應用於居家環境之身體活動監測與評估系統之開發

Development of a Portable System for Physical Activity Assessment in a Home Environment

Che-Chang Yang

Prof. Yeh-Liang Hsu, *advisor*

***HIWIN* Thesis Award 2007**

Optimal Design Laboratory & Gerontechnology Research Center

Yuan Ze University

Physical Activity

- Physical activity can be regarded as any bodily movement or posture produced by skeletal muscles and results in energy expenditure

  [Capspersen *et al*., 1985]

- Long-term activity patterns of daily living are indicative of one's functional ability and overall health status

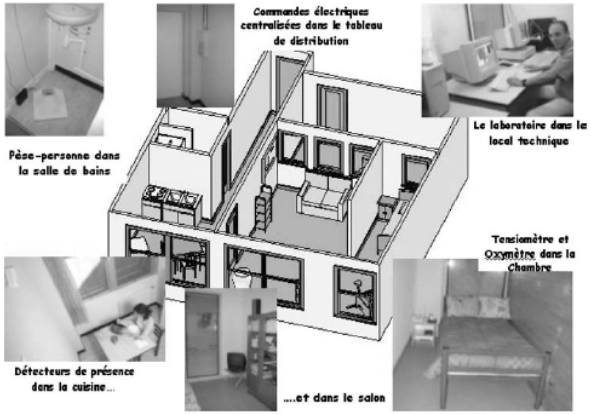
  [Mathie *et al*., 2003]

- Quantitative assessment of daily physical activity at home is a key determinant in evaluation of health and the quality of life of subjects with limited mobility and chronic diseases, such as the elders.

  [Foerster *et al*., 1999].

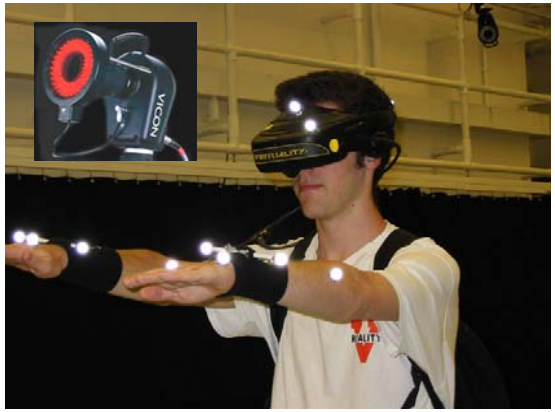
Monitoring Techniques

- **Home-fixed sensor array**
  - Sensors: switches and video cameras
  - Non-invasive monitoring
  - insufficient accuracy in dynamic motion analysis



HIS^2 [Nourg *et al*., 2003]

- **Human motion tracking system**
  - Optical, ultrasonic and magnetic
  - High accuracy in dynamic motion detection and positioning
  - Hardly implemented out of lab-like sites



[Vicon, Inc., 2005]

Monitoring Techniques (*cont'd*)

Wearable (body-worn) systems

- Integrated into ***clothing***, ***wearable devices*** or directly ***skin-mounted***
- Core sensor units: pedometer, gyroscope, accelerometer, barometer, etc.
- Types of data processing: ***off-line*** and ***real-time*** systems
- Convenient, less discomfort
- Provide detailed information on dynamic activities and postures
- An appropriate alternative for human activity monitoring at acceptable cost

[Aminian, Najafi, *et al.*]

Purpose of the Research

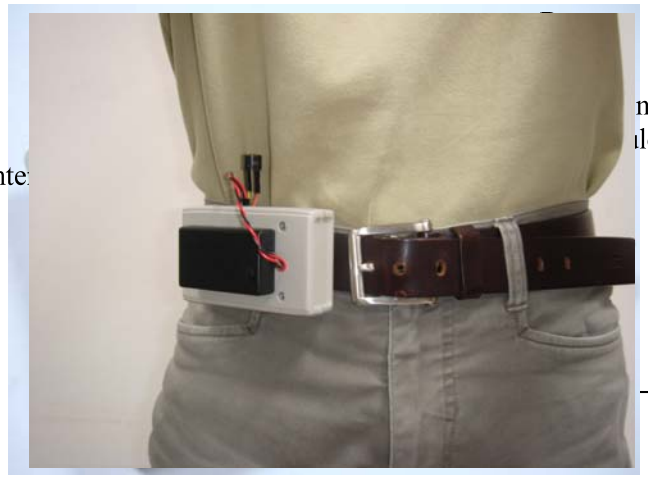
- Develop a home tele-health-based physical activity monitoring system utilizing wearable motion detector for ambulatory use.

