ISSN: 2395-1680 (ONLINE)
DOI: 10.21917/ijme.2020.0158

ANALYSIS OF COMPUTATION TIME IN FALL DETECTION SYSTEM EMBEDDED WITH WHEEL CHAIRS

G. Uma Devi, Rupayan Das and V. Malathy

[1,2]*Department of Computer Science and Engineering, University of Engineering and Management, Jaipur, India*

[3]*Department of Electronics and Communication Engineering, SR Engineering College, India*

Abstract

The fact that falling is often accepted as a natural part of the aging process is of little surprise. In fact, it is the impact that is of greatest concern rather than the occurrence of falls in the elderly. Typically aging people are frailer, more unstable, and have slower reactions, so they are more likely to fall and get injured than younger people. Typically, research and industry presented various practical solutions to assist the elderly and their caregivers against falls through the detection of falls and the triggering of notification alarms calling for help as soon as falls occur to diminish the fall consequences. In addition, fall probability prediction systems have recently emerged based on manipulating the medical and behavioral history of older patients to predict the possibility of falls occurring. Accordingly, caregiver response may be triggered before most fall occurrences and thus prevent falls from occurring. This paper presents an extensive review of the state-of-the-art trends and fall detection and prevention technologies that assist the elderly and their caregivers. This paper also discusses the main challenges facing elderly fall-prevention, together with suggestions for future directions for research.

Keywords:

Fall Detection Algorithm, Wheel Chair, Hardware Implementation, Detection System

1. INTRODUCTION

The physical fitness of elderly people decline with age and, if they fall down in that condition, it might mostly lead to serious health problems [1]. Fracture is the most common injury in an elderly person's fall and there is also a certain chance of getting coma, brain trauma and paralysis. Due to the high impact, the fall process is the main source of injury at most fall situations, and late medical salvage can sometimes make the situation worse [2]. This implies that immediate/faster medical salvage in the event of a fall reduces the risk that the elderly face.

Technology advances bring more opportunities to help us protect the elderly. Components with low power consumption allow the realization of wearable monitoring devices. The MEMS sensors have simplified sensor design and implementation. Location based service (LBS) makes it easier for the elderly to be located in health monitoring. Besides these, mobile computing facilitates the realization of remote health monitoring.

Sensor-based method of motion is also commonly employed. Accelerometer and gyroscope could provide information directly concerning linear and angular motion. Measurements of the sensors or their proper fusion could be used to distinguish a true fall. There are several types of detection methods that differ in motion sensor constitution and algorithms for detection. The first sort of method of detection is to use an accelerometer.

Some kinds of information on angular motion may also be calculated based on the relationship between the components of acceleration and their vector sum [6]. The second type of method of detection is based on an accelerometer and a gyroscope [7]. Gyroscope could offer angular velocity, and the accelerometer could provide information on linear motion. The third type of method of detection also employs a magnetometer.

A triaxial magnetometer can detect magnetic force in three directions and can also provide information about angular motion in the horizontal plane. But, the reliability of the magnetometer outputs could be reduced by the disturbances of the magnetic field of the environment, which may include the steel structure of some architecture or objects with strong electromagnetism.

Angular information can also be extracted from accelerometer measurements. In this regard, a commonly used technique for combining angular motion information is the state space filter, like the Kalman filter [8]. Besides these, sensors such as barometer can also aid the recognition of human gait by pure motion sensors [9].

But, in fact, using more sensors means more power consumption, and designing a proper algorithm for fusing different types of sensors is a challenge. For human fall detection a single triaxial accelerometer is quite sufficient as all the required information could be extracted from its measurements. Besides, if only the magnitude of the sum vector is required [3]-[5], the accelerometer coordinate does not have to be fixed, and that is quite convenient for wearable application.

In this paper a wearable device based fall detection system is developed. Realization of the device hardware and software is based mainly on a single triaxial accelerometer and GPS / GSM module.

1.1 CAUSES AND CONSEQUENCES OF ELDERLY FALLS

Falling among the elderly happens because of various causes as well as leading to various consequences. Awareness of these reasons and consequences is used by researchers, designers and developers of fall detection and prevention systems to develop various creative solutions to the problem of falling elderly.

1.2 CAUSES

There are multiple reasons why elderly people fall. Some reasons like age, gender, unconsciousness, and chronic neurological or mental problems cannot be controlled. Whereas, other causes like side effects of medications, insufficient vision, and poor hearing or muscle weakness could be controlled or modified. The Fig.1 classifies the most common causes of falls in the elderly by their origin and controllability.

