Thesis for the Degree of Master of Engineering

Human Activity Recognition to Estimate Burning Calories as Health Data using Features Extraction of Accelerometer Sensor Data

by

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Interdisciplinary Program of Information System

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(가속 센서 데이터의 특징 추출을 이용한 건강 데이터의 칼로리 소모 측정을 위한 인간 활동 인식 연구)

Advisor: Prof. Chang Soo Kim

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가속 센서 데이터의 추출 기능을 사용한 건강 데이터로서의 칼로리 소모를 측정하기 위한 인간 활동 인식에 관한 연구

타우피크 샤흐리르

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요약

오늘날 모바일 폰은 통신 수단 뿐만 아니라 오락, 교육, 헬스 미디어로도 사용되고 있다. 본 논문에서는 모바일 폰을 가속도 센서와 모션 센서를 활용하여 사용자의 눕기, 앉기, 서기, 걷기, 조깅, 달리기 등의 활동을 식별하는 등의 헬스 미디어로의 활용에 초점을 맞추고 있다. 인간이 하는 모든 활동은 그들의 고유 특성을 가지고 있기 때문에 가속도 센서 데이터의 특징을 활용하여 사람의 동작을 인식할 수 있다. 이러한 활동 데이터를 사용하여 칼로리 소모를 추정함으로 인해 건강에 관련된 자료들을 얻을 수 있다.

칼로리 소모에 대한 추정은 해리스 베네딕토 방정식을 사용한 활동 데이터 변환으로부터 얻어진다. 또한 사용자의 성별이나 나이, 몸무게, 키와 같은 신체 정보를 기반으로 한 칼로리 소모 요구사항을 체질량 지수 공식을 사용하여 계산한다. 이러한 두 가지 데이터를 사용하여 모바일 폰에 사용자의 건강에 대한 데이터가 표출된다.

키워드 : 인간 활동 인식, 가속도 센서, 건강 데이터, 휴대 전화, 칼로리 소모 측정

Human Activity Recognition to Estimate Calorie Burn as Health Data Collection using Features Extraction of Accelerometer Sensor Data

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Abstract

Today the use of mobile phones not only for communication media but also as an entertainment, education, and even a health media. In this paper we focus on utilizing mobile phones as a health media by utilizing mobile phone sensors such as accelerometer or motion sensor to detect common user activities like lying, sitting, standing, walking, jogging and running. It can be recognized by extract the feature of accelerometer data because every activity has its own characteristics. Using these activities data we can obtain health data by estimate the number of burned calories.

The estimation of burned calories is obtained from the activity data conversion using Harris Benedict equation. We also calculate user burned calorie needs based on body condition like gender, age, weight, and high. It calculated using body mass index formula. Using both of these data, the mobile phone can know the progress of user to live healthily.

Keyword: Human Activity Recognition, Accelerometer Sensor, Healthcare Data, Mobile Phone, Estimation of Burned Calories

Chapter 1

Introduction

1.1. Background

Nowadays, the number of people using mobile phones increases rapidly. The function of mobile phone has also grown. It is not just for communication toll, but also for daily activity tolls. Even it can increase motivation for daily activity [1]. Mobile phone has been equipped with various sensors, such as a touchscreen, camera, GPS sensor, GSM signal sensor, bluetooth sensor, compass, motions sensor, and others. Motions sensor is a sensor that can be used without disturbing user activity and consuming less power at mobile phone. With these advantages, we propose accelerometer to detect human activity. So, it can be used nearly as ubiquitous system.

Human activity recognition is not a new topic. Generally people can recognize human activity manually. Another way to recognize it is by using accelerometer sensor. It has studied by Ling and Stephen [2]. Their research has high accuracy. It can recognize some activity like walking with 89% accuracy, running 87%, biking 96%, and another activities. But their system is still very difficult to implement because it requires the user to use five accelerometer sensors on his body. Some related researches are also trying to recognize human activity using wearable device like smart watch, wristband, or smart belt.

This research will try to make a human activity recognition application that utilizes only one accelerometer sensor on mobile phone placed in trousers pocket. So it can be possible to use by many people wherever and whenever. And this research is focused on how to recognize human activities using accelerometer at mobile phone and then estimate it calorie burn.

1.2. Problem Statement

Based on the background of the above problems, it is necessary to formulate a settlement related problems concerning:

a. How to design and implement application recognizing human activities and its calories?
b. What kind of activity that can be recognized?
c. How to detect a variety of user activity?
d. How to make a medical application capturing health data anywhere and anytime?
e. How makes it easy to use without disturbing user activities?
f. How to change the user activity data into health data?
g. How to create applications that can motivate users to adopt healthy lifestyle patterns according to their needs?

1.3. Thesis Objective

Here are the objectives to be achieved in the design and implementation of the study:

a. Design and implement application recognizing human activities and its calories using accelerometer sensor.

b. Create an application that can detect various user activities like sit, stand, walk, run, and others.

c. Implement feature extraction method on accelerometer sensor data to recognize kind of activities.

d. Apply detection on a smartphone device that can be used anytime and anywhere.

e. Implement applications that perform automatic detection without the need for manual input, so it does not interfere user's activities.

f. Convert accelerometer data into value of calories burned by analyzing its kind of activity, speed, and the length of time.

g. Apply gamification through calories burned mission adjusting health needs of user.

1.4. Scope

To make the scope of the problem is not too extensive, there are some limitations problem to be solved by the application include:

a. Health data monitored are user activity data converted into calories.

b. Health information provided are information relating to the health and condition of the user's body.
c. User’s motivation in this application is a gamification feature that recommends users to implement a healthy lifestyle by recommend some motion activities that adjust health needs of the user.
d. The system is not designed to replace the role of the doctor, but rather as a tool that will provide health information to the user.