Main system features:

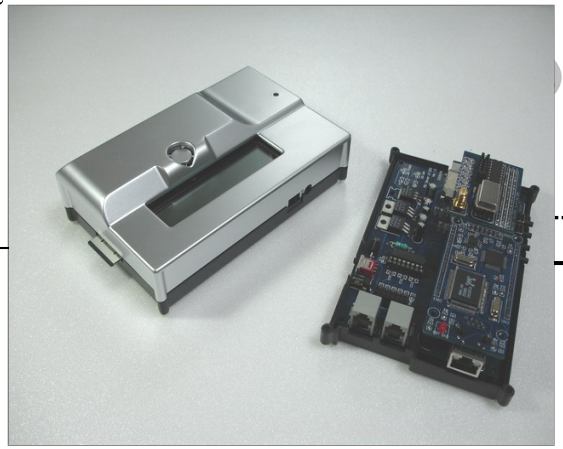
- Mobile sensing architecture (wearable system)
- Home tele-health based application
- Continuous monitoring and real-time identification of human movements
- Irrecoverable fall detection and immediate alarm report
- Provide the information on preliminary assessment of physical mobility level

System structure

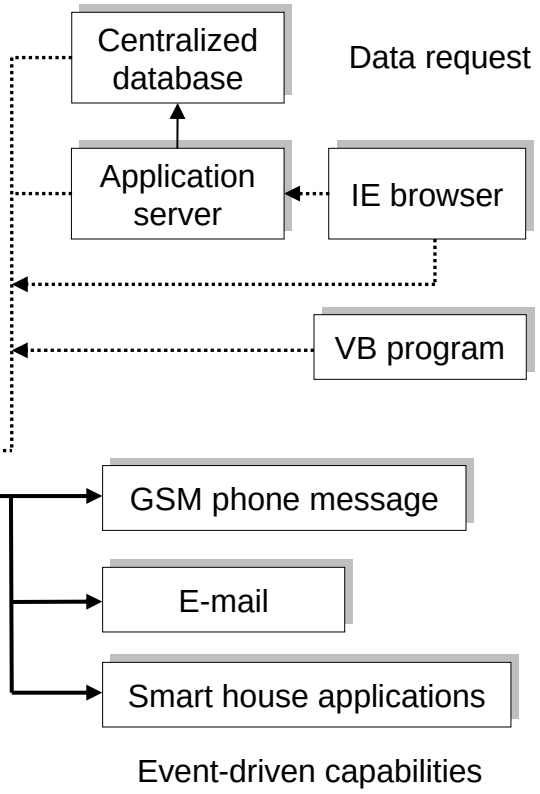
Measured signals → **Real-time data processing** → **Wireless event delivery** → **Data storage** → **Data management**



Wearable motion detection unit (MDU)



Household distributed data server (DDS)



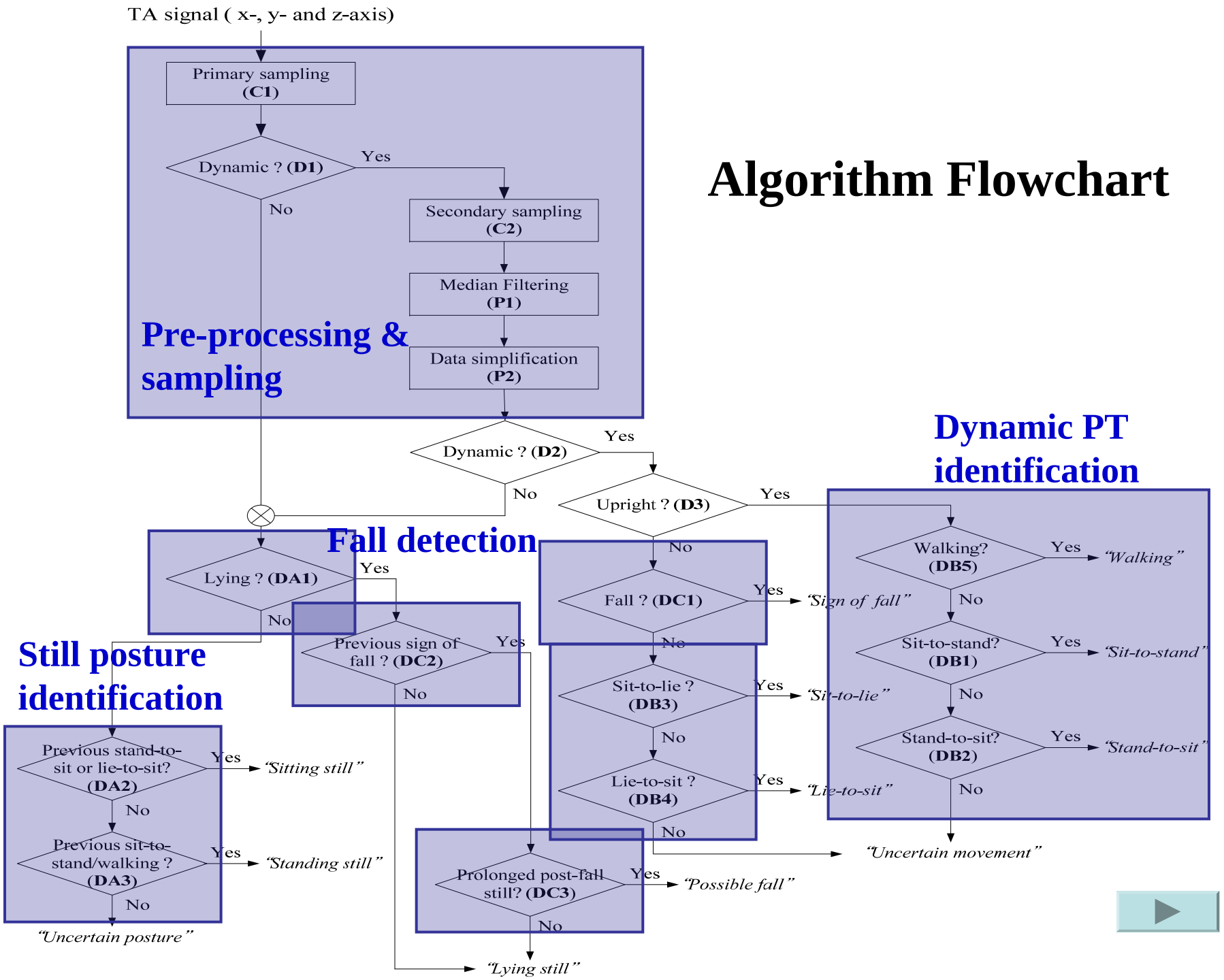
Algorithm Design

- The algorithm for real-time identification is designed to identify nine target items:

3 still postures:	*Lying*, *sitting*, *standing*
6 dynamic activities:	*Sit-to-stand*, *stand-to-sit transitions*
	Lie-to-sit, *sit-to-lie transitions*
	Walking
	Possible fall (irrecoverable)

- Identify one of the target items in every 2.5s or 0.5s consecutive interval
- An irrecoverable fall is recognized in 15s

Algorithm Flowchart



Principle of signal identification

- The sensor outputs ➔ trunk orientation & accelerations
- The trunk orientation is used to determine:

  ➔ *Dynamic/still*, *upright/lying*, *lie-sit transitions*
- The vertical acceleration component for

