Current art of Fall detection

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Title	Authors	Published in
~~Fall detection – Principles and Methods~~	~~N. Noury, A. Fleury, P. Rumeau, A.K. Bourke, G. Ó Laighin, V. Rialle, J.E. Lundy~~	~~Proceedings of the 29th annual international conf. of the IEEE EMBS (2007)~~
Approaches and Principles of Fall detection for Elderly patients	Xinguo Yu	e-health Networking, Applications and Services, 2008. HealthCom 2008. 10th International Conference.
Survey and Evaluation of Real-Time Fall Detection Approaches	James T. Perry, Scott Kellog, Sundar M. Vaidya, Johg-Hoon Youn, Hesham Ali, Hamid Sharif	High-Capacity Optical Networks and Enabling Technologies (HONET), 2009 6th International Symposium
Survey of Fall Detection and Daily Activity Monitoring Techniques	Farrukh Hijaz, Nabeel Afzal, Talal Ahmad, Osman Hasan	Information and Emerging Technologies (ICIET), 2010 International Conference

Taxonomy

- Availability dependent (Location or Technology) solutions
  - Computer vision
  - Infrared
  - Acoustic
  - Vibration
- Ubiquitous solutions
  - Walking devices
  - Level switches
  - Kinematics

Availability dependent solutions

(Location or Technology)

Computer vision – approaches

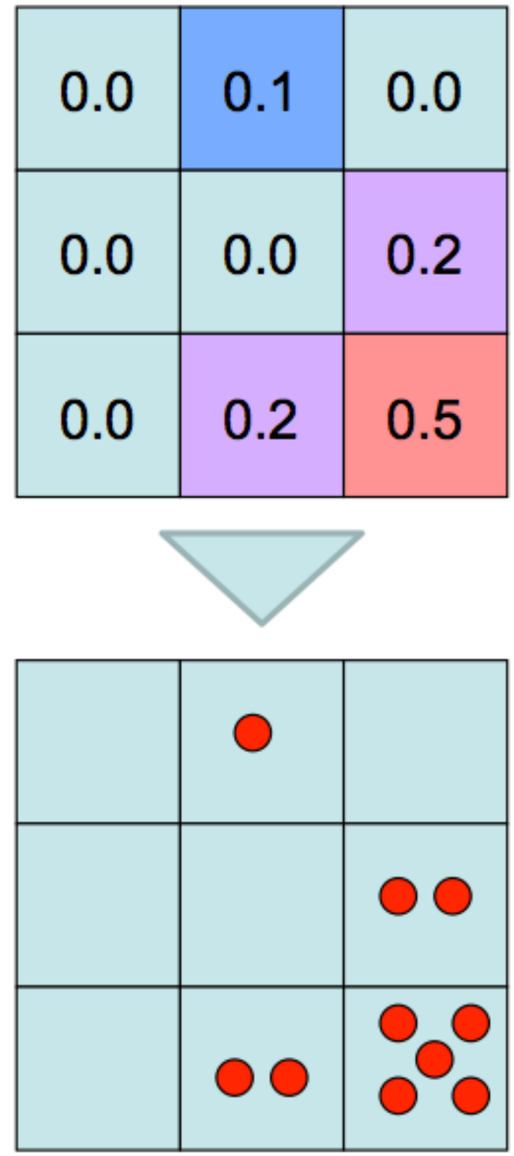
- Inactivity detection
- Polygonal orientation (body) analysis
- 3D head motion analysis

Computer vision – prior art

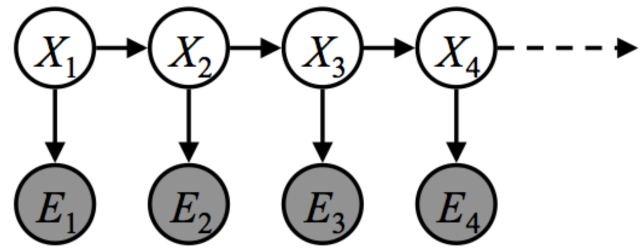
- Cucchiara (2004)
  - Lying and static over a threshold of time
  - Up to 90% success
  - In 2007 suggested 3D cameras, using body shape to infer falls
- Nait-Chariff (2004)
  - 360 degrees camera
  - Inactivity detection
- Hsu (2005)
  - Body shape: Deformable triangulation to classify postures from 3D cameras