1.5. Thesis Outline

This thesis has been divided into five chapters, which are:

a. Chapter I, Introduction

   Discuss the global structures on the background, problem statement, thesis objective, scope, and thesis outlines.

b. Chapter II, Literature Review

   Literature Review explains the theoretical outlines supporting this thesis topic discussion.

c. Chapter III, System Requirements and Design

   This chapter discusses the analysis of the need to establish an electronic health record system in intelligent health system, system design and system specification, contains with the functional requirements and actors involved in the system.

d. Chapter IV, System Implementation for the Application

System Implementation contains the process of development using java and XML programming language. It is also consists of the overall architecture of the system and the database schema.

e. Chapter V, Comparison

This chapter contains the review of related works and how the proposed system compared with the reviewed related works.

Chapter 2

Literature Reviews

2.1. Health

In 1941 Henry Sigerist, analyzing the relevance of health for human welfare, stated that a healthy individual is an individual who has the mental balance of the body and adapted to the physical and social environment. He can control the physical and mental, and can adapt to environmental changes, the origin does not exceed the normal limits. Therefore health, not just because someone does not have the disease. [3]

The founders of the World Health Organization also defined health as a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity of the various definitions of health, it can be concluded that health coverage is very broad, but it is generally known that health is the completeness and balance the body and physical.

2.2. Obesity

Obesity is excess fat in the body, which is generally deposited in the subcutaneous tissue under the skin, around organs and occasional extension into the organ. According to WHO Obesity is the accumulation of abnormal or excessive fat that can harm health. The occurrence of obesity is determined by too much eating, too little physical activity exercise, or both. Thus each person needs to pay attention to the amount of food inputs (tailored to the needs of daily energy) and physical activity undertaken. Greater attention on these two items especially needed for those who happen to come from a family of obesity, female sex, sedentary work, not love doing exercise, and emotional instability.

Definition of Obesity and overweight have in recent decades become a global problem - according to the World Health Organization (WHO) back in 2005 approximately 1.6 billion adults over the age of 15+ are overweight, at least 400 million adults were obese and at least 20 million children under the age of 5 years are overweight. Experts believe that if current trends continue by 2015 about 2.3 billion adults will be overweight and more than 700 million will be obese. The scale of the problem of obesity has a number of serious consequences for the individual and the government health system [4]. The way to determine the degree of obesity that most often used is to measure the Body Mass Index, or BMI.

2.3. Physical Activity

Physical activity is body movement produced by skeletal muscles that requires energy expenditure. Lack of physical activity is a major factor is the fourth global mortality of 6%. Physical activity is also expected to be the main cause for approximately 21-25% of breast and colon cancers, 27% of diabetes and approximately 30% of the burden of ischemic heart disease [5].

Regular and adequate levels of physical activity in adults:

- Reducing the risk of stroke, coronary heart disease, hypertension, breast and colon cancer, depression and the risk of falls,
- Strengthen bones, and
- Determining the energy expenditure for energy balance and weight control

2.4. Body Mass Index (BMI)

BMI is the unit to measure the height (in meters) and weight (in kilograms), and then dividing weight by the square of the height. See the formula below:

BMI = Weight / ((Height (m)) x (Height (m)))

Examples of a person weighing 70 kg and height 160 cm, then obtained

BMI = 70 / (1.6 x 1.6) = 27.3 (Fat).

According to WHO, the normal BMI is 18.5 to 24.9. BMI less than 18.5 is said to be thin. A BMI of above 25 is called obesity, which is shared also in the degree of obesity (BMI 25 to 29.9), second-degree obesity (BMI 30 to 39.9), and three or morbid obesity degree / severe obesity (BMI 40 or more). For more details, here are obese, according to WHO classification table and the public.

Table 1 Obesity classification by WHO

Obesity Classification of WHO	BMI	
	POPULER / UMUM	(kg/m2)
Underweight	Thin	< 18,5
Healthy weight	Normal	18,5 – 24,9
Obesity degree 1	*Overweight*	25 – 29,9
Obesity degree 2	Obesity	30 – 39,9
Obesity degree 3	Morbid Obesity	> 40

A healthy body weight, normal, or ideal (Healthy Weight) is the weight that is not underweight nor overweight (obesity) or obese, mean BMI of 20-25, waist circumference below 88 cm for women and below 102 cm for men [4].

2.5. Gamification

Gamification is the use of game design techniques, game thinking and game mechanics to enhance non-game contexts. Gamification usually applies to non-game applications and processes, to encourage people to adopt a person, or to affect the person. Gamification making the technology more attractive to encourage users to engage in desired behaviors, pointing the way to the ruler and autonomy, help solve problems and not be a nuisance, and by taking advantage of human psychological tendency to get involved in the game.

2.6. Pervasive Health Monitoring

Pervasive monitoring called non-invasive monitoring is a method for monitoring without having exchanged by the user. This research looks at technology as a pervasive technology that will be implemented in many human activities. In the world of pervasive healthcare technology can certainly be used to improve human health by utilizing existing sensors on the existing devices for monitoring human health [5]. Devices that can be used is a smartphone used as a tool to monitor the daily activities, counting the number of steps and the amount of calories burned.

