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Acceleration and Orientation Multisensor Pedometer Application Design and Implementation on the Android Platform

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Abstract

This paper presents an Android platform's pedometer application design which uses SOLite database to provide the historical data query function and bases on the acceleration sensor and the orientation sensor. This paper first introduces the background of the application and the principle of Android platform pedometer. In addition, it also analyzes and compares the different design between the single acceleration sensor pedometer and the multi-sensor pedometer, which proves the advantage of this design. And then, