

Detecting human motion: Introducing step, fall and ADL algorithms


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I. CAUSE OF RESEARCH



Rising problem

- Elderly people = fastest growing segment of the population
- 2050: 27% of Belgian population > 65y
- 2020: people who live with serious limitations
-> increase of 25%

⇒ Huge strains on health care services
⇒ Cost reduction objectives in Public Health Services



Rising problem – Press releases

Brussels, 29 April 2009

2009 Ageing Communication: a renewed strategy for tackling Europe's demographic challenge

Aging Population & Healthcare Reforms Driving Russian Pharma
Mar 27, 2009

Article: Growing Elderly Population in the United States Spurs Demand for Disposable Gloves.
set in Russia has medical market is

Article from: PR Newswire | Article date: August 5, 2002 | [Copyright](#)

SAN JOSE, Calif. -- As the number of aging Baby Boomers requiring surgeries and other healthcare services increases in the United States, there will be a corresponding rise in demand for disposable gloves.

New analysis from Frost & Sullivan (<http://www.healthcare.frost.com/>), U.S. Disposable Gloves Markets, reveals that revenues in this market totaled \$1.39 billion in 2001, and are projected to reach \$1.54 billion by 2008.

Manufacturers have several opportunities for growth, as the trend among end users shifts from traditional powder natural rubber latex (NRL) to powder-free NRL and synthetic gloves. This transition is largely induced by the presence of...

...The phenomenon of a rapidly aging population can no longer be considered to be confined only to affluent nations, a World Health Organisation (WHO) official said here Wednesday.




What do the elderly want?

- Wish of elderly for **independence** and **keep living in their own houses**

⇒ Combine the problem and patient's demand

⇒ Increasing number of high risk populations (elderly, revalidation, ill,...) will be living alone at home



Healthcare statistics

- Fall = main cause of hospitalization for 65+ people
- 30% of older people fall at least once a year
- Fall responsible for 70% of accidental deaths of 75+ persons

➔ Clear necessity for an automatic fall detection system.



Summary

Request for a system which is able to monitor the movements and falls of the elderly and other patients suffering from muscle weakness.
The emphasis lies primarily on fall detection.

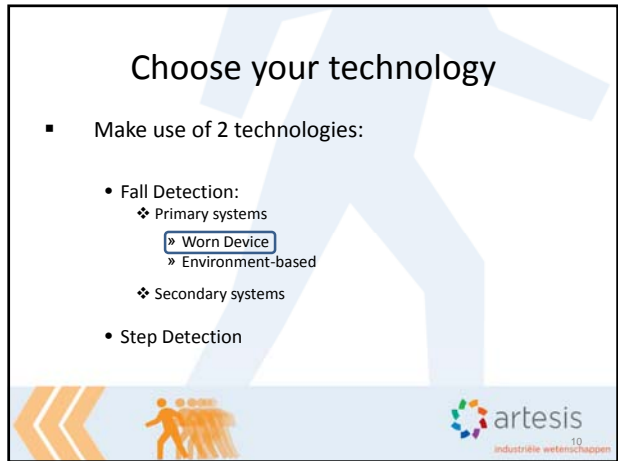


II. SOLUTION



Choose your technology

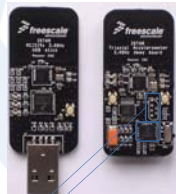
- Make use of 2 technologies:
 - Fall Detection:
 - ❖ Primary systems
 - » Worn Device
 - » Environment-based
 - ❖ Secondary systems
 - Step Detection



Choose your equipment

- Freescale Zstar Board

- Advantages:
 - ❖ Wireless (ZigBee)
 - ❖ Plug & Play
 - ❖ Cost price: 100 \$
- Disadvantages:
 - ❖ Limited range (15m)

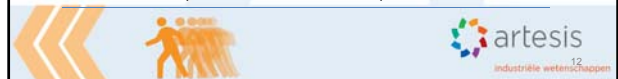


BDM-interface
MMA7260QT



Where do we place the sensor?

	Advantages	Disadvantages
Foot	+ Zero Detection + Large swing	- Difficult for fall detection
Thigh	+ Similar signal to foot	- Fluctuations due to movement other leg
Torso	+ Constant orientation to user's heading + Easy to attach	
Waist	+ Hip swing	- Disturbed movement in case of hip surgery
Head		- Head movements
Wrist	+ Easy to wear	- Unpredictable reflexes

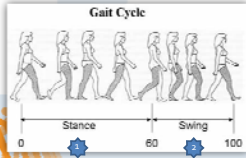



III. STEP DETECTION



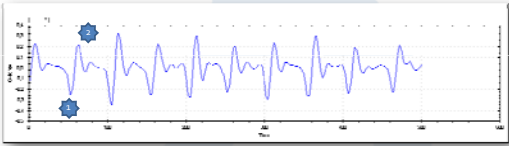
Step Detection

- Model of human motion during walk:
 - > repeated cyclical movement that is remarkably consistent
- Clycical movement: 2 parts:
 - Stance phase: foot placed on the ground
 - Swing phase: foot lifted off the ground and brought forward





Link the signal with the phases



- These 2 phases can be recognized in accelerometer signal by 2 peaks



- Stance Phase
- Swing Phase



Algorithm: How it works?