2.7. Electronic Health Record

Medical records become one of the basic things that can help doctor to make decisions in a given way better treatment or medication to patients [6]. Medical record contains the records of any activity related to the health of a patient, ranging from hospital treatment, immunizations, allergy list, up to their daily activities. Medical records in electronic form is applicable for all hospitals that will be very useful when the patient moves a check, hospital town A to town B hospital, the data to be accessed by the hospital remains the same. In the block diagram of the system of health record system, explained that the system is expected to be used to record all activities relating to the health of patients and save them in one unified database system and users concerned as doctors or patient can access the system to obtain information about the data medical records that have been recorded. In addition, apart from medical records for treatment activities, health record also serves to record the measurement results of pervasive health monitoring devices.

2.8. Physical Activity and Metabolic Equivalent of Task

The definitions of physical activity are “Athletic, recreational or occupational activities that require physical skills and utilize strength, power, endurance, speed, flexibility, range of motion or agility” [7]. Another definition of physical activity are “Bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure." [5]

Physical activity is all body movements that require energy. medical research creating a methodology to measure physical activity in the form of energy expenditure and also gives a unit called Metabolic Equivalent of Task (MET) to measure this energy. Metabolic Equivalent is a way to determine the energy cost of a physical activity. This unit is used to estimate the level of user activity and also to calculate how many calories are burned.

Metabolic Equivalent of Task is the ratio of the work metabolic rate to the resting metabolic rate. One MET is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly. A MET also is defined as oxygen uptake in ml/kg/min with one MET equal to the oxygen cost of sitting quietly, equivalent to 3.5 ml/kg/min. [8]

2.9.Resting Metabolic Rate and Basal Metabolic Rate

BMR (Basal Metabolic Rate) and RMR (Rate Metabolic Rate) are estimates of how many calories are burned if there is no activity for 24 hours. They are the minimum amount of energy needed to maintain a healthy body, such as a beating heart, lungs breathing, and maintenance of normal body temperature [9].

BMR measurement is more complicated, because the measurement is done in a dark room after the wake up at 8 hours of sleep, 12 hours of fasting to make sure the digestive system is inactive, and the rest in a lying position. RMR is easier in the measurement because the subject does not need to spend a sleepless night [9]. The following equations were developed to estimate BMR without clinical approach.

The Harris-Benedict equation for BMR [10]:

$$BMR\_men\ (kcal/day) = (13.75 * w) + (5 * h) - (6.76 * a) + 66$$

$$BMR\_women\ (kcal/day) = (9.56 * w) + (1.85 * h) - (4.68 * a) + 655$$

Where w = weight in kg, h = height in cm, a = age in years

2.10. Activity levels and MET

MET classification was not developed to determine the exact energy cost of physical activity but only a classification system activity [8]. MET level is a multiple of the standard resting energy values. When people are sitting, the standard MET value equal

1.8 (1.8 kcal-kg^{-1}-h^{-1}), an activity like walking at 2.5 mph equal 3 MET (3 kcal-kg^{-1}-h^{-1}). This is the MET values per kind of activities.

Table 2 MET per kind of activities [8]

Code	METS	Spesific Activity	Example
7030	0.9	inactivity, quite	Sleeping
9040	1.8	miscellaneous	sitting-writing, desk work, typing
11795 11796	3	occupation	walking 2,5 mph slowly, gathering things at work, ready to leave
12020	7	running	jogging, general
12050	10	running	running, >= 6mph (10 min/mile)

2.11. Energy expenditure or Calories Burned

METs on the previous Table give the multiple energy expenditure per kg and per hour. With these values, it is possible to estimate in kcal the energy cost for an activity. For example, we want to estimate the energy cost for a men (24 years old, 54 kg, 167cm) during 30 minutes of jogging.

First, calculate the BMR (Harris-Benedict equation) [10]:

BMR for men = (13.75 * w) + (5 * h) - (6.76 * a) + 66

(13.75 * 54) + (5 * 167) - (6.76 * 24) + 66 = 1481.26(Cal/day)

Then, adjust MET with BMR:

1481.26 Cal/day = 61.71 Cal/h

Jogging MET values (on the previous table) = 7.0

MET_adjusted = 7 * 61.71 Cal/h = 432.03 Cal/h

Finally, calculate in kcal the energy cost during the activity:

432.03 (MET_adjusted) * 0.5(30minutes) = 216.02 Cal

With the using of this method, it is possible to calculate the total energy cost or burned calories for a whole day.

2.12. Accelerometer

Accelerometer is a sensor that measures the physical acceleration of object due to inertial forces or mechanical excitation. Its technique uses uniaxial or three-axial accelerometer. There are many types of accelerometer like mechanical and electronica. Many researches tried to detect body movements with this kind of sensors and converted these movement results into energy expenditure.

2.13. Treadmill

Treadmill is a tool used to walk or run in the same place. Treadmill fitness equipment can be used for walking and jogging. Typically these tools have many kinds, from which only has one function to which has numerous functions. Its use also vary, like manual, magnetic, and electrically way. At this research, we use Stex S25T treadmill brand to compare the calorie burn estimator result. These tools just need input like age, weight, and height. And it can estimate speed, time distance, calorie, heart rate, PACE, METS, Calories per minute, VO2Max, and exercise profile. Its ability can run between 0.8 – 25 km per hours with incline range between 0% - 20%. [11]

Figure 1. Treadmill tool (Stex S25T)

2.14. Pedometer

Pedometer is a complete portable device for activity monitoring (Fig. 2.2). The device can be used as a necklace, stored in the waist, or stored in a trousers pocket. It has the capability of capturing the energy expenditure. Many sensors inside it like 3D accelerometers. Pedometer measures the total energy expenditure (MET), physical activities levels, calories burned, steps and distance. From this device user can read how many calories he burned during the day.