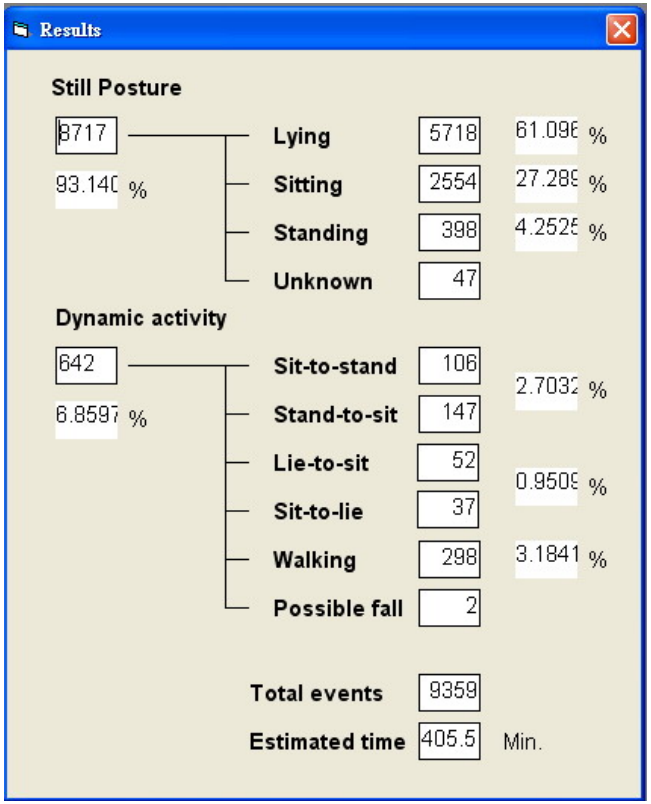
  ➔ *Sit-stand transitions and walking*
- Distinguishing upright still postures (sitting or standing) requires the information of previously identified posture transitions or movements
- Triaxial acceleration integral is used to determine whether a fall occurs
- 15 ostensibly healthy subjects in various ages were recruited to extract parameters and thresholds for processes in the algorithm.

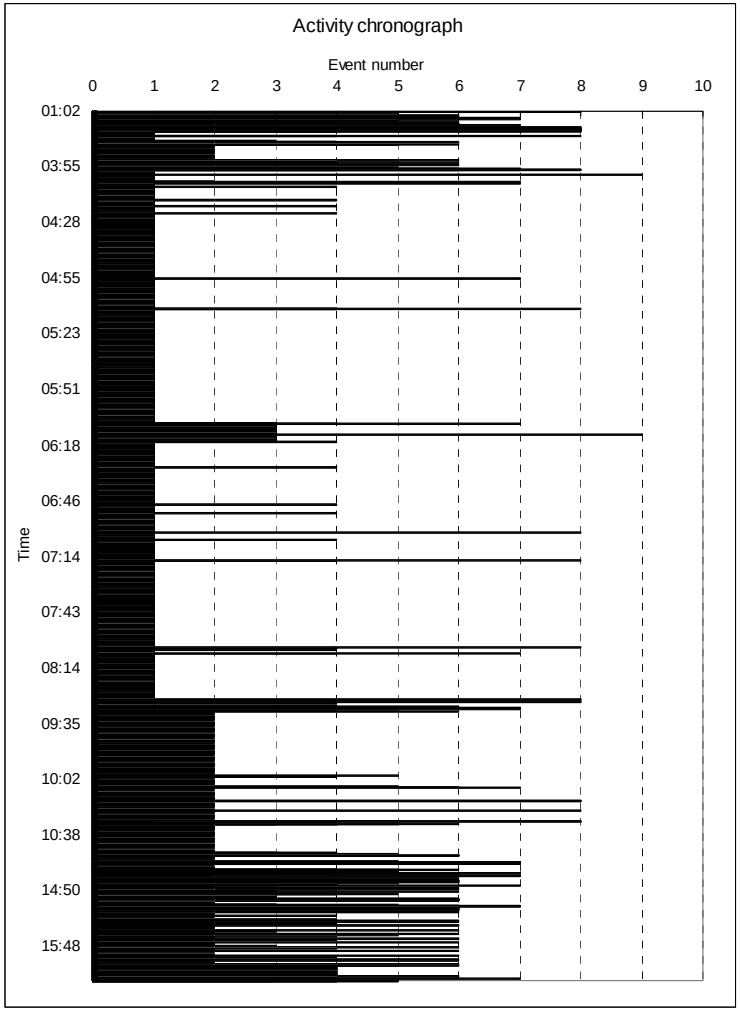
Performance Evaluation

10 subjects were recruited for a laboratory-based test in evaluating sensitivity and specificity of the algorithm

