

Frankfurt University of Applied Science
Faculty 2: Computer Science and Engineering
Vietnamese - German University
Department of Electrical Engineering and Information Technology

DESIGN AND IMPLEMENTATION OF A WIRELESS FALL DETECTION NETWORK PROTOTYPE USING MEMS SENSORS

by

Ho Ngoc Khang Minh

Matriculation No.: 1148602

First Supervisor: Prof. Dr.-Ing. Kira Kastell
Second Supervisor: Dipl. -Ing Mohammad Reza Mansooji

Submitted in partial fulfillment of the requirements
for the degree of Bachelor Engineering in study program
Electrical Engineering & Information Technology,
Vietnamese - German University

Frankfurt am Main, Germany 2018

Design and Implementation of a Wireless Fall Detection Network prototype using MEMS sensors

Approved by

Prof. Dr.-Ing Kira Kastell, First Supervisor

Dipl.-Ing Mohammad Reza Mansooji

Disclaimer

I hereby declare that this thesis is a product of my own work, unless otherwise referenced. I also declare that all opinions, results, conclusions and recommendations are my own and may not represent the policies or opinions of Vietnamese - German University and Frankfurt University of Applied Science.

Ho Ngoc Khang Minh

©2018 by Ngoc Khang Minh, Ho. All right reserved.

Abstract

Falling is becoming a serious problem to elderly people with the age of over 65, often causing unpredictable injuries such as hip fractures, head traumas, etc. More seriously, falls may lead to disability or even death on the victim if assistances from caregivers are not received in time. From this situation, there is a need for a wireless communication network which can automatically detect the fall and send an alarm to the caregivers if there is no safe signal from the victim within 10 minutes. There have been several algorithms such as detection of body orientation after a fall, image processing to detect the fall or applying machine learning techniques (Support Vector Machine (SVM), Markov model) in classifying between falling and other activities of daily living (ADL). However, these complex techniques require a huge amount of computations which can result in the system being overloaded or heavily delayed.

Addressing this problem calls for less computation-intensive techniques while retaining the accuracy and robustness of the system. One such approach is the combination of data from both accelerometer and gyroscope. The focus of this thesis is developing a wireless fall detection network which can combines the data from above sensors to detect falls and distinguish them from fall-like activities. A comparison on the performance of this network with other existing works is also included to evaluate the robustness of the system.

Keywords: *elderly people, fall detection, accelerometer, gyroscope, wireless communication network*

Acknowledgements

I would like to express my sincere appreciation to Prof. Dr.-Ing. Kira Kastell, Vice President of Frankfurt University of Applied Science (FRA-UAS) for supervising, supporting and encouraging me during the time I conduct my senior project and final thesis. Also, I would like to thank Mr. Dipl.-Ing Mansooji - communication lab engineer at FRA-UAS, Dr. Vo Bich Hien - lecturer and Mr. Duong Huynh Bao - former control lab engineer at Vietnamese German University for guiding me on technical and programming aspect. I also would like to thank my family for their supports during my bachelor degree time. This project will not be completed without their grateful guidances and supports. Thanks to their encouragements, I can improve myself, not only on the fundamental background in my major, but also necessary skills for my future career. I would like to mention all of my seniors and classmates who have helped me through this thesis.

Table of Contents

List of Tables	viii
List of Figures	ix
1 Introduction	2
1.1 Introduction to Fall	2
1.2 Definition of a Fall	2
1.3 Cause of a Fall	2
1.3.1 Intrinsic risk factors	3
1.3.2 Extrinsic risk factors	4
1.4 Consequence of Falls	4
1.5 Challenge in Detecting Falls and Motivation for This Thesis	4
1.6 Objectives	4
1.7 Overview of Thesis Works	4
1.8 Thesis Organization	4
2 Literature Review	5
2.1 Existing Commercial Devices	5
2.2 Existing Products from Other Research Groups	5
3 Statement of Problem and Methodology	6
3.1 Problem	6
3.2 Methodology	6
3.2.1 Position of sensor	6
3.2.2 Fall detection algorithm	6
3.3 Algorithm	6

