DEVELOPING A FALL DETECTION ALGORITHM FOR ELDERLY BY USING GSM

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ABSTRACT

World Health Organization (WHO) define that elderly are people who are 65-year-old and above. Besides that, WHO found that fall events are one of the major problem that cause elderly injury and even lead to disability and death. Some elderly fall relate to late of giving emergency aid. In this study, a combination of fall detection algorithm is introduced. The algorithm used is the total sum of 3-axis acceleration and orientation of human body. After study the fall characteristics, both threshold values are set. When the falling condition meets the threshold values, recovery time start counting. Recovery time is to reduce false detection. Recovery time is for elderly to get back to their original position within time limit. If the elderly did not back to dedicated position, an alert message will send out to personnel care via GSM module. The algorithm introduced can differentiate between falls and activity daily living (ADLs).

ABSTRAK

World Health Organization (WHO) mentakrifkan bahawa orang tua adalah orang yang berumur lebih daripada 65 tahun. Selain itu, WHO organisasi mengatakan jatuh merupkan salah satu kes kesihatan yang serius dan mengakibatkan orang tua cedera dan cacat badan atau mati. Terdapat kes jatuh yang serius disebabkan kelewatan pertolongan cemas dan menyebabkan akibat yang serius. Dalam projek ini, gabungan algoritma jatuh digunakan. Algoritma yang digunakan adalah tambahan kelajuan 3-paksi dan orientasi badan. Selepas mempelajari ciri-ciri jatuh, kedua-dua nilai ambang ditetapkan. Apabila nilai ambang dicapai, pemasa akan diaktifkan. Kalau orang tua itu tidak kembali ke keadaan asal, satu SMS akan dihantar ke penjaga orang tua itu.

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CHAPTER 1

INTRODUCTION

This chapter will discuss about the project overview, problem statement, objective and scope of the project.

1.1 Project Overview

For a human, experiencing fall is normal especially when human learn to walk or cycle, fall always happened and injured but this does not come with death because of young age. Human experience rapidly changes into aging society which point to people who are above the age of 65. Elderly having high risk on expose to falls due to aging physical body.

Falls often lead to serious medical problem such as hip fractures and hospitalization. Most elderly face health problem such as dizziness and weakness of bone structure. There are statistics show that the majority of elderly fall does not cause death but are due to delay of medical treatment. The most dangerous condition of fall is "long-lies" condition where the person is unable to get up within times and lie on the floor. For an elderly, this condition can lead to serious health problem which is permanent disable or die.

Based on research of World Health Organization (WHO), fall are the second leading cause of accidental injured or deaths worldwide [1]. Every year, there will be an estimation of 42400 individuals die from falls and most of the victims are elderly. For each year, there are about 37.3 million falls required medical attention. There are two types of fall define by WHO, fatal fall and non-fatal fall. For fatal fall, it causes death. While for non-fatal fall, the person is seriously injured, unconscious, or permanent disability.

All age level of people is at the risk of fall injury. Even a young, healthy and strong person also have the risk to fall but may not cause fatal. Age is one of the important factor cause fall. The elderly having the highest risk of death or serious injury from fall.

A late treatment may cause death or permanent disable. Therefore, a real-time fall detection is developed that allows immediate communication with care persons and medical treatment can be given within short period. Although alert message and fall detection cannot avoid elderly from fall but it can reduce the risk of elderly death because late treatment. For an elderly who live alone and experience a fall at home, he or she may not able to get to the phone or alarm button due to injuries or fainted.

1.2 Problem statement

Falls is one of the major medical problem among elderly. Elderly fall cases increase from year to year and there are millions of elderly injured caused by fall and required medical attention. For this reason, many real-time or automated fall detection method were developed over years. The detection approach included camera-base, ambient-based, smart-phone based and wearable-based.

There are previously many studies on monitoring the fall and activities of daily living (ADL) by using wearable sensors. The technology today more preferred to small, light, low cost, low power consumption and portable. Different approaches had been made to detect fall and ADLs by using accelerometer or gyroscope or both. These sensors can detect specific events such as walk, sit, lying, run and falls based on statistical or simple threshold.

The simple threshold method using the data measured by 3-axial accelerometer that is the acceleration to calculate fall and is only single parameters. As an improvement, another parameter which is orientation is included to detect fall event. The fall detection will now use two parameters to detect fall that are calculate using the acceleration and angle using roll and pitch formula. These are simple to implement and their computation effort is minimal.

Experiment is done to collect fall event data. However, the real-world fall data is difficult to collect because the people who volunteer to participate is healthy. It is difficult to call an elderly to fall and collect each volunteer data of their daily living activities. Besides that, the material for fall detection may affect the data collection as the fall impact can be on matters for safety reason.