Posture/activity	*Sensitivity (%)*	*Specificity (%)*
Lying still	100	*
Sit-to-stand	92.2	91.5
Stand-to-sit	95.6	88.5
Sit-to-lie	92.2	99.5
Lie-to-sit	95.6	88.0
Walking	98.9	99.5

Example of Long-Term Monitoring





No.	Event
1.	Lying still
2.	Sitting still
3.	Standing still
4.	Walking
5.	Sit-to-stand
6.	Stand-to-sit
7.	Lie-to-sit
8.	Sit-to-lie
9.	Possible fall

Discussion & Conclusion

- **Achievements and implementation:**
  1. Distinguish rests and activities, and further identify postures or posture transitions and walking movement
  2. Provide sufficient information of activities of daily livings
  3. Technically feasible for long-term ambulatory monitoring in home environment
- **System limitations:**
  1. Restricted computation capability and memory capacity
  2. Real-time data processing issue
  3. Limited precision in measurement [Elble, 2005]

Current efforts and future work

- **Application fields need to be identified**

  Collaboration with nursing home, rehabilitation, etc.

- **Advancing instrumentation**

  ZigBee™ or Bluetooth® modules

  Enhanced functions

  Commercialized-level product design

- **Robustness and reliability in ambulatory evaluation**

  Large-scale ambulatory tests and evaluation

- **Toward an ubiquitous computing environment**

  Integration with different ADL-related and vital sign monitoring systems

Thank you for your attention!

Che-Chang Yang

E-mail: s958702@mail.yzu.edu.tw

TEL: +886-3-4555726

Optimal Design Laboratory & Gerontechnology Research Center

Yuan Ze University

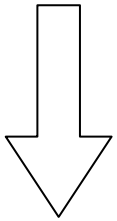
Sampling & Pre-processing

- **Dual-stage data sampling**
  - 60Hz at 0.5s (still) or 2.5s (dynamic), respectively.
  - Preserve the data integrity in sampling dynamic movement
- **Median filtering (n=3), low-pass filtering (f_c=50Hz)**
  - Eliminate high frequency spikes over data spectrum
- **Data simplification**
  - One-third scaling (averaging)
  - Reduce the amount of data while preserving most apparent characteristics of the original signals.

