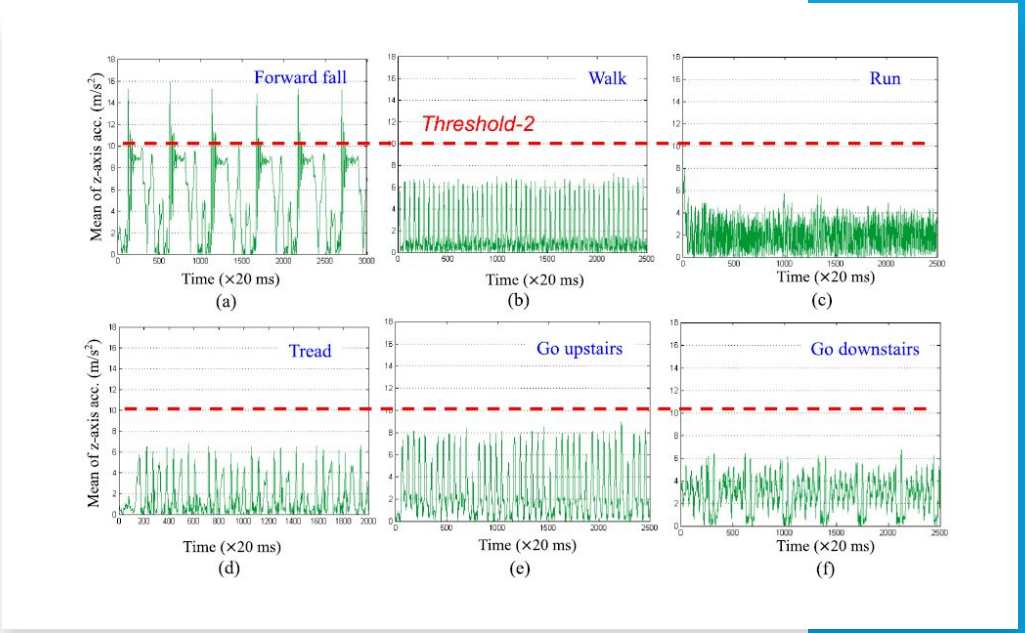
Activities	Walk	Run	Tread	Go upstairs	Go downstairs	Fall down	Sit down	Squat down	Stand up
SMA (m/s^2)	30 +	30 +	30 +	30 +	30 +	30 +	25 -	25 -	25 -

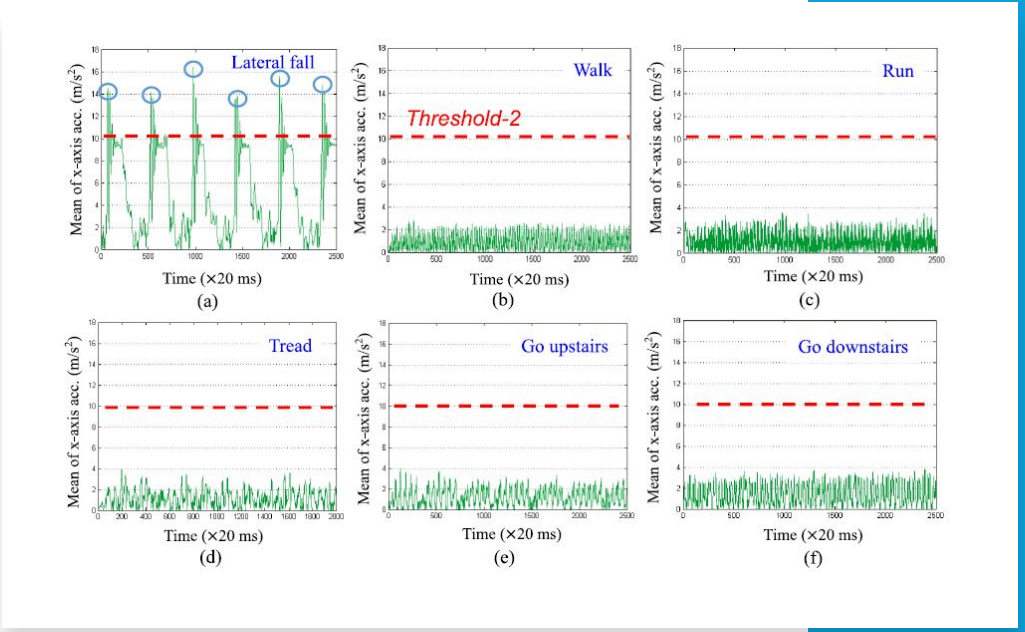
\+ means more.
\- means less.

Threshold = 27 (determined via experimental observations)

Directional Fall : Average of absolute for *x* and *z* axes

$$x_{\text{mean}}[n] = \frac{1}{N}\left(\sum_{i=n-N+1}^{n} |x[i]|\right)$$

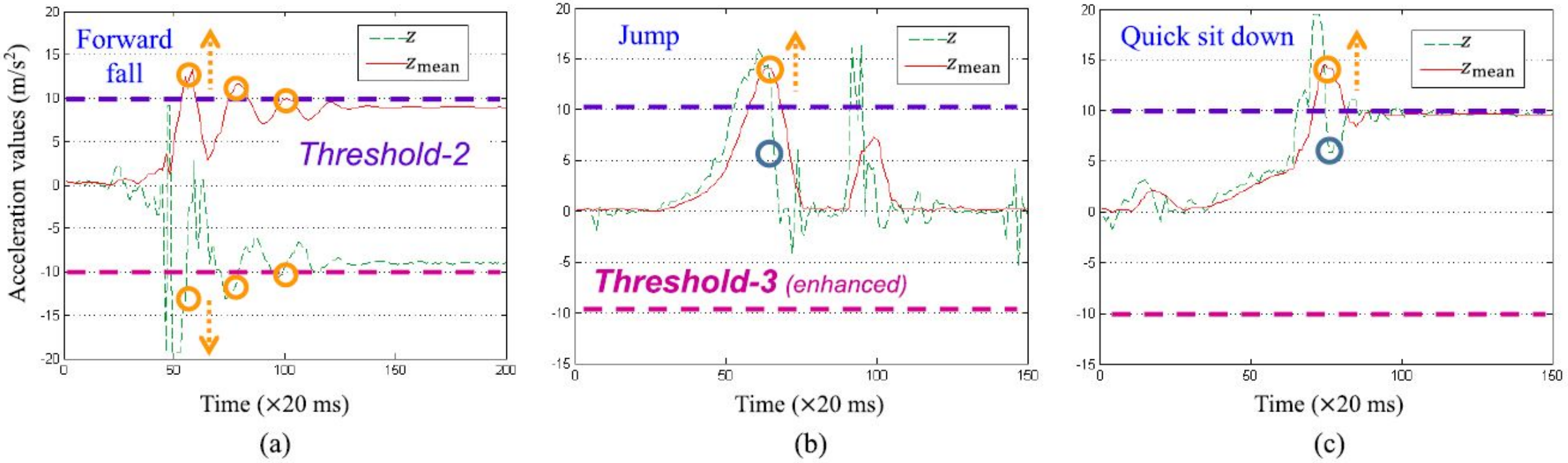




If X axis, it can only be lateral fall

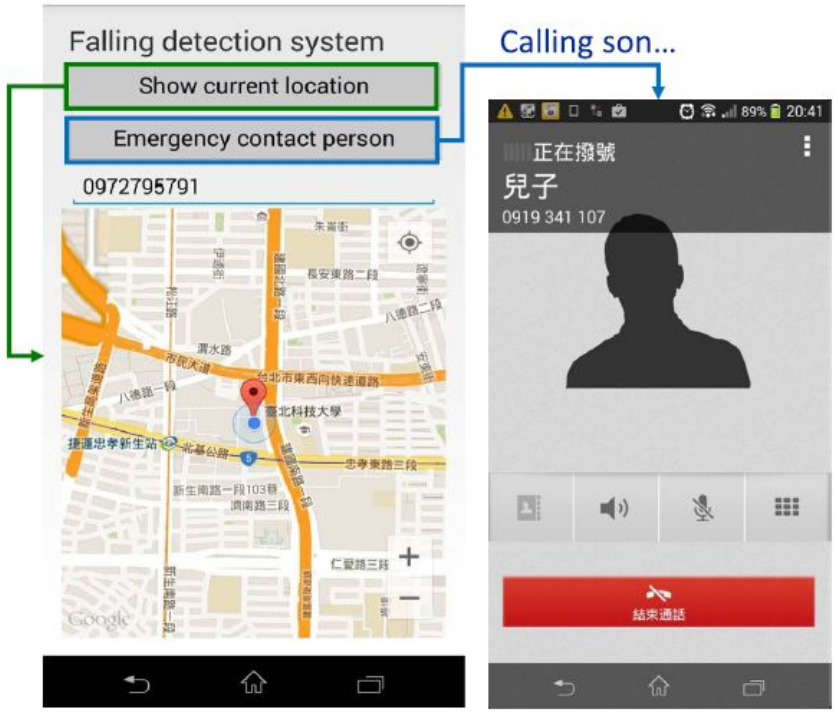
If Z axis, could be forwards/backwards fall

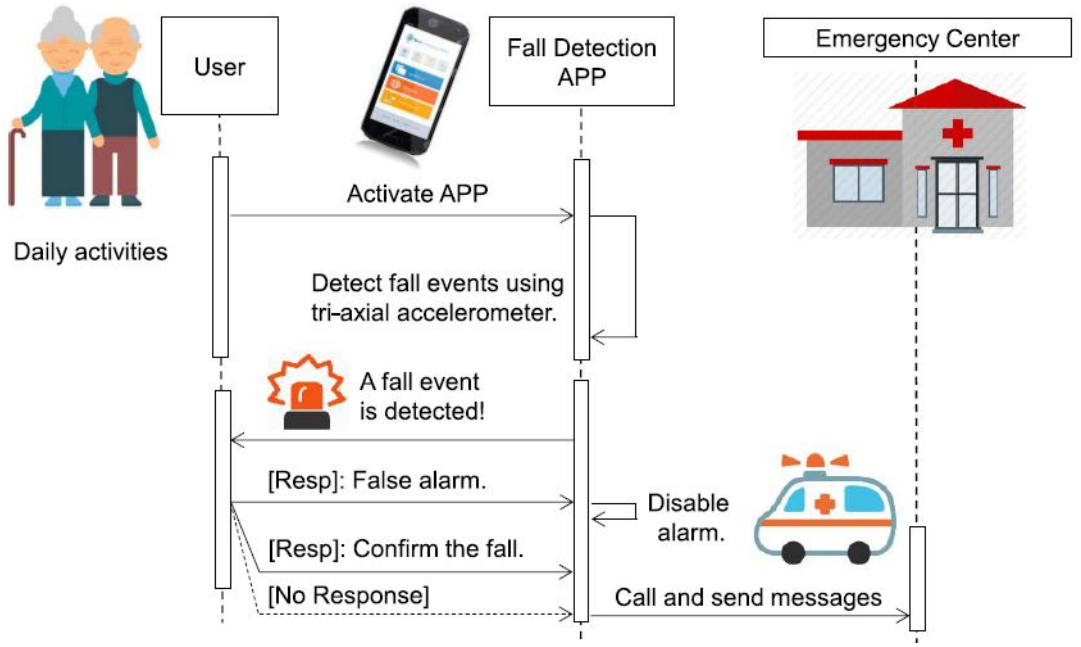
Specific Z-axis analysis



If while meanAbs of z is above 10.05 m/s^2, instant z is below -10 m/s^2, then it is certainly a forwards fall

For other ranges, it could be either a Backwards fall, or a non-consequential event like jumping or sitting.





Paper Implementation and results

- Idea was implemented on Android Platform, as an app that would call an emergency contact and show the current location.