It is common to have more than one cause of decline, and several studies have shown that the risk of decline increases dramatically as the number of causes increase. Several studies classify the falls or causes-related factors as extrinsic or environmental and intrinsic or personal. Extrinsic or environmental factors originate from the surroundings of the patient, like a loose carpets, wet or slippery floors, and poorly built steps.

Fig.1. Architecture of the developed system

On the other hand, considering that the major causes of elderly people's injury and mortality are no longer infectious in nature, personal factors also appear to contribute to increased risk of falling. Intrinsic or personal factors related to age-related changes in physiological and neurological functions, medicines (such as: antidepressants or sedatives), as well as diseases, are factors related to co-morbid conditions and reflect the rise and predominance of chronic diseases and, consequently, the increase in the falling of elderly people due to these diseases.

1.3 CONSEQUENCES

Any individual, especially aging persons, may be adversely affected by falling caused by different reasons. The average length of hospital stay for people over the age of 65 is more than twice the duration of people in other age groups in case of falling related hospitalizations. Hence, falls among the elderly are increasingly recognized as a matter of concern in all kinds of countries, whether developed or developing.

Even a small fall can have profound effects on older people's health. Falls continue to be a predominant cause of loss of function and death in this population. Falls in the elderly may precipitate adverse physical, psychological, social, financial and medical consequences, as well as negative consequences for the government and the community. The Fig.2 shows the major consequences associated with falling elderly people.

Physical consequences are possible injuries like broken bone or soft tissue, pain and discomfort, reduced mobility, and long-term disability. These injuries, in most occasions, lead to the loss of independence, and the inability to care for oneself.

Psychological consequences lead to loss of trust in walking and moving due to increased fear of repeated falling, fear and anxiety, as well as distress, and embarrassment.

2. REVIEW OF LITERATURE

For many years there has been considerable interest in falls from both research and commercial perspective. Technologically, a variety of approaches to falls detection with varying degrees of accuracy were adopted. There have been a number of attempts to monitor not only falls, but also to monitor daily activities generally without attaching devices to the body, and then to prevent falls accordingly. On the other hand, a lot of approaches have been proposed for using accelerometer to detect falls. A change in body orientation from upright to lying which takes place immediately after a large negative acceleration indicates a fall in those approaches.

However, despite all the research devoted to fall detection in general, there is still no 100% reliable algorithm that detects all falls without false alarms. In addition, a limited number of research works have been carried out on the scope of fall prediction through the monitoring and modeling of the behavior of patients to take protective actions that prevent falls from occurring. This section presents a detailed review of the research work that strives to highlight various proposed solutions for addressing the problem of fall detection and prevention from different perspectives. The proposed approaches towards the automatic detection are surveyed in this review to measure the disadvantages/challenges involved in each research work.

As a wearable monitoring device, authors designed and created a fall detection system for the elderly, distinguishing between fall and non-fall events, which can connect wirelessly to a pre-programmed laptop computer or Bluetooth-compatible mobile phone. The device communicates wirelessly with the laptop / cell phone to call emergency contacts upon detection of a fall.

The device also detects anomalous tilt and warns users to correct their posture in order to minimize the risk of falling. In addition to the visual alert fall alert, the proposed fall detection device also offers audio and tactile alert options for viewing / hearing-impaired people, and facilitates a manual cancel button in the event of a false alarm or fall that the user can recover. With regard to the performance assessment of the proposed device, some actions, by one of the proposed algorithms, were not successfully distinguished as falling or non-falls.

Generally, many authors have proposed approaches to capture people images and then detect visual defect based on image processing techniques. Such approaches, however, still have challenges and limitations regarding affordability and acceptability of omnipresent detection. That is because of many reasons, such as the area of detection within monitoring environment, which is expensive to build up. The privacy of the people, too, is compromised.

In addition, visual fall detection is inherently prone to high levels of false positives since most current systems are unable to discriminate 100% between context-based events such as real fall incident and an event when a person lies or sits abruptly. In addition, existing fall detection systems tend to deal with restricted movement patterns and limited normal scenarios such as walking; however different normal / abnormal motions occur in real indoor environments.

3. SYSTEM DESIGN

The Fig.1 outlines the architecture of the developed system. A wearable device is placed on the human waist. The system can detect falling elderly people by analyzing the acceleration. It will then get the geographic position of the elderly and send short message of the fall alarm to the caregivers. So elderly people who have fallen can get help on time to minimize the negative influence.