For our experimentation, we made a comparison with our application and Pedometer.

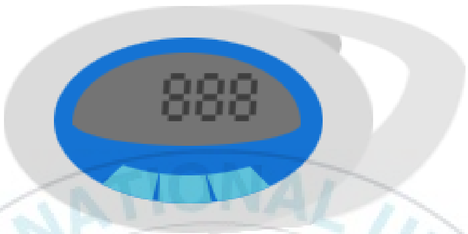

Figure 2. Pedometer

The device is very small and can be clipped on the belt, putted in trouser pocket, or worn around the neck.

2.15. Mobile Phone Device

This application is on a mobile phone because actually, there are many of them provide powerful computing, storage and communication systems and also different sensors. This kind of device was made with powerful processor and mainly of them had accelerometers. We made a comparison with these devices actually available on market.

2.16. Android Platform

The Open Handset Alliance was created by Google in 2007. The main idea was to provide an open source system available for different devices without compatibility issues. To realize that idea, they developed Android system and released the first mobile in 2009. All system in android mobile are open source, except for the Google API. So, developers can do whatever they want. It is also possible to provide homemade applications through the Market Store. Developers also don’t need to wait for an agreement from Google to provide applications. It is also possible to install their applications directly from a website or from a computer.

The others benefit to use android platform because it already has many features. It include some sensors like accelerometer, gravity, gyroscope, proximity, ambient light, temperature, and many others. It makes developer possible use it to recognize many kind of activities.

Chapter 3

System Requirements and Design

3.1. Requirement Analysis

This application is a breakthrough in the field of health technology that attempts to monitor health data anywhere and anytime using personal devices owned by the user. To achieve that goal then there is some requirement analysis either by the system or by user.

3.1.1 User Requirement Analysis

Overall, the design and implementation of this system aims to help users to be able to monitor their activities and motivates the users to actively increase their activity fit health needs of the body. To use this system requires a user to be a marker of identity, in this case can be ID on the system. User ID will serve as the digital identity of the user that contains data burning calories obtained from use of the system by the user. Users are also required having personal mobile phone devices that will be used to obtain data such health. The user is expected to become proficient in the use of mobile phones in general to perform some inputs when first using this application. Data that has been owned by the user from the use of this application activity is sent periodically into the server of the system so that it can be accessed if the users use other devices or accessed by other people who have access rights.

3.1.2 System Requirement Analysis

The design of the system must be able to answer the needs of users of the system, the following system requirements specification that is designed and constructed:

a. The system is able to record activity and burned calories of users as retrieval time.
b. The system is able to display calorie needs to be burned in accordance with the body health needs of users.
c. Data that are already available from the use of the system should be sent into the server as a medical record system of users.
d. The system is able to provide feedback or suggestions to the user when using the application.
e. The system makes users more concerned about the health of the application by implement gamification.
f. The system must be able to provide information that is clear and can be perceived by the users.

3.2. System Specification

In development process, system requires some hardware and software integrated with each other. Here are the devices needed in system development.

3.2.1 Software Requirement

The software used in the development of the system are as follows,

a. System Operation of PC : Windows 10 64-bit dan Max OS X.
b. System Operation of Mobile Phone: Android 4.3 Jelly Bean
c. Android Studio
d. Android IDE
e. Android SDK Tools
f. Android emulator system image with Google APIs
g. SQL Server

The software used in deployment of the system are Android Smartphone with Minimum OS 2.2 (Froyo).

3.2.2 Hardware

The hardware used in the development of this application is as follows:

a. PC or laptop:

- MacBook Air,
- 1.6GHz dual-core Intel Core i5 processor,
- Intel HD Graphic 6000,
- 256GB PCIe-based flash storage.

b. Android Smartphone:

- 720x1280 pixels,
- 1 GB RAM,
- 2100mAh Battery,
- 16GB storage, micro SD.

3.3 System Architecture

The design of the system architecture is the initial stage of software design. This design is done to determine the condition of the system in general. The design of the system is done after obtaining a clear picture of what needs to be done.

3.3.1 Architecture Design Process

Application design process measurement application consists of two main features and several support pages, which are categorized as below:

a. Start page

This page displays tutorial how to use this application. It just appears at the beginning of application if user never login before.

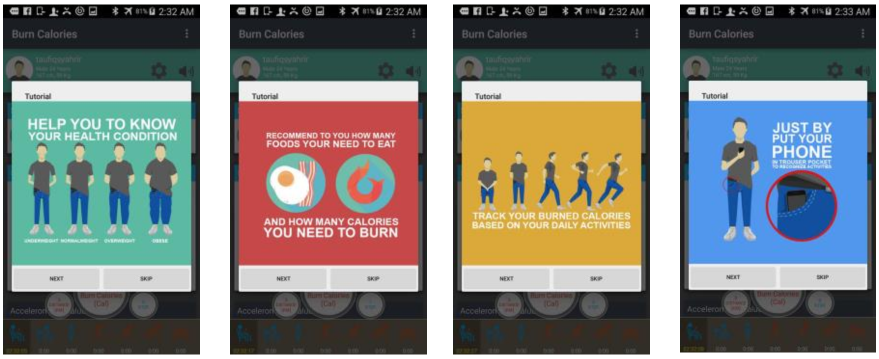

Figure 3. Start Page

b. Main Page

This page displays currently recognition result such kind of activity and calorie burn. It also displays user's health recommendation, mission, and health data record.