4	Sytem overview	7
4.1	System Components	7
4.1.1	Hardware Components	7
4.1.1.1	Sensor	7
4.1.1.2	Microcontroller	7
4.1.1.3	Wireless Module	7
4.1.2	Software	7
4.1.2.1	Embeddded Software on Sensor Node	7
4.1.2.2	Communication System	7
4.1.2.3	Data Acquisition Software	7
4.1.2.4	Data Analysis Software	7
4.1.3	System Intergration	7
5	Experimental and Procedure	8
5.1	Data Collection	8
5.2	Data Analysis	8
5.3	Experiment on Real Subjects to Evaluate the Performance of The Network	8
6	Results and Discussion	9
6.1	Results Assessment	9
6.2	Comparing the performance with existing works	9
7	Conclusion and Future Works	10
7.1	Summary	10
7.2	Limitations	10
7.3	Future works	10
	APPENDICES	10
A	C/C++ Code for Reading Data from Sensor	11
B	Python Code for Data Acquisition Program	16
	References	18

List of Tables

List of Figures

Acronyms

WHO World Health Organization. 2

1. Introduction

1.1 Introduction to Fall

Nowadays, fall is becoming a dangerous issue which mostly cause the injuries and even leads to disability or fatal death on human, especially the elderly. According to Hwang *et.al.* [1], in the United State, one-third to one-half of elderly people over 65 years old fall at least one time each year and two-third of them will do so again within the next 6 months. Every 11 seconds, there is an elderly person is treated in the hospital's emergency area due to fall-related injuries and every 19 minutes, one faller die [2]. It is also reported that one out every 200 falls results in a hip fracture on people with age among 65 and 69 and increase to one out of 10 for those aged 85 and more [3]. The most profound effect of falling is the loss of functioning associated with the dependency of the elderly for the rest of their life. Besides, a great amount time and money have been spent on the medical treatments for the falls. Approximately \$179 million were used as direct medical costs for treating fatal falls and \$19 billion for non-fatal fall injuries within 2000 [4].

1.2 Definition of a Fall

Before starting a research about falls, it is necessary to understand about the meaning of the term *falls*. According to World Health Organization (WHO), a fall is defined as an event which results in a person coming to rest inadvertently on the ground or floor or other lower level with or without loss of consciousness or injury [5].

1.3 Cause of a Fall

In recent years, a lot of researches have been done by different groups to find out the causes of falls. There have been different ways to classify the causes of a fall such as age and sex, drugs, cognitive functions, postural control, etc. However, because falling is an unintentional action, many causes usually combine to produce a fall. Therefore, these causes can be divided into two main categories, intrinsic and extrinsic.

1.3.1 Intrinsic risk factors

Intrinsic factors are the factors which are within the body. It is also the physical aspect of the body that can cause injuries. Intrinsic factors include physical diseases such as cognitive impairment, postural hypotension, cardiovascular problems, etc.

Cognitive Impairment

It is well recognized that cognitive impairment is the common cause of fall on human, especially the elderly. Due to the research of Prudheim *et al.* in 1981, fallers have in general been found to have a higher prevalence of cognitive impairment than non-fallers [6]. It is also reported that human with dementia are approximately 3 times more likely to fall than non-demented [7]. The reason why patients with cognitive impairment are likely to fall is that they have increased reaction time, increased postural sway and increased leaning balance which result in the decrease on muscle strength, worse balance and poorer mobility, respectively.

Postural Control

Postural control is a complex motor skill that requires interaction of multiple body systems which results in the ability to maintain postural orientation or postural stability [8][9]. The impairment of postural control is indicated as one of significant causes of the fall during any activities at any age. Impaired control of gait and balance are two main aspects of the postural control that have been considered in many studies about falls. Subjectively assessed gait has been reported to be abnormal in many fall activities and other studies using more objective measurements have found some relations between the impaired gait and balance and risk of falling [10].

Cardiovascular problem

Cardiovascular disorders are responsible for approximately 77% of patients with unexplained or recurrent falls and falls associated with unexplained loss of consciousness [11]. There is a fact that fallers with cardiovascular disorders have a greater mortality than those with non-cardiovascular or unknown causes[12].

1.3.2 Extrinsic risk factors

Extrinsic factors are those related to the environment such as lighting, walking surface, loose carpets, and high or narrow steps.

Dim lighting or glare

Dim lighting is one significant cause of fall on human, especially on the elderly. While walking on the low light condition, the patient's visibility is reduced which prevents them from detect the obstacles on the walking path and causing stumble and fall. Lighting is so bright can also cause fall on human because of creating glares and distorting the way object look.