1.3 Objective

1. To develop an algorithm that can differentiate between fall and activities of daily living (ADLs)
2. To program an Arduino that can receive signal and send an alert message to phone

1.4 Scope of project

In this project, a fall-detection algorithm by using only 3-axial accelerometer is proposed. The purpose of this project is to develop a fall algorithm to distinguished between fall and activities of daily living (ADLs). The daily activities for an elderly include walk, lie and sit. The acceleration that collect from accelerometer is used to calculate the pitch, roll and threshold-value and is applied to fall detection algorithm. The results taken are analyzed and improved.

CHAPTER 2

LITERATURE REVIEW

There are few approach and method to detect or calculate a fall activity. Type of fall include camera based, android based, ambient based and wearable based. Researchers using different types of algorithm to calculate fall activity for each method. The following will explain previous researchers' research.

2.1 Camera-based approach

Camera-based method used one or more camera that fixed at a position to detect fall. Camera capture the posture and motion of the person and will process the image capture to determine whether falls occur. This approach is useful for multiple event because camera can capture many persons in one shot and an easy way to detect fall.

2.1.1 Integrated Monitoring System for Fall Detection in elderly

The method that proposed by this paper [1] is by using an integrated monitoring system to detect falls among elderly in home environment. The hardware used are webcam and a heart rate tracking system which is heart rate accelerometer. When fall activity detected, alarm will be triggered and signal is transfer to medical center or caring person through a base device that is connected to internet. By capturing the image, data is obtained and is process by neural network (MLP).

Few features which is background subtraction, aspect ratio and angle, skin color and HSV detection, face detection and speed is detected in order to detect fall. Heart rate accelerometer is used to monitor elderly heart beat rate. The researchers used a bounding box instead of using human for collecting experimental result. Background subtraction is

added to captured image. The reason is for detecting moving object in the image by comparing the current image and reference background image.

When fall activity detected, the width and height of bounding box changes according to their aspect ratio and angle. Aspect ratio is measured by comparing standing position with abnormal activities. Angle is measured along the vertical line through the center of the bounding box which is the 3-axis of the body for human with respect to the horizontal axis of the bounding box. This paper results shows the vertical angle is 90 degrees when the person is standing and less than 45 degrees when fall.

Major features that used is speed detection. When a person falls, the final position will be different from initial. Shape changes is being analyze. The planar speed of movement is calculated using certain formula. As a conclusion made by them, the speed is in pixels and from range of 90 to 700.

Planar speed formula [1]:

Planar speed = distance/time (pixel/s);

- Distance: between the same face in consecutive frames (pixel)
- Time: processing time between two consecutive frames

The heart rate accelerometer monitor person's heart rate using ZigBee. This system consists of bandage size heart beat sensing unit, wireless communication link, networkable computer and a data base. This heart rate monitor able to measure his/her heart rate in real time or recorded it.

2.2 **Smartphone approach**

Smartphone is a common all in one technology nowadays. In a smartphone, it includes almost everything new technology such as camera, texting and calling system, various sensors, and WIFI module. Since it is all-in-one, therefore it considers as a low cost application to detect fall activities. Regardless the price of smartphone, each of it

having the most common sensor: accelerometer. Besides that, each smartphone having wireless communication such as WIFI and GSM.

2.2.1 A Simply Fall-Detection Algorithm Using Accelerometers on a Smartphone

Samsung Galaxy S III is used in this research [2]. This phone is chosen because all the sensor needed are built in. The software used is from open-source which is Accelerometer Monitor software for recording the acceleration. From their research, the device is better put or attach on the upper part of the user's body or above the waist. This is because the 3-axis (x-axis, y-axis, and z-axis) of upper part body have less changes compare to lower part of body. In this paper they proposed the smartphone put in the pocket of the shirt and the front side of the smartphone facing user's body.

The algorithm that proposed in this paper is rate of change of acceleration of any plane. The time taken to perform normal ADLs is compared with the time taken for a plane to change its acceleration. For example, if the time take for y-plane change from 0g to 10g is shorter than performing a regular ADLs, then fall occurs.

Table 2.1: Approximate change of acceleration during fall

Falls/Axis acceleration	x-plane	y-plane	z-plane
Front side	-	From 10g to 0g	From 0g to 10g
Back side	-	From 10g to 0g	From 0g to -10g
Left side	From 0g to 10g	From 10g to 0g	-
Right side	From 10g to 0g	From 0g to -10g	-

Table 2.2: Time taken for activities of lying down

Activities	Acceleration (y-plane)	Time Taken / ms

Lying down to front	10g to 0g	1912
Lying down to back	10g to 0g	1168
Lying down to left	10g to 0g	427
Lying down to right	10g to 0g	885

2.2.2 iFall: An android application for Fall Monitoring and Response

The method used in this paper [3] is by using advance technology which is android smartphone. They proposed a low cost system that fulfill all requirements since smartphone is one of the fast growing device which almost whole world using it. According to them, using existing device as fall detector not only reduce cost but also exploits the uses of communication capabilities and integrate both hardware and software features.

Few algorithms and two level of communication is applied in order to limit false positive. For first stage, device try to communicate with user. If there is no respond from user, it proceeds to which contacting user's social network members. The second stage is alerting an emergency service when both contacting fail.