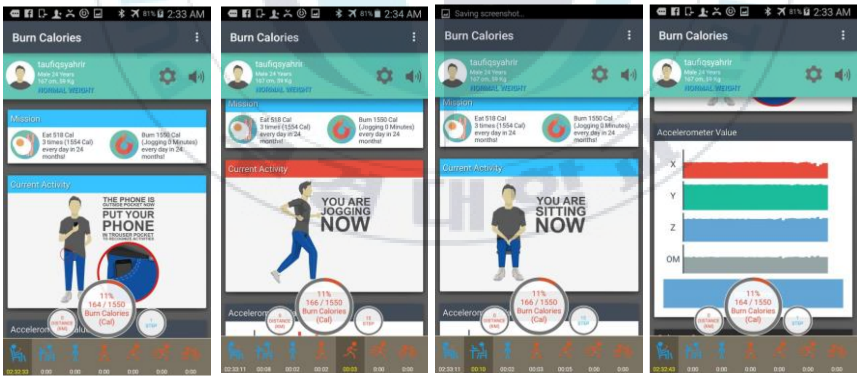

Figure 4. Main Page

c. Login page

This page is a login form to access user personal data.

c. Profile page

It will be used to see and update personal data like name, age, height, weight, and other body condition and health data.

Figure 5. Profile Page

3.4 Database Design

The Database design for the application consists of 4 table with modeling as described below.

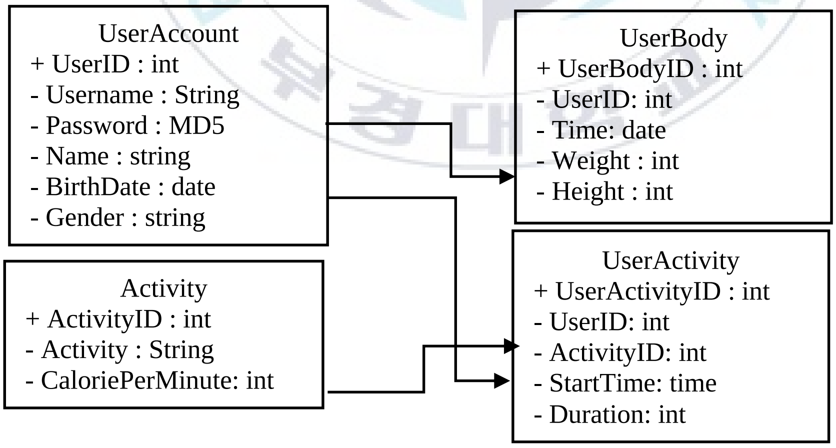

Figure 6. Database design

3.5 Block Diagram

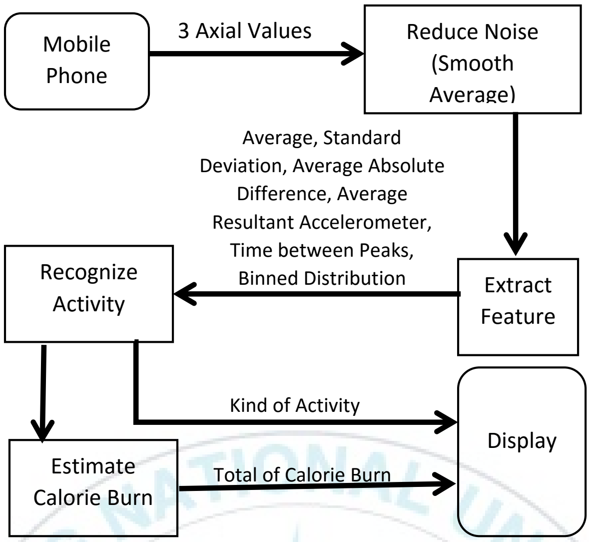

Figure 7. Block Diagram

3.5.1 Collecting Data from Sensor

Mobile phone like android phone provides several sensors that let user monitor the motion of a device. These are accelerometer, gyroscope, the gravity, linear acceleration, and rotation vector sensors. All of the motion sensors return multidimensional arrays of sensor value. For example, accelerometer returns acceleration data for the three coordinate axes, the gyroscope returns rate of rotation data, the gravity returns force of gravity, linear acceleration returns acceleration force excluding gravity, and rotation vector returns rotation vector component along the three axes.

Acceleration is a measure of how fast the speed of something is changing. Generally, it is used as an input to control systems at mobile phone. The following figure shows the variation in accelerometer values based upon given device and orientation. They include a portrait-native device, and a portrait device rotated to landscape, with Canonical x/y/z accelerometer axes/values labelled.

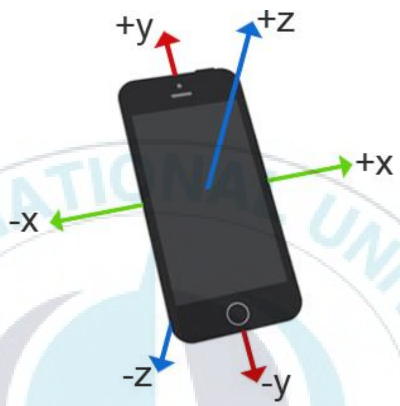

Figure 8. Accelerometer values based upon given device

Figure 9. Waves of 3 Accelerometer Axial Values

These data will be captured in 15 times in one second. It makes the data will become two dimensional waves respect to time.

3.5.2 Noise Reduction

There were two primary sources of noise in the received signal. The first was irregular sampling rates and the second was the noise inherent in discrete physical sampling of a continuous function.