Surface of the tread

1.4 Consequence of Falls

1.5 Challenge in Detecting Falls and Motivation for This Thesis

1.6 Objectives

1.7 Overview of Thesis Works

1.8 Thesis Organization

2. Literature Review

2.1 Existing Commercial Devices

2.2 Existing Products from Other Research Groups

3. Statement of Problem and Methodology

3.1 Problem

3.2 Methodology

3.2.1 Position of sensor

3.2.2 Fall detection algorithm

3.3 Algorithm

4. Sytem overview

4.1 System Components

4.1.1 Hardware Components

4.1.1.1 Sensor

4.1.1.2 Microcontroller

4.1.1.3 Wireless Module

4.1.2 Software

4.1.2.1 Embeddded Software on Sensor Node

4.1.2.2 Communication System

4.1.2.3 Data Acquisition Software

4.1.2.4 Data Analysis Software

4.1.3 System Intergration

5. Experimental and Procedure

5.1 Data Collection

5.2 Data Analysis

5.3 Experiment on Real Subjects to Evaluate the Performance of The Network

6. Results and Discussion

6.1 Results Assessment

6.2 Comparing the performance with existing works

7. Conclusion and Future Works

7.1 Summary

7.2 Limitations

7.3 Future works

A. C/C++ Code for Reading Data from Sensor

```
#include "Arduino.h"
#include "MPU6050.h"
#include "Wire.h"
#include "WiFiClient.h"
#include "ESP8266WiFiMulti.h"

ESP8266WiFiMulti WiFiMulti ;

#if I2CDEV_IMPLEMENTATION == I2CDEV_ARDUINO_WIRE
#include "Wire.h"
#endif

MPU6050 accelgyro;
//MPU6050 accelgyro(0x69); // <-- use for AD0 high

int16_t ax, ay, az;
int16_t gx, gy, gz;
float rotX, rotY, rotZ, normAcc;
float gyroX, gyroY, gyroZ, normGyro;
#define OUTPUT_READABLE_ACCELGYRO

#define LED_PIN 2
bool blinkState = false;

void Print_IMU()
{
#ifdef SERIAL_DEBUG
Serial.println("Accelerometer:");
Serial.print(rotX);
```

```

Serial.print("\t");
Serial.print(rotY);
Serial.print("\t");
Serial.println(rotZ);
Serial.println("Gyroscope: ");
Serial.print(gyroX);
Serial.print("\t");
Serial.print(gyroY);
Serial.print("\t");
Serial.println(gyroZ);
#endif
Serial.print(normAcc);
Serial.print(" ");
Serial.println(normGyro);
}

void init_IMU() {
// join I2C bus (I2Cdev library doesn't do this automatically)
Wire.begin();
Serial.begin(115200);

// initialize device
Serial.println("Initializing I2C devices...");
accelgyro.initialize();

// verify connection
Serial.println("Testing device connections...");
Serial.println(accelgyro.testConnection() ? "MPU6050 connection successful"
: "MPU6050 connection failed");

// use the code below to change accel/gyro offset values

```

```

Serial.println("Updating internal sensor offsets...");
//reading current sensor's offset
Serial.print("\n");
accelgyro.setXGyroOffset(55);
accelgyro.setYGyroOffset(-28);
accelgyro.setZGyroOffset(-2);
accelgyro.setXAccelOffset(-2581);
accelgyro.setYAccelOffset(-3937);
accelgyro.setZAccelOffset(1199);
}

```

```

void Init_Wifi()
{
// Initialize Wifi_connection
WiFiMulti.addAP("Connectify-me", "hazeduh5");
Serial.println();
Serial.println();
Serial.print("Wait for WiFi... ");
while(WiFiMulti.run() != WL_CONNECTED) {
Serial.print(".");
delay(500);
}
Serial.println("");
Serial.println("WiFi connected");
Serial.println("IP address: ");
Serial.println(WiFi.localIP());
delay(500);
}