Computer vision – prior art

- Rougier (2005 – 2007)
  - Monocular 3D head tracking using Particle filter
  - Vertical and horizontal head velocity are compared against a threshold
- Miaou (2006 - 2007)
  - 360 degrees camera
  - Height to width ratio of enclosing rectangle
  - 78% success with out personal data up to 90% with



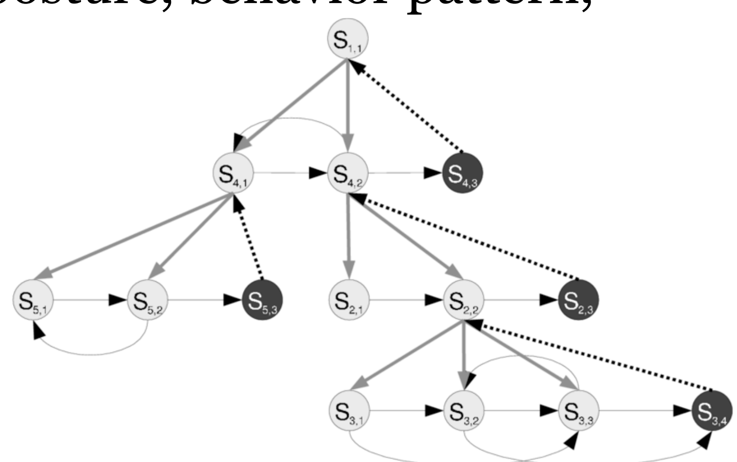
Computer vision – prior art



- Anderson (2006)
  - 3 fps
  - HMM
    - Height of the enclosing rectangle
    - Height to width ratio of enclosing rectangle
    - Magnitude of the motion vector
    - Determinant of the covariance matrix
  - Trained to distinguish walking, kneeling, getting up, and falling
- Jansen (2006)
  - Stereo camera to acquire depth
  - Body area, orientation, and inactivity

Computer vision – prior art

- Toreyin (2006)
  - HMM
    - Ratio of height to width using HMM
    - Audio difference between talking and falling
- Thome (2006)
  - Hierarchal HMM
    - Orientation of the body blob and posture, behavior pattern, and motion



Computer vision – prior art

- Nasution (2007)
  - Horizontal and vertical projection histograms
  - Angle between the last standing posture with current enclosing rectangle
  - Falling speed
  - About 90% success
- Williams (2007)
  - Smart camera network using a number of low resolution cameras
  - Using very low frame rate
- Lin (2005 – 2007)
  - 2D shape directly from compressed data

Computer vision – prior art

- Huang (2008)
  - Distributed cameras
  - Tight or marked clothes
  - Height to width ratio of enclosing rectangle (α)
  - RMS of widths and heights of two consecutive enclosing rectangles (β)
  - α accounts for 52% of recognition rate, with β brings it up to 78%, and up to 85% with personal data
- Foroughi (2008)
  - Feature combination: Best-fit approximated ellipse around the human body, projection histograms, temporal change of the head pose
  - 88% success

Computer vision – prior art

- Ng (2009)
  - Camera attached to a walker
  - Detects legs position and calc velocity, determining if mobility is lost over time
  - High error rate

Computer vision - summary

- Advantages
  - Not physically obtrusive
  - Multiple people are tracked by one system
  - Easy link to communicate alerts
  - Recorded video can be used for verification
- Disadvantages
  - Works only where there are cameras
  - Dynamic and fixed obstructions between the camera and tracked object (for some algorithms)

Infrared– prior art

- Sixsmith (2004)
  - Eliminates background challenges prevalent in regular video
  - Algorithm uses location and velocity to infer Motion & Inactivity of thermal obje