The accelerometer was likely sampled irregularly because of the Android framework's implementation of the sampling mechanism. The Android API offers four abstract sampling rates for its accelerometer sensor (listed from fastest to slowest): Fastest, Game, Normal, and UI. The actual physical sampling capabilities of the accelerometers likely vary from device to device, so these sampling rate options are used more as guidelines than as actual physical sampling rates. Another reason is because of how application on the Android framework receives acceleration readings. The Android API only allows the acquisition of an acceleration sample at onSensorChanged() event, which fires whenever the Android OS determines that the accelerometer values have changed. As such, an acceleration sampling application cannot force a reading of the accelerometer at predetermined intervals. Combined with the fact that Android OS likely has varying loads of activity from moment to moment, the "onSensorChanged()" is not scheduled firmly, resulting in irregularly sampled values. To regularize sampled values, the holes in the signal were interpolated via a process called data linearization. Outside of irregular sampling rates, additional noise was periodically introduced to the signal just from the nature of the activity patterns performed. For example, a slight change in the orientation of the phone is quite common even in an idle position, but can result in an anomalous peak in the resultant signal. This type of noise was handled by running the signal through a 5-point smoothing algorithm.

Motion Sensors are very sensitive to motion even for small motions. It makes the data be fluctuating and disturb the recognizing process. This process will reduce small fluctuating using smooth average. It will change the data of each frame according average several data around it.

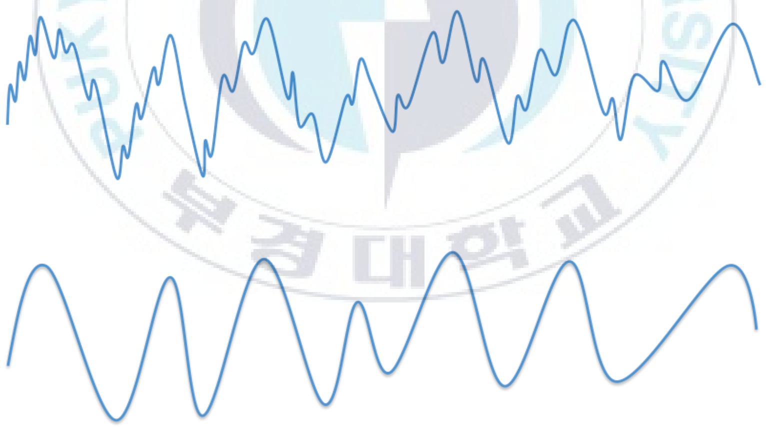

Figure 10. RAW Signal of axial value and axial value after Noise Reduction Process

3.5.3 Feature Extraction

Features are extracted from the raw motion sensors data using window size of 150 sample data each axes in 10 seconds. This amount of sample is considered capable capturing repetition motion. By using the data from the window, we can get some features that will be using to recognize the kind of human activities [12, 13]. The features are:

3.5.3.1 Average Resultant

This step taken was to merge the three dimensional input signal into one acceleration magnitude. The original signal can be seen in Figure 2. We found the magnitude of the acceleration vector by taking the Euclidean magnitude of the three individual values, that is:

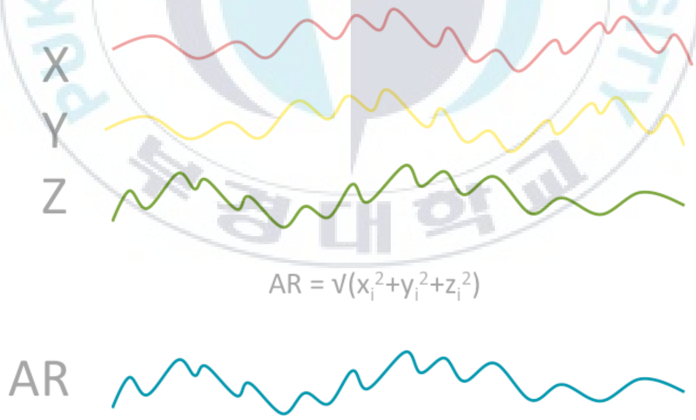

Figure 11. AR (Average Resultant) Signal

The merger was done to simplify feature extraction, because the overall theme in the acceleration pattern was deemed to be sufficient for the recognition of our original set of activities, none of which required distinction of directional accelerations. However, features from individual acceleration axes may be important in determining activities where directional information is relevant, such as differentiating between martial arts motions.

3.5.3.2Average

Average of each axes and AR

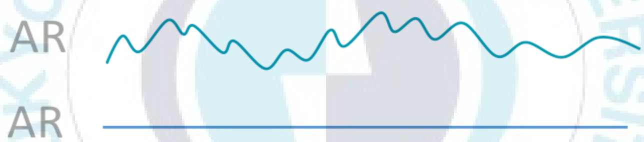

Figure 12. Average of AR signal

3.5.3.3Standard Deviation

Standard Deviation of each axes and AR

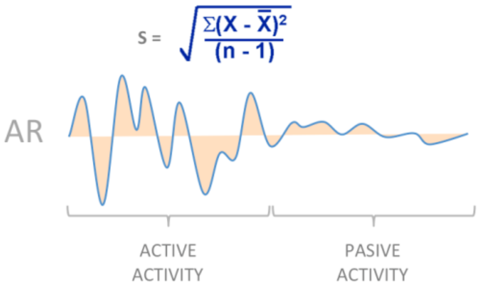

Figure 13. Standard Deviation

3.5.3.4Time between Peaks

Time between peaks means time in milliseconds between peaks in the sinusoidal waves of each axes and AR.