The algorithm used are calculating root-sum-of-squares which the value is taken from accelerometer's three axials. A fall will experience a short free fall period and result the acceleration's amplitude to drop significantly. Besides root-sum-of-squares, position of elderly before and after, duration of back to original position and recovery stage are also considered. When the fall person back to original position within threshold value, alarm will not be activated. Vice versa, if the person or phone fall on ground, a short time window will pop out and wait for response. Alarm will be triggered if the response not received.

2.2.3 Fall Detection Algorithm based on Tri-axial Accelerometer Data

The algorithm used in this paper [4] is by calculate the data collected from tri-axial accelerometer and differentiate fall activity and activities of daily living (ADL). The accelerometer used is already built-in in smartphone. The data receive can send to computer by using wireless communication. Power source, microcontroller, wireless module, Bluetooth and interaction component are included. This paper proposed the method is relying on the Bluetooth protocol for data transmission.

The fall detection algorithm is designed based on measured acceleration values. The acceleration sum vector (SV), using formula SV=sqrt ($A_x^2+A_y^2+A_z^2$) where "sqrt" represent square root function while "A_x, A_x, A_z" are the three spatial axis. There are six parameters to differentiate fall and ADL's.

Six parameters [4]:

1. SV peak value, P
2. Base length of triangle form by peak value and1000mg horizontal axis, B
3. Ratio of P and B, R1
4. Independent on R1, and so call velocity after impact, V
5. Ratio between V and R1
6. Activity level after impact, A

2.2.4 SVM-Based Fall Detection Method for Elderly People Using Android Low-Cost Smartphone

According to this paper [5], the algorithm used to detect fall event is by using multidimensional Support Vector Machine (SVM) method. The data used is coming from two sensors, accelerometer and magnetometer. SVM method already commonly used for many type of fall detection but only with one accelerometer signal. In order to get a set of useful data, a long period of simulation of falls and activities daily life is performed. To avoid false positive, a set of arrays is obtained and continuously adjusted.

At first, the value for SVM is calculated from the values of acceleration and geomagnetic field. From the two sensors, the RMS value is calculated over the three raw

acceleration components. Then a threshold value is set after studying all possible events. The value is set to 2g which 1g is calculated from RMS including gravity acceleration. The threshold value is decreased in order to detect more ADLs events.

To detect fall, a 4s window is introduced. The 4s window is for signal processing which is determining the maximum value of RMS and sampling interval of [-2s, 2s] is taken. A counter is started when fall event detected. When the counter reach its limits, the alert is activated. This counter can also be cancel when the known event is updated to the window.

The algorithm used:

(a) Maximum RMS raw value;

$$Max(RMS_{RAW} = \sqrt{a_{x_{RAW}}^2 + a_{y_{RAW}}^2 + a_{z_{RAW}}^2}) \quad (1)$$

(b) Maximum RMS value computed over a_d;

$$Max(RMS_0 = \sqrt{a_{x0}^2 + a_{y0}^2 + a_{z0}^2}) \quad (2)$$

(c) Maximum absolute value of the three angle changes;

$$Max(\{Max(|\Delta y|)\}, \{Max(|\Delta p|)\}, \{Max(|\Delta r|)\}) \quad (3)$$

(d) Maximum variance over the three angle changes;

$$Max(\{Max(Var(\Delta y))\}, \{Max(Var(\Delta p)\}, \{Max(Var(\Delta r)\}) \quad (4)$$

(e) Maximum value of $a_{z_{EF}}$;

$$Max(a_{z_{EF}})$$

(f) Signal magnitude area of $a_{z_{EF}}$.

$$SMA(a_{z_{EF}}(t)) = \frac{1}{4}\int_{t-2}^{t+2} a_{z_{EF}}(t)\,dt$$

(g) Variance of $a_{z_{EF}}$.

Figure 2.1: Algorithm used to detect fall events [5]

2.3 **Ambient based approach**

Ambience device detect fall by using multiple sensor installed in the housing environment to collect data of the elderly. The sensor used are pressure sensor and use to detect location of the user.

2.3.1 **A method for automatic fall detection of elderly people using floor vibrations and sound-proof of concept on human mimicking doll falls**

This paper [6] proposed a fall detection using combination of vibration and sound sensors. Based on these sensors, the vibration of fall and how did the fall sound are known. After the sound and floor vibration signal is detected, it is processed by using advanced signal processing techniques.

The algorithm consists of two phases which is training phase and testing phase. The inputs are the same which use vibration and sound signals as inputs. The significant event of both phase is vibration signal. When an activity is detected, vibration signal is first analyze follow by sound signal.

2.4 **Wearable device approach**

Wearable device approach is a method that using device shape like watch, vest or belt with embedded sensors to detect either posture, motion of the user to detect and identified falls occurring. This approach detect falls by assuming user's posture and motion principle. There are many previous systems developed product that attach to any part of body by using accelerometer or gyroscope or both.