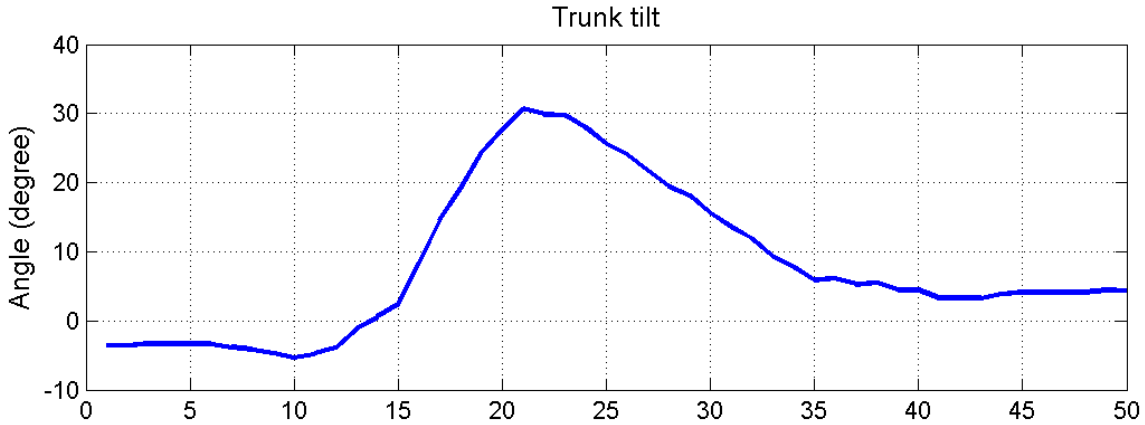
Slope Mapping Technique

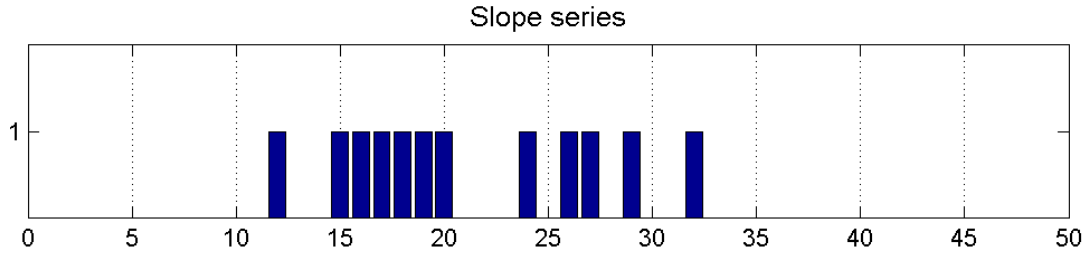
- Commonly used to register apparent changes and characteristics over the data spectrum
- Time-domain data processing