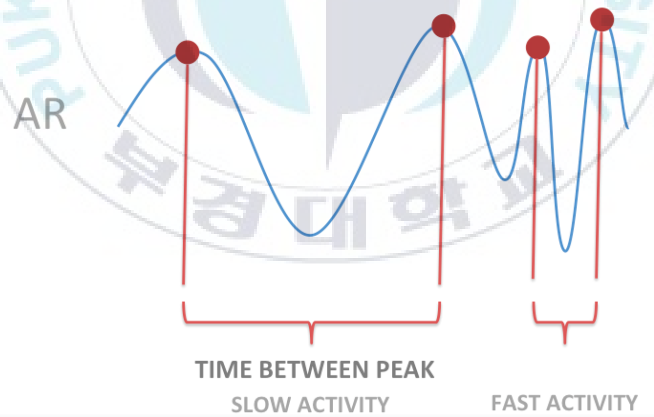

Figure 14. Time between Peak

3.5.3.5Binned Distribution

It determines the range of values for each axis (maximum – minimum).

3.5.4 Recognize Activity

This process matches all the features from previous process and feature of template that we get from experiment.

3.5.5 Estimate Calorie Burn

This process estimate kind of activity data and time data become total calorie burn. This data will be used as health data that will be compared with calorie burn needs.

3.5.5.1Resting Metabolic Rate and Basal Metabolic Rate

BMR and RMR are estimates of how many calories you would burn if you were to do nothing but rest for 24 hours. They represent the minimum amount of energy required to keep your body functioning, including your heart beating, lungs breathing, and body temperature normal.

The Harris-Benedict equation for BMR (calories per hour 2007):

- BMR_men (kcal/day) = (13.75 * w) + (5 * h) - (6.76 * a) + 66
- BMR_women (kcal/day) = (9.56 * w) + (1.85 * h) - (4.68 * a) + 655

Where w = weight in kg, h = height in cm, a = age in years

3.5.5.2 Activity Levels and Metabolic Equivalent of Task (MET)

The MET level is defined as multiple of the standard resting energy values.

MET_adjusted = MET level * BMR (km/h)

Table 3. MET per kind of activities

Physical Activities	MET
sitting	1.8
standing	2
walking	3
jogging	7
running	10

METs on the previous table give multiple energy expenditure per kg and per hour that makes possible to estimate energy cost for an activity in kcal.

Chapter 4

System Implementation, Testing, and Analysis

4.1. Implementation

After determining the design and conduct the system requirement, the next stage is doing the implementation. The components that have been addressed in the design will be implemented in the form of prototype software products into a system of mutually integrated. Human activity recognition and estimation burn calorie processes are implemented on android mobile phone. It is used by put it in the trouser pocket. So, the application will calculated both of them automatically and without disturb user main activity.

4.2. Testing

The process of testing will be done by comparing the results issued by the application to actual results or outcomes of the output of similar applications. Here, there are several tests to measure the accuracy and see the symptoms that occur from the process of recognition of activities and estimation of burned calories.

4.2.1 Passive activities recognition

Passive activity recognition is a process to recognize activities like break, sit, and stand. The accuracy of this process will be tested 20 times with different position in 20 seconds each position.

Table 4. Testing of passive activities recognition

Number	Real Result	Application Result	Accuracy (%)
1	Sit (20s)	Sit (20s)	100
2	Sit (20s)	Sit (20s)	100
3	Sit (20s)	Sit (19s)	100
4	Sit (20s)	Sit (20s)	100
5	Sit (20s)	Stand (20s)	0
6	Sit (20s)	Sit (20s)	100
7	Sit (20s)	Sit (20s)	100
8	Sit (20s)	Sit (21s)	100
9	Sit (20s)	Stand (20s)	0
10	Sit (20s)	Sit (20s)	100
11	Stand (20s)	Stand (20s)	100
12	Stand (20s)	Stand (21s)	100
13	Stand (20s)	Stand (20s)	100
14	Stand (20s)	Sit (20s)	0
15	Stand (20s)	Stand (20s)	100
16	Stand (20s)	Stand (20s)	100
17	Stand (20s)	Stand (21s)	100
18	Stand (20s)	Stand (19s)	100
19	Stand (20s)	Sit (20s)	0
20	Stand (20s)	Stand (19s)	100
Number of True Accuracy			1600
Accuracy = 1600/20			80

$$Accuration = 1 - \frac{|Ract - Rapp|}{Ract}$$

4.2.2 Accuracy of Active activities recognition

Active activity recognition is a process to recognize activities like walk and run. The accuracy of this process will be tested 20 times with different position in 20 seconds for each position.

Table 5.Testing of movement or active activities recognition

Number	Real Result	Application Result	Accuracy (%)
1	Walk (20s)	Walk (22s)	100
2	Walk (20s)	Walk (22s)	100
3	Walk (20s)	Walk (23s)	100
4	Walk (20s)	Walk (24s)	100
5	Walk (20s)	Walk (23s)	100
6	Walk (20s)	Walk (23s)	100
7	Walk (20s)	Walk (24s)	100
8	Walk (20s)	Walk (23s)	100
9	Walk (20s)	Walk (22s)	100
10	Walk (20s)	Walk (24s)	100
11	Run (20s)	Run (22s)	100
12	Run (20s)	Run (23s)	100
13	Run (20s)	Run (24s)	100
14	Run (20s)	Run (24s)	100
15	Run (20s)	Run (22s)	100
16	Run (20s)	Run (22s)	100
17	Run (20s)	Run (23s)	100
18	Run (20s)	Run (23s)	100
19	Run (20s)	Run (24s)	100
20	Run (20s)	Run (24s)	100
Number of True Accuracy			2000
Accuracy			100

$$Accuration = 1 - \frac{|Ract - Rapp|}{Ract}$$

4.2.3 Burned Calories Estimation Accuracy of Passive Activities

The accuracy of burned calories estimation is calculated by compare the application result with another application result. In this case, comparator application is Sense Me application that can estimate burned calories including passive activity like sitting and standing which also need to burn calories for activity like breathing.

