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

by

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

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Disclamer

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

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*

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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 5

1.6 Objectives 5

1.7 Overview of Thesis Works 5

1.8 Thesis Organization 5

2 Literature Review **6**

2.1 Existing Commercial Devices 6

2.2 Existing Products from Other Research Groups 6

3 Statement of Problem and Methodology **7**

3.1 Problem 7

3.2 Methodology 7

3.2.1 Position of sensor 7

3.2.2 Fall detection algorithm 7

3.3 Algorithm 7

4 Sytem overview **8**

4.1 System Components 8

4.1.1 Hardware Components 8

4.1.1.1 Sensor 8

4.1.1.2 Microcontroller 8

4.1.1.3 Wireless Module 8

4.1.2 Software 8

4.1.2.1 Embeddded Software on Sensor Node 8

4.1.2.2 Communication System 8

4.1.2.3 Data Acquisition Software 8

4.1.2.4 Data Analysis Software 8

4.1.3 System Intergration 8

5 Experimental and Procedure **9**

5.1 Data Collection 9

5.2 Data Analysis 9

5.3 Experiment on Real Subjects to Evaluate the Performance of The Network 9

6 Results and Discussion **10**

6.1 Results Assessment 10

6.2 Comparing the performance with existing works 10

7 Conclusion and Future Works **11**

7.1 Summary 11

7.2 Limitations 11

7.3 Future works 11

APPENDICES **11**

A C/C++ Code for Reading Data from Sensor **12**

B Python Code for Data Acquisition Program **17**

References **19**

List of Tables

List of Figures

Acronyms

NCOA the National Council of Aging. 4

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.at.* [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 [**?**]. 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 [2]. 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 [3].

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 [4].

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 to ease the complication of research activities.

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 [5]. It is also reported that human with dementia are approximately 3 times more likely to fall than non-demented [6]. 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 [7][8]. 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 [9].

Cardiovascular problem

Cardiovascular disorders are responsible for approximately 77% of patients with unexplained or recurrent falls and falls associated with unexplained loss of consciousness [10]. There is a fact that fallers with cardiovascular disorders have a greater mortality than those with non-cardiovascular or unknown causes[**?**].

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 detecting the obstacles on the walking path and causing stumble and fall. Too bright lighting can also cause fall on human because of creating glares and distorting the way object look.

Bad staircase design

Bad staircase design is also another extrinsic risk that cause the fall on human. Too high or too low rise of staircases have caused a number of falls because people fail to perceive the abnormal elevation change or incur a misstep on descent. Besides, slippery surface of the treads can cause strip on patients while walking up or down the stairs. One more mistake of staircase design that can lead to the fall is lighting on the stair. Poor visibility and inadequate lighting can cause a user to misread the stair edge, resulting in faulty foot placement and falls.

1.4 Consequence of Falls

The consequences of falls are serious to human at any age in any circumstance, but to the elderly they have significance beyond that in younger people. There are different consequences related to the falls on humans including physical effects, psychological effects and other consequences such as dependency, hospital admission or economic consequences.

Physical consequences

Physical consequences of falls are always a significant aspect that many scientists have focused on in recent years. According to the the National Council of Aging (NCOA) of the U.S., falls are the leading cause of fatal injuries and the most common cause of non-fatal traumas [11]. There are several physical injuries such as bruise, fracture or head injury reported to happen with patients who suffer from falls. In such injuries, hip fractures and head traumas are two common problems which usually analyzed by researchers when study about falls and their health effects.

Hip fractures cause the greatest health problems and greatest number of death. It is reported that a quarter million hip fractures occur each year among people older than 50 years in the U.S. but more common in woman than men and increase in frequency with increasing age [9] [12]. Most patient with the hip fractures after falls are hospitalized for about 2 weeks. However, about half of all seniors cannot return home or live independently after that. In 1986, it costs for more than $3 billion for direct medical for hip fractures.

1.5 Challenge in Detecting Falls and Motivation for This Thesis

1.6 Objectives

1.7 Overview of Thesis Works

1.8 Thesis Organization

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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

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4.1 System Components

4.1.1 Hardware Components

4.1.1.1 Sensor

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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()
```

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