Performance comparison

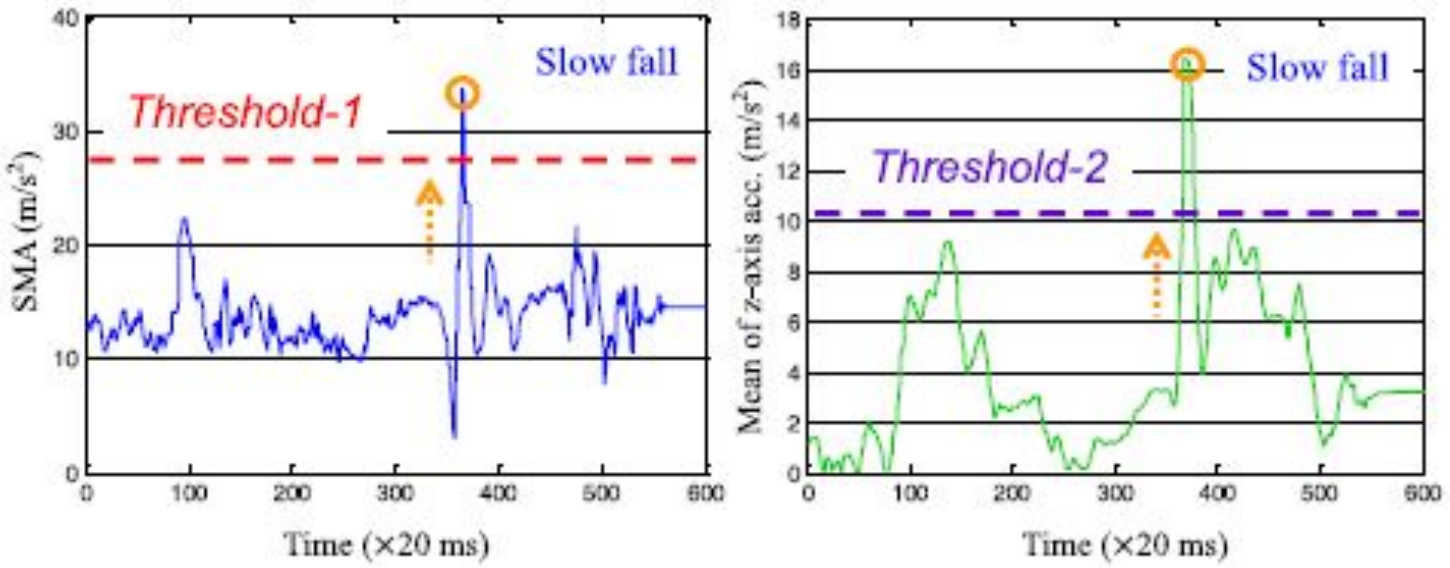
EXPERIMENTAL RESULTS OF THE ENHANCED FALL DETECTION APPROACH

This extended work	Walk	Run	Tread	Go upstairs	Go downstairs	Sit down	Squat down	Stand up	Jump	Lie down	Quick sit down	Fall down (4 types)
Test samples	50	50	50	50	50	50	50	50	50	50	50	100
TP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	96
FP	0	0	0	0	0	0	0	0	0	0	0	N/A
TN	50	50	50	50	50	50	50	50	50	50	50	N/A
Accuracy rate							99.38%					
Detection rate							96%					
False alarm rate							0%					
Computation time							25.33 ms					

Approaches/Indices	Accuracy rate (%)	Detection rate (%)	False alarm rate (%)	Computation time (ms)
[13] Cheng and Jhan	98.23	88	1.27	–
[16] Hsieh *et al.*	98	95.5	0	–
[19] Kau & Chen	98.88	92	0.25	226.43
[20] Our previous work (8 ADLs)	99	96	0.25	17.8
Our previous approach (11 ADLs)	76.15	96	27.45	17.8
This extended work (11 ADLs)	99.38	96	0	25.33

Possible Expansions of this work

- Improve detection of slow fall



- Adapt to different smartphone positions (shirt pocket, backpack, jacket pocket …