Infrared - summary

- Advantages
  - Not physically obtrusive
  - Simple & inexpensive hardware
  - ~~Passive & alleviates privacy issues~~
  - Multiple people are tracked by one system
  - Easy link to communicate alerts
- Disadvantages
  - Works only indoors

Acoustic – prior art

- Popescu (2008)
  - Array of sensors detect loudness and height of sound
  - 70% fall detection success with no no false alarms,
  - Or, with difference calibration: 100% success with “high” (5) false alarm rate per hour

Acoustic - summary

- Advantages
  - Not physically obtrusive
  - Simple & inexpensive hardware
  - Passive & alleviates privacy issues
  - Multiple people are tracked by one system
  - Easy link to communicate alerts
- Disadvantages
  - Works only indoors
  - Fast degradation in environments with high ambient noise

Vibration– prior art

- Alwan (2006)
  - Floor vibration (piezoelectric) detect occupant location
  - 100% success
  - Minimum false alarms

Vibration - summary

- Advantages
  - Not physically obtrusive
  - Simple & inexpensive hardware
  - Passive & alleviates privacy issues
  - Multiple people are tracked by one system
  - Easy link to communicate alerts
- Disadvantages
  - Works only indoors
  - Limited sensing range
  - Does not work on all kinds of floor materials

Ubiquitous solutions

Walking devices

- Almeida (2007)
  - Gyroscope to measure angular velocity of the cane

Level switch

- Construction system pte LTD (commercial) (unknown year)
  - Built a detector based on detecting the Mercury top level in a capsule
- Lin (2007)
  - 10 Mercury and optical sensors embedded into a coat

Kinematics – many approaches

- Variants on accelerometers & gyroscopes
- Both onboard and remote-server algorithms were tried
- Single & multi wearable sensor(s) approaches
- Sensors positioning

Kinematics – prior art

- Williams (1998)
  - Impact of the fall, wait for status switch to be pressed before alert is sent
- Wu (2000)
  - Identified the velocity features of ADL and Falls
- Depeursinge (2001) (US patent 6,201,476 B1)
  - Monitoring a person activity and detecting falls
- Petelenz (2002 US patent 6,433,690)
  - Using accelerations
  - Targeted to detect impeding falls

Kinematics – prior art

- Naury (2000-3)
  - Vertical acceleration shock (piezoelectric accelerator), Body orientation (tilt switch), Mechanical vibration of the body surface (vibration sensor)
  - Boolean value from each sensor is sent (low power RF) to a nearby computer
    - Fall = (Vibrations) AND (Vertical acceleration > threshold) AND (Horizontal)
  - One health male to test 5 types of falls & 7 ADL, each tested five times
    - Fall detection varied significantly (20% - 100%) based on the type
    - All ADL were categorized as falls (false positives) at least once
  - Algorithm runs on the server (some?)

Kinematics – prior art

- Lindemann (2005)
  - Two accelerometers
  - Hearing aid housing
  - Integrated acceleration to obtain velocity
    - Suggests to dynamically determine the integration period
  - Can detect & distinguish between 7 types of falling and 5 types of ADL
- Hansen (2005)
  - Three accelerometers
- Nyan (2006)
  - 3-axis MEMS accelerators embedded in a specially design garment
  - Detecting ADL and Falls

Kinematics – prior art

- Narayanan (2007)
  - Detection and Prevention of falls
  - Tri-axial accelerometer. A base unit calls in case of an emergency (also has speaker phone)
  - Waist
  - Tested with only 1 individual
- Kangas (2007)
  - Conducts research on threshold and placement of accelerometers
- Purwar (2007)
  - Activity monitoring research
  - Suggests that false positives can be removed by determining the angle between the axes

Kinematics – prior art

- Clifford (2007) (US patent 7,248,172)
  - Using a monitoring unit: accelerometer(s), processor, and wireless transmitter to detect falls
- Doukas (2007)
  - Accelerometers send data to SVM to distinguish falls from non-falls

