

A Review on Wearable Tri-Axial Accelerometer Based Fall Detectors

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Abstract Falling is the crucial concern in elder adults which can result into serious injury or rupture of bones especially hip bone injury or other joint fractures. Hence fall detection is necessary to minimize risk of injury. Accelerometer is the most widely used device to detect falls as it provides information about the sudden downward tilt. Tri-axial accelerometer provides measure of acceleration in three dimensions. Paper describes the review on fall detectors in which tri-axial accelerometer is used as the main component along with different sensors and systems.

Keywords: fall detectors, acceleration, tri-axial accelerometer, downward tilt

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1. Introduction

Elderly Population is expected to grow drastically in coming decade. Ageing causes a lot of complications to arise in people's lifelike reduced physical activity and old-age diseases. United Nation reported that by the year 2050 it is estimated that one in five people will be aged 60 and more and that will increase to one out of five [1]. Generation today is secure about lifestyle in aging due to the technological growth in the era of assistive technology. Development in the assistive technologies like Physiological monitoring, wireless sensor networks, Smart homes, fall detectors are making independent living of older adults peaceful and comfortable.

In this review paper we discuss about Wearable Tri-axial Accelerometer Based Fall Detectors by presenting their types, mountings, methods of detecting falls, their perspective in the elderly people and related research. Falling is the crucial concern in elder adults which can result into serious injury or rupture of bones especially hip bone injury or other joint fractures. Hence fall detection is necessary to minimize risk of injury. Statistics show that falls are the key reason of injuries for aged 79 or more. The need for observation systems for fall detection has increased within the healthcare industry as the population of elderly is increasing day by day. The paper has been organised as follows. Next section introduces types of falls and detection techniques after that the tri-axial accelerometer is introduced for fall detection. Then the case studies and research in this era is discussed.

2. Classification

2.1. Types of Fall

This section classifies different types of falls which will help in understanding the fall detection techniques. Falls may indicate an acute problem a chronic disease or the age-related changes in vision, gait, and strength [2]. Generally falls occur while walking or standing, standing on supports, sleeping or lying in the bed and from sitting on a chair. Intrinsic factors on which falls are dependent are Gait and balance impairment, peripheral neuropathy, Vestibular dysfunction, Muscle weakness, Vision impairment, Medical illness, Aging, Orthostasis and Drugs; extrinsic factors include environmental hazards, poor foot wares and detrainments which gives rise to slips, drop attack, syncope and drowsiness [3].

2.2. Types of Fall Detection Techniques

Fall detection can be roughly categorised in three techniques namely wearable sensor based fall detection in which use of accelerometers, inertial sensors, motion sensors and gyroscopes are done.

In vision based detection cameras are used which is not wearable; can be mounted in the room and in other approach, use of acoustic waves and vibration monitoring can ensure the fall detection.

There is also a mixed approach in which multisensors and two or more methods are used to detect the fall.

3. Tri-axial Accelerometers

An accelerometer is a device that gives the measure of acceleration using defined principles. It can be used to measure both dynamic and static acceleration. Dynamic acceleration is the acceleration caused by forces other than gravity and static acceleration is caused by gravity. Measurement of acceleration can be done in one, two or three dimensions. Dual axis accelerometer for fall detection is designed by University of California, Berkely

[15]. Tri-axial accelerometers are generally used to capture and monitor human motion by real-time detection of acceleration in 3 directions; senses tilt in X, Y and Z axes. It can measure three degrees of freedom measuring translation, rotation and the acceleration due to gravity. When the downward acceleration increases suddenly, a fall is detected. EcoIMU [14] describes a tri-axial accelerometer unit with gyroscope forming a sensor node that can be mounted on human body for various wearable applications.

4. Wearable Tri-Axial Accelerometer Based Fall Detector

Wearable fall detectors don't require human involvement as they can be mounted wirelessly on person's body. They detect impact on the ground by a sudden change in downward acceleration; various algorithms are used to improve the selectivity and accuracy of the device. Wearable sensors are the devices that can be mounted on the patient's body and based on the patient's motion or body movements falls can be detected. Accelerometry is the most extensively used method for falls detection in case of older adults as it doesn't interfere the free human movements being wireless. In this method, a change in positioning from upright to lying that occurs immediately after a sudden impact indicates a fall [15]. Figures below shows classification of tri-axial accelerometer based fall detectors.