```

```

void sendData()
{

```

```

const uint16_t port = 8000;
const char * host = "192.168.85.1"; // ip or dns

// Use WiFiClient class to create TCP connections
WiFiClient client;

if (!client.connect(host, port)) {
Serial.println("connection failed");
client.stop();
return;
}

client.print(normAcc);
//      client.print(" , ");
//      client.println(normGyro);
//Serial.println("closing connection");
client.stop();
}

void setup(){
Serial.begin(115200);
Wire.begin();
init_IMU();
delay(10);
Init_Wifi();
}

void loop() {
accelgyro.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);
rotX = ax / 16384.0;
rotY = ay / 16384.0;
rotZ = az /16384.0;
normAcc = sqrt(rotX*rotX + rotY*rotY + rotZ*rotZ);
gyroX = gx /131;

```



```
gyroY = gy /131;  
gyroZ = gz /131;  
normGyro = sqrt(gyroX*gyroX + gyroY*gyroY + gyroZ*gyroZ);  
Print_IMU();  
sendData();  
}
```

B. Python Code for Data Acquisition Program

```
import matplotlib.pyplot as plt
import matplotlib.animation as animation
from drawnow import *
import socketserver

accel = []
gyro = []

plt.ion() #tell the matplotlib that we want to draw live data
def makeFig():
    plt.subplot(2,1,1)
    plt.plot(accel, 'r', label= 'Normalized Acceleration')
    plt.legend(loc='upper left')
    plt.ylim(0,5)
    plt.subplot(2,1,2)
    plt.plot(gyro, 'b', label = 'Normalized Angular Velocity')
    plt.legend(loc='upper left')
    plt.savefig('testplot.png')

class myTCPServer(socketserver.StreamRequestHandler):
    def handle(self):
        data = self.rfile.readline()
        dataArray = data.decode().split(',')
        normAcc = float(dataArray[0])
        normGyro = float(dataArray[1])
        accel.append(normAcc)
        gyro.append(normGyro)
        if len(accel) > 100:
            accel.pop(0)
```

```
if len(gyro) > 100:
    gyro.pop(0)
    drawnow(makeFig)
#create TCP server
serv = socketserver.TCPServer(("",8000),myTCPServer)
serv.serve_forever()
```

References

- [1] J. Y. Hwang, J. M. Kang, and H. C. Kim, “Development of novel algorithm and real-time monitoring ambulatory system using bluetooth module for fall detection in the elderly,” *Proceedings of the 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (IEMBS 04)*, vol. 1, pp. 2204–2207, September 2004.
- [2] Nation Council of Aging, “Falls prevention facts.” [Online]. Available: <https://www.ncoa.org/news/resources-for-reporters/get-the-facts/falls-prevention-facts/>
- [3] “10 shocking statistics about elderly falls,” Aug. 201. [Online]. Available: <https://www.shellpoint.org/blog/2012/08/13/10-shocking-statistics-about-elderly-falls/>
- [4] E. A. F. T. R. M. J. A. Stevens, P. S. Corso, “The costs of fatal and non-fatal falls among older adults,” Oct. 2006.
- [5] World Health Organiztion, “Falls.” [Online]. Available: <http://www.who.int/en/news-room/fact-sheets/detail/falls>
- [6] E. J. Prudham D, “Factors associated with falls in the elderly: a community study.” in *Age Ageing*, 1981.
- [7] J. C. M. E. H. R. E. J. M. S. A. Mandel, “Senile dementia of the alzheimer’s type: An important risk factor for serious falls,” *Journal of Gerontology*, vol. 42, no. 4, Jul.
- [8] D. M. Asir John Samuel, John Solomon, “A critical review on the normal postural control,” *Physiotherapy and occupational Journal*, vol. 8, no. 2, pp. 71–75, 2015.
- [9] R. C. W. N. K. L. P. N. A. M. J. Poonam K. Pardasaney, Mary D. Slavin, “Conceptual limitations of balance measures for community-dwelling older adults,” *Physical Therapy*, vol. 93, pp. 1351–1368, 2013.

- [10] J. H. Downtow, *Falls in the Elderly*. Edward Arnold, 1993, ch. 1, p. 5.
- [11] K. R. Davies AJ, “Falls presenting to the accident and emergency department: types of presentation and risk factor profile,” *Age Aging*, vol. 25, p. 3626, 1996.
- [12] W. S. P. J. L. G. W. N. K. M. K. S. W. J. R. P. G. S. L. Kapoor WN, Karpf M, “A prospective evaluation and follow-up of patients with syncope,” *New England Journal of Medical*, 1983.