3.1 FALL DETECTION ALGORITHM

Choosing the recognition feature has crucial significance for successful detection of fall. Information such as linear movements and angular motion could be obtained either directly or indirectly. Besides these, frequency domain parameters could be extracted by techniques such as FFT and wavelet [11] [12] from the basic sensor measurements. Accelerations and derived angular parameters could be used as reconnaissance features for single triaxial accelerometer application.

The design of the fall detection algorithm is based on the identifying features. The recognition feature classifies fall detection algorithms as threshold-based, and machine-based learning. For threshold-based method, the threshold of recognition feature is set before the application by the designer, and this makes the algorithm to have rapid response and less resource consumption [13].

But, threshold choice requires both rigorous schemes and proper experiments. The classification of fall and normal activities is available for machine learning based design with the assistance of technologies such as support vector machine (SVM) and neural network [14] [15]. Machine learning, to some extent, may enhance system robustness, but its algorithm, due to its high computing design, always consumes more resources, and this limits its use in wearable devices. Given that the compact wearable device requires low power consumption and that a single triaxial accelerometer could provide effective information, this system will use a threshold based fall detection algorithm.

4. EVALUATION

The algorithm used in this fall alarm system is based on sum acceleration thresholds and information regarding the angle of rotation. When a real fall occurs, collision between the human body and the ground will produce an obvious peak value at the magnitude of the sum acceleration.

$$|a| = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (1)$$

where a_x, a_y, and a_z present accelerometer measurements of three axes. The system uses the acceleration of the sum as the first step in distinguishing motions of high intensity from others. But normal motions like jumping or sitting also produce peak values which require additional detection features.

The second feature used here is an angle calculated based on measured acceleration. Because the motion of humans has low acceleration, it is possible to obtain component of gravity in each axis by using a low pass filter. If components of gravity can be separated before and after human fall, then the angle of rotation of the accelerometer coordinate can be calculated in 3D space, which is also equivalent to the angle of rotation of the gravity vector relative to the fixed coordinate. Coordinate built by the accelerometer and vector of gravity is shown in Fig.2.

Quaternion is an effective tool for describing rotational movement in the change in human gait that also includes falling [16]. As shown in Fig.3, rotation angle of Q equals θ. The rotation axis is orthogonal to the rotation plane and its direction is in accordance with right hand screw rule. q_x, q_y, and q_z are three components of the unit vector which describes the orientation of the quaternion at the fixed coordinate. Besides rotation movement, quaternion can also describe a vector in 3D space, such as the gravity vector g which could be described as a quaternion

4.1 HARDWARE IMPLEMENTATION

ADXL345 ADI digital triaxial accelerometer is the movement sensor used in this system. SIMCom's SIM908 module incorporates the GPS service and GSM communication function. TI's 16-bit MCU MSP430F1611 is used to control the entire system and implies the detection algorithm [19].

The accelerometer measurement range could be set at ±2g, ±4g, ±8g, or ±16g, and the maximum sampling rate could be set at 3.2kHz. As the activities of humans are normally at low frequency bands [20], 100Hz is a proper sampling rate for detection of human fall. In ADXL345 there is an internal digital filter that could weaken the noise and somewhat reduce the burden of digital signal processing in MCU. The measurements will be sent between the sensor and the MCU via IIC (integrated circuit) bus communication.

SIM908 can offer serial port communication with MCU with GPS and GSM service, and it can also work in low power mode. Each hardware component of the wearable device operates under low voltage, and the detection algorithm does not need a complex calculation resource, so the entire device's power consumption is quite low. A 1200mAh, 3.7V lithium polymer battery is quite enough to power the wearable device for a few days. The hardware structure of the Detection Device is shown in Fig.2.