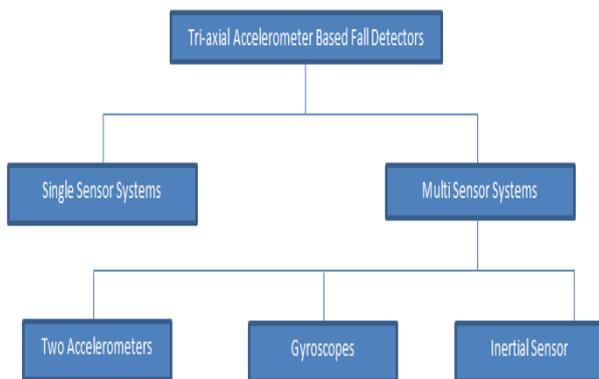


Figure 1. Classification based on number of sensors

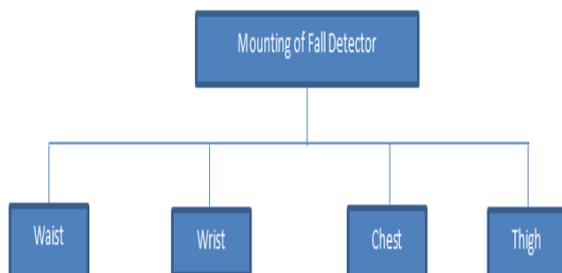


Figure 2. Classification based on mounting of fall detectors

4.1. System Components

Components of the wearable tri-axial accelerometer based fall detector systems are accelerometers, gyroscopes,

inertial sensors, a data logger system, a microcontroller, RF transceiver unit, alarming circuit and a computer interface like PC, mobile phone or smart phone.



Figure 3. Framework for existing wearable sensor and ambience based approaches [2]

5. Related Research

Significant research on wearable tri-axial accelerometer based fall detectors started in the year 2003. Following are the methods for the fall detection using wearable accelerometers. Further classification is accelerometer based and gyroscope based methods. Accelerometers are the main component of the wearable fall detectors however some systems use inertial sensors and gyroscopes to detect the falls, even some systems use wireless sensor network with the multisensor systems. Mounting of the fall detectors varies from waist, wrist, chest and thigh so they can be classified in the broader perspective according to the mounting of sensors.

5.1. Single Sensor Waist Mounted with Accelerometer

A system designed in 2005 comprised of body worn accelerometer [6] that can monitor acceleration of lower body and differentiates between gait and stance tasks to find disorder in the balance. Fall detection is confirmed if angle of inclination measured is more than 60 degrees. Data logger is also provided to store data in the text file so that fall can be analysed by software. A graphical display is also provided to visualize the fall.

Institute of Medical Equipment, Academy of Military Medical Science, Tianjin, China [4] in 2009, designed an automatic fall detector based on this approach where tri-axial accelerometers are mounted on the patient's waist near centre of mass from which signal then is sent to the microcontroller. 0.25Hz FIR filter is used to categorize fall from the daily human activities which comes under 0.3 to 3.5Hz band. A two-step algorithm has been developed to ensure the fall and the information is conveyed through the SMS and alarms.

A system which uses tri-axial accelerometer approach is designed in Tsinghua University, China in 2010 [5]. They have used MEMS based tri-axial accelerometer for collecting motion data and a pair of transmitter and receiver to transmit data to PC. Time-domain characteristics are studied and feature selection is performed to get the features that make the fall sure. A MATLAB based algorithm is developed using support Vector Machine for this purpose.

An automatic fall detector that uses tri-axial accelerometer to be worn on the waist of elderly [7] was designed in 2011. It consists of a ZigBee gateway from

which provides an access to PC for monitoring and long-term analysis of the data. It also has an alarm unit to notify that the fall has been detected. In this paper falls have been categorized in forward, backward, right and left directions which drive the algorithm which differentiates between daily activities and abnormal movements.

A wireless reconfigurable fall detector [8] was designed in 2012 using 3D accelerometer to detect falls autonomously. This system is known to be the latest form of body worn tri-axial accelerometer based fall detectors. It comprises of wireless sensors and FPGA platforms. Signal from accelerometer is sampled at high rate to detect tilt in body. Fall is detected when change in orientation from upright position to non-upright position in less than a second is observed and threshold is crossed by acceleration stress. Hardware of the system consists of a wearable sensor, serial Bluetooth adapter, FPGA board and UART. Bluetooth is connected to the iPhone where fall is notified.

5.2. Multi-sensor Systems

5.2.1 Waist Mounted with Motion Sensor

Wireless Sensor Network Based automatic fall detector developed in 2007 [9] uses tri-axial accelerometer with motion sensors. Accelerometer offers information about motion of the body during fall and motion sensors detect presence or absence of motion in general. IEEE 802.15.4 is used to transfer information wirelessly to the central node.

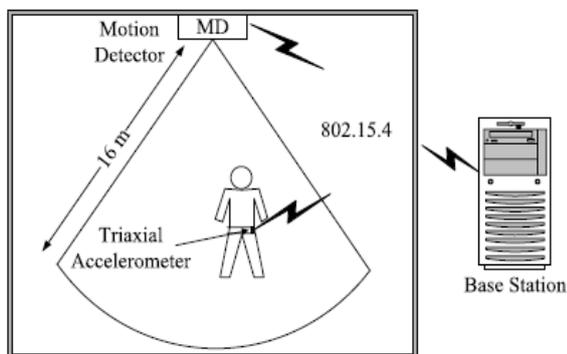


Figure 4. Fall detector using wireless sensors [9]

System works on the two step algorithm in which first stage falls are detected measuring normalised energy expenditure in the acceleration and in the second stage falls are ensured by the motion detectors due to lack of motion.

5.2.2. Waist Mounted with Inertial Sensors

Along with the use of accelerometers, fall detectors also utilize inertial sensors and gyroscopes. System with inertial sensor consists of inertial sensor developed in 2008 [10] to be mounted on waist, data logger and a fall detection algorithm. It includes tri-axial accelerometer and angular rate sensor from which data is given to the microcontroller unit and HP Pocket PC is used as a data logger.

5.2.3. Thigh and Chest Mounted with Gyroscope

Some systems use gyroscopes with accelerometers developed in 2010 [13] for detecting static and dynamic

posture transitions. Two tri-axial accelerometers at two different body locations one on chest and one on thigh along with the tri-axial gyroscopes forms two sensor nodes.



Figure 5. Chest mounted fall detector [13]

They determine static postures like standing, bending, sitting and lying along with motions which are considered as dynamic posture. Linear and angular acceleration decides if the body is in motion or not. Fall detecting algorithm couples response from both accelerometers and gyroscopes. TEMPO 3.0 nodes are used here are controlled by TI MSP430 microcontroller. A drawback of this method is problem in differentiating between jumping into bed and falling against wall. However as this method combines two types of sensors, reduces the possibility of false alarms.

5.2.4. Wrist Watch Type of Systems

Wrist is possibly the most difficult position to detect falls. Detectors can be embedded in the wrist watch. "SPEEDY" [11] is a fall detector which can be wore as a wrist watch. SPEEDY was developed in 2003 and it is a first known fall detector system that uses accelerometers. It has an inbuilt wireless transceiver unit and an alarm system that provides alert when a major fall is occurred. This system uses two sensors to measure acceleration in three directions and tilt or angle detection is not provided here. Microcontroller used here is MSP 430 by Texas Instruments and RFM DR3001 is used as a radio link to convey message to the base station.

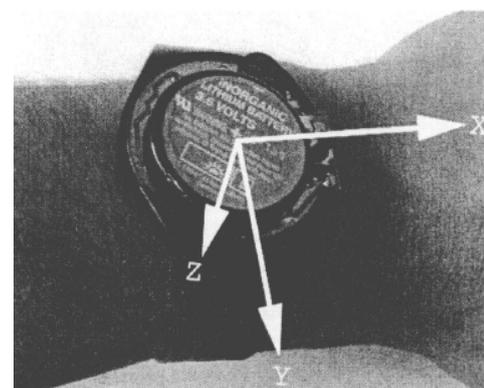


Figure 6. SPEEDY with its axes [11]

Another fall detector embedded in wrist watch developed in 2012 [12] uses two MEMS based 3D accelerometers arranged in perpendicular fashion with equal ranges, MSP430 microprocessor, Nokia 3310 LCD screen display, a vibrator and an alarming circuit.

6. Discussion

We have discussed research about fall detection techniques using tri-axial accelerometers in the paper. The biggest advantage of the accelerometer type device is cost efficiency of the devices and easy installation. These devices are easy to operate as they don't have complicated setups. Also, being wireless they do not cause much obstruction in the daily activity of the person. But the disadvantage is mobility is slightly reduced as a device has to be carried on the person's body and it may get disconnected if the wired connections are provided.

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