Analog signal



Binary sequence

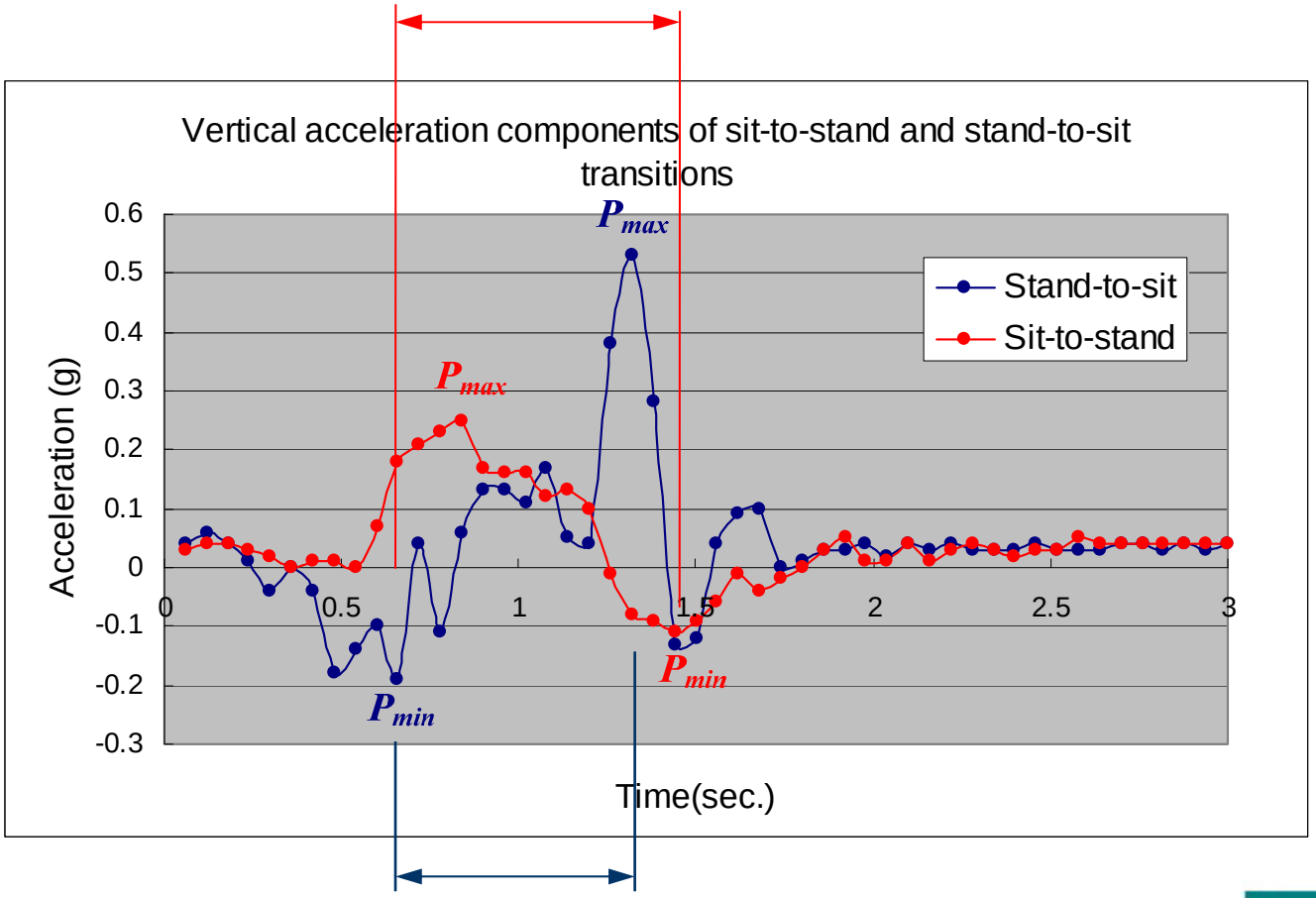




Acceleration pattern of sit-Stand Transition

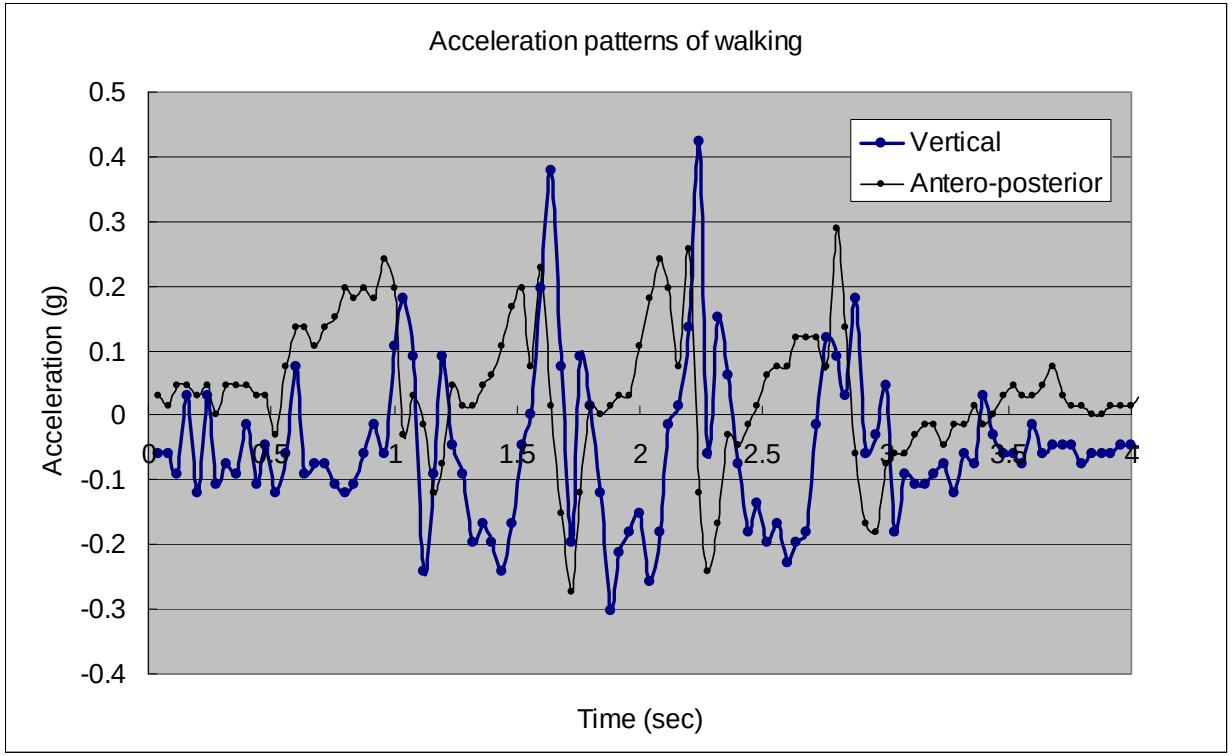
Identification criterion:

1. Peak order 2. peak distance 3. Peak values



Acceleration pattern during normal walking

- The pattern of walking is characteristic of a majority of apparent acceleration changes and higher peak values in vertical direction.



Identification procedure for fall detection