Table 6. Testing the result of calorie burn estimation of passive activity

Number	Application Result (Cal)	Other App	
		Result (Cal)	Error (%)
1	10	11	9.090909091
2	12	13	7.692307692
3	9	11	18.18181818
4	10	9	11.11111111
5	11	9	22.22222222
Average Error:			13.65967366

$$error = \frac{|Ract - Rapp|}{Ract}$$

4.2.4 Burned Calories Estimation Accuracy of Active Activities

The accuracy of burned calories estimation is calculated by compare the application result with another application and device result. In this case, comparator application are pedometer, treadmill, and NikeRun application on android device. All of them can estimate burned calories for active activity like walking and running with different speed.

Table 7. Testing the result of calorie burn estimation of active activity

Number	Application Result (Cal)	Pedometer		Treadmill		Other App	
		Result (Cal)	Error (%)	Result (Cal)	Error (%)	Result (Cal)	Error (%)
1	53	56	5.35714	52	1.92308	55	3.63636
2	58	64	9.375	57	1.75439	62	6.45161
3	55	58	5.17241	55	0	58	5.17241
4	60	64	6.25	58	3.44828	62	3.22581
5	57	59	3.38983	58	1.72414	60	5
Average Error:		5.908877432		1.769975336		4.697239357	

$$error = \frac{|Ract - Rapp|}{Ract}$$

4.3 Analysis

From four testing process we can analyze some fact like:

a. This system can recognize some activity like sit, stand, walk, and run with different speed.

b. It can recognize passive activity (sit and stand) with 80% accuracy.

c. It can recognize active activity (walk and run) with 100% accuracy.

d. Movement or active activities always have long different result about 3.3s (window time). This app is very accurate to detect this 3 activity, but it's always wrong to calculate the time of activity, because it needs at least 3.33 second to recognize an activity.

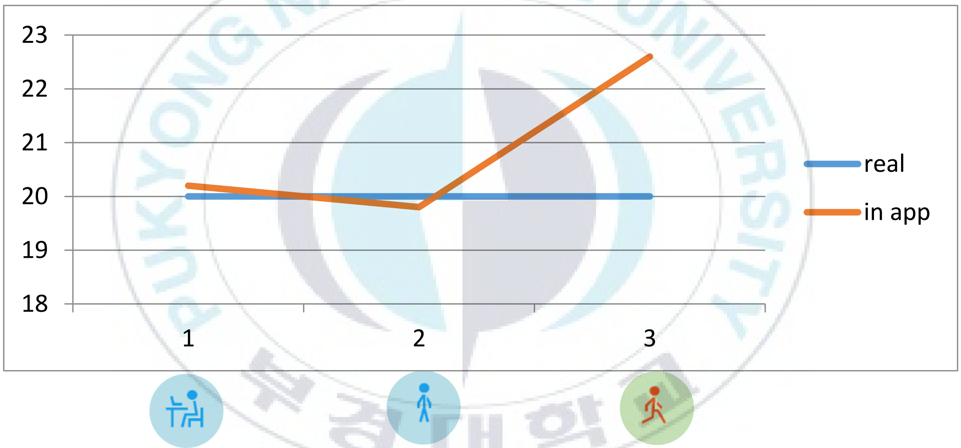

Figure 15. Average Time of each Activities

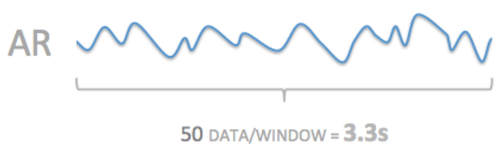

Figure 16. Window Size

e. Accuracy of burned calories estimation at passive activity is 86.3% compared with another similar application (Polar Flow Apps).

f. Average Error of burned calories estimation at movement or active activity is 5.9% compare with pedometer, 1.7% compared with treadmill, and 4.7% with similar application.

Chapter 5

Conclusions and Future Works

5.1. Conclusion

This thesis is focused on how to utilize mobile phone technology to obtain health data such as calories burned on daily activities of users. There are some statements that can be inferred from the results of tests and analysis, as follows:

a. With the used method, this application achieves high accuracy up to 90% to recognize common activities.

b. This method also has drawbacks. It uses the window time for 3 seconds to analyze a movement. It makes the different time that consistently occur when analyzing movement activities.

c. This method also has a high accuracy in estimating burned calories. It can be seen from the average error that has no more than 14% as compared to various device.

5.2. Future Works

This thesis is focused on how to utilize mobile phone technology to recognize daily activities of users. The selection of mobile phone because it is the most frequently taken anywhere and anytime. But it has some lack on accuracy because the position of mobile phone always changes. Its position sometimes on trouser pocket, shirt pocket, bag, or held on hand. So, we recommend for the future works to use another device like wearable device that has same feature in it and more consistence on its position. Another way is the combination of some device like mobile device in trouser pocket with wearable device at another body location, so it can recognize more kind of activity.

This thesis is also focused on how to utilize mobile phone technology to obtain health data such as calories burned on daily activities of users. With the ability of this method to recognize activity, it does not just obtain health data. It also can be used for entertainment like recommend music based on user activity or for advertisement that can recommend ads based on user activity.

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