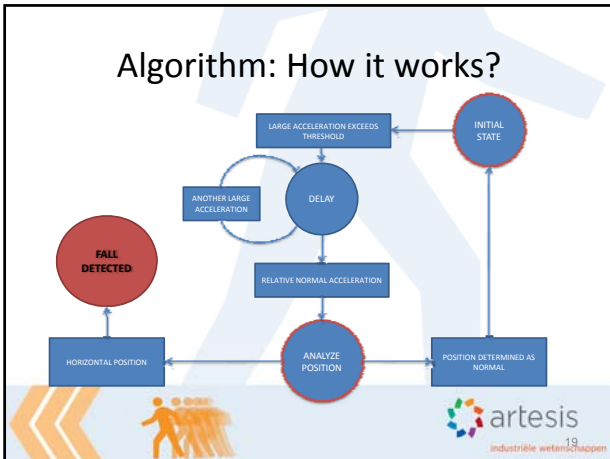
IV. FALL DETECTION



Fall Characteristics

- End of a fall characterized by an impact and horizontal orientation of the faller.
- Detect both or one of these events
- Detect the shock by using a threshold technique

$$\text{Magnitude vector } r = \sqrt{(x^2 + y^2 + z^2)}$$




V. POSTURE DETECTION

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Posture Detection

- Placement of an extra thigh sensor creates the possibility to detect 3 postures:
 - Sitting
 - Lying
 - Standing

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VI. VALIDATION

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Validation in 2 parts

A. Experimentation part:
Used to debug our system and to become an accuracy percent that satisfies the requirements.

B. Objective Validation:
Used to validate our methods

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Validation step detection

- Conditions:
 - Terrain with various obstacles and subsoils
 - Fast walking, slow walking, stumbling
 - Carrying an object or not
 - Young and old persons

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Validation step detection

A. Experimentation part:

- Several series of 100 steps
- Pedometer as a reference

#	Steps Taken	Pedometer	Algorithm	Type
1	100	101	101	Normal walking
2	102	101	102	Normal walking
3	101	99	107	Normal walking
4	99	100	100	Normal walking
5	100	102	102	Normal walking
6	100	100	102	Fast walking
7	100	99	96	Stumbling
8	100	100	102	Normal walking
9	100	98	104	Doing activities
10	100	89	103	With charge
11	100	89	101	With charge
12	100	100	98	With charge
13	100	100	98	With charge
14	100	99	102	With charge
15	100	98	105	With charge
16	100	100	103	With charge
17	9	/	9	Elder subject
18	16	/	16	Elder subject
	100%	97.80%	97.78%	



Validation step detection

B. Objective Validation part:

- Several observers:
 - Reference human observer who sees the events
 - Human observer who makes use of sensor data and doesn't see the events
 - Pedometer
 - The Mems Motion Detection system

- Score:
 - Signal observer: 92,4 %
 - Pedometer: 92,8 %
 - Mems Motion Detection system: 92,2 %



Validation fall detection

Conditions:

- Gym with large crash mats
- Crash mats with variable thickness
- Various activities (lying, jumping,...)



Validation fall detection

A. Experimentation part:

- 20 series of 5 falls
- Five possible fall variations:
 - Fall forward with legs straight
 - Fall forward with knee flexion
 - Fall sideward
 - Fall backward without support
 - Fall backward with support

- Score:
 - Mems Motion Detection system: 97% accuracy



Validation fall detection

B. Objective validation part:

- Several observers:
 - Reference human observer who sees the events
 - Human observer who makes use of sensor data and doesn't see the events
 - The Mems Motion Detection system

Score:

#	Events Observed	Falls Observed	Data Observer	Algorithm	False Pos.	False Neg.
1	10	5	6	5	0	0
2	21	10	12	12	2	0
3	5	5	5	4	0	1
4	5	5	5	5	0	0
5	5	5	4	4	0	1
6	5	5	5	5	0	0
	100%	93%	93%			



Validation summary

- Overall:
 - System delivers sufficient accuracy but can be enhanced by for instance:
 - ❖ Dynamic thresholding
 - ❖ Parameter tweaking based on patient data

- Other systems:
 - G. Perolle: Fall detection (90%)
 - A. K. Bourke: Fall detection (93,3%)



The End

Thanks for your attention!



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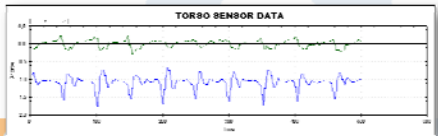



APPENDIX




Detect on x,y or z axis?

- Both horizontal Z-axis as well as vertical Y-axis data is usefull
- Due to experiments:
 - Y-axis gives the best result, Z-axis fails while making turns

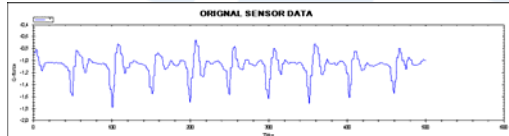
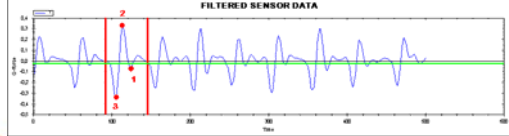



Need for filtering

- Used to reduce unwanted high frequency elements and noise
- Which filters?
 - Kalman filter:
 - ❖ reduces influence of artifacts
 - Average filter:
 - ❖ smoother signal
 - ❖ removes high frequency components
 - Gravity filter:
 - ❖ Compensate gravity to bring 3 axes to 0 g




In practice


Fall Detection methodology

- **Sensor position?**
 - Make use of a sensor attached to the torso
- **Data filtering?**
 - Due to experiments we have to conclude that unfiltered data works better than filtered data
 - ❖ Reduced computing effort
 - ❖ Avoid peak cut-off



In practice

- Algorithm based on peak detection of **data** from the **sensor**.