Kinematics – prior art

- Bourke (2007)
  - Tri-axial accelerometer, detecting a single threshold
  - Thigh vs. Trunk study (Falls by 10 volunteers, ADL by 10 elderly)
  - 100% fall detection with few ADL falsely identified
    - Trunk was a better placement
- Bourke (2008)
  - Chest placement
  - Used algorithm by Ferraris (1995) and numerical integration method by Degen (2003)
    - Velocity based algorithm
    - Handles noise using a Butterworth filter with pass band between 0.15 – 15 Hz
    - Three variances of 1-second acceleration data windows are used to identify static activity
  - Experiments by 5 young healthy males, performing 4 types of falls and 6 ADL
  - Data analysis concluded that a threshold of -1.3 m/s vertical velocity can be used to ADL with 100% specificity and 100% sensitivity

Kinematics – prior art

- Boyle (2008)
  - 2-axis accelerometer (no sideways fall detection)
    - Used only vertical acceleration for fall detection
  - Waist level (belt pouch)
  - Acceleration magnitude was not useful by itself, more reliable with jerk
  - Empirical study
    - **15 real elderly patients**
    - 309 patient days
    - Average time sensor was worn by a patient for 18 days
    - 4 falls detected
  - Simulated falls
    - Health younger volunteers

Kinematics – prior art

- Wang (2008)
  - Expanded on the algorithm by Lindemann by finding the sum of all three axial acceleration components. Also used the sum of the frontal and sagittal acceleration as additional fall detection parameters in the algorithm
  - Tested with 5 volunteers (3 male, 2 females) performing 21 falls each
  - Correctly identifying 8 types of falls & 7 ADL
- Anania (2008)
  - As part of his efforts to develop a fall detection algorithm articulates how to improve the reading by filtering extraneous data collected by the accelerometers

Kinematics – prior art

- Tong (2009)
  - Accelerometer, Gyroscope, and button for false positive elimination
  - Single acceleration threshold detection, followed by orientation, followed by 20 s. window for event cancelation button
  - Onboard algorithm
  - Preferred Chest or Back placement after considerable research
- Li (2009)
  - Designed a new embedded system
  - Accelerometer & Gyroscope
  - Dual sensing on chest and thigh
  - Onboard algorithm using linear acceleration and angular velocity (from gyroscopes)
  - Can identify ADL: Standing, sitting, bending, lying

Kinematics – prior art

- Zheng (2009)
  - Tri-axial accelerometer, Non-movement, GPS, and button for false positive elimination
  - Waist
  - Onboard algorithm
  - 78% success
- Nguyen (2009)
  - Tri-axial accelerometer & 3 channel ECG
  - Waist
  - Algorithm runs on server

Kinematics – prior art

- Dinh (2009)
  - Accelerometer, Gyroscope, acoustic sensor for heart beat detection, Low battery alert
  - Chest
  - Tested 5 different algorithms w accuracy ranging from 92% to 97%
    - Accelerometer only alg. yields 90%, gyroscope brings it to 97%
  - Dinh suggests that additional sensors might lead to a more reliable algorithm. In this case it is a heart rate sensor.
- Huang (2009)
  - Designed a new embedded system
  - Tri-axial accelerometer, GPS
  - Algorithm proposed by Wang (2008)
    - Accurately distinguish 8 kinds of falls and 7 ADL

Kinematics - summary

- Advantages
  - Works everywhere
  - Not subject to noisy environment
  - High detection rate and low error rates
- Disadvantages
  - Physically obtrusive
  - Battery life
  - Weight of the device
  - Device needs to stay fixed relative to the faller
  - No easy link to communicate alerts
- Observations
  - Placement might be key
  - Derived data is important

Summary & Opinions

- Use cell phones for computing and communication
- Strategically place micro-sensor(s), say an accelerometer, on the body
- Embed the sensor in utilitarian everyday artifact
- Add a layer for indoors monitoring (computer vision?)
- Conduct unbiased and consistent study on target audience