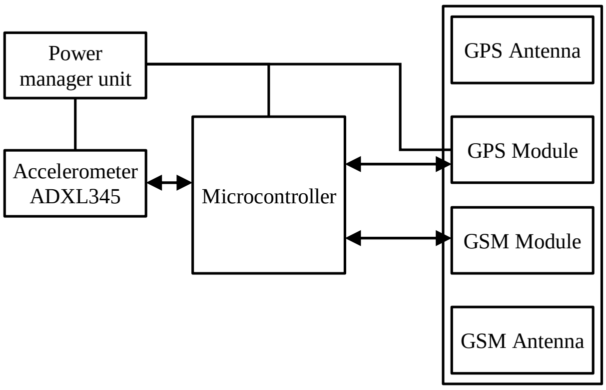

Fig.2. Hardware System

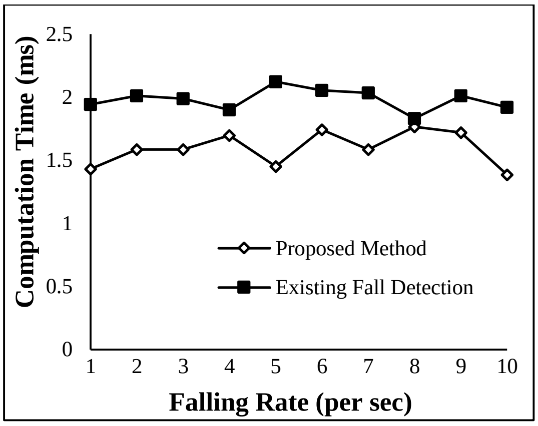

Fig.3. Result of Computational Time

The Fig.3 shows the results of computational time between the proposed method and the existing method. The result shows that the proposed method achieves better operational scalability with reduced computational time than other methods.

5. CONCLUSION

This purpose of this project is to develop a wearable device based on a single triaxial accelerometer-based fall detection system. There is no special requirement for the mounting orientation of the device, because the algorithm does not require that the accelerometer axes be strictly fixed. The system has low power consuming hardware design, and a highly efficient algorithm that could extend the service-time of the wearable device. The designs of both the hardware and software are suitable for wearable and outdoor applications.

As normal resting activity also has similar rotation as falling, when the body hits ground heavily it can trigger fall alarm. So it's quite important to choose a threshold to distinguish falling from heavily lying activity. Sufficient samples collected from subjects of different age and gender will enhance the threshold's reliability and robustness. Further, the technologies like SVM and neural network could be considered in the search for a proper method of classification as per the features used in this system.

REFERENCES

[1] M.E. Tinetti and M. Speechley, "Prevention of Falls Among the Elderly", *The New England Journal of Medicine*, Vol. 320, No. 16, pp. 1055-1059, 1989.

[2] A.K. Bourke, P.V.D. Ven, M. Gamble, R. OConnor, K. Murphy, E. Bogan, E. McQuade, P. Finucane, G. Olaighin and J. Nelson, "Evaluation of Waist-mounted Tri-axial Accelerometer Based Fall-Detection Algorithms During Scripted and Continuous Unscripted Activities", *Journal of Biomechanics*, Vol. 43, No. 15, pp. 3051-3057, 2010.

[3] C.E. Coogler, "Falls and Imbalance", *Rehab Management*, Vol. 5, pp. 53-117, 1992.

[4] S. Sadigh, A. Reimers, R. Andersson and L. Laflamme, "Falls and Fall-related Injuries Among the Elderly: A Survey of Residential-Care Facilities in a Swedish Municipality", *Journal of Community Health*, Vol. 29, No. 2, pp. 129-140, 2004.

[5] V. Spasova and I. Iliev, "Computer Vision and Wireless Sensor Networks in Ambient Assisted Living: State of the Art and Challenges", *Journal of Emerging Trends in Computing and Information Sciences*, Vol. 3, No. 4, pp. 585-5985, 2012.

[6] S. Musthak Ahmed, A. Yasmeen and B. Jagadeesh Babu, "Wheelchair with Auto Navigation for Adults with Physio and Cognitive Impairments", *International Journal of Innovative Technology and Exploring Engineering*, Vol. 8, No. 2, pp. 458-463, 2018.

[7] S.M. Kamali and V. Malathy, "Modern Cane Enabling Obstacle Detection and Navigation based on Human Gesture using Voice Board", *Test Engineering and Management*, Vol. 81, pp. 3900-3906, 2019.

[8] R. Vijaya Prakash and Taduri S. Safe, "Navigation for Elderly and Visually Impaired People Using Adhesive Tactile Walking Surface Indicators in Home Environment", *Advances in Intelligent Systems and Computing*, Vol. 933, pp. 771-778, 2020.

[9] A. Yulianto, "Design Prototype of Audio Guidance System for Blind by using Raspberry Pi and Fuzzy Logic Controller", *Journal of Physics: Conference* Series, Vol. 1230, No. 1, pp. 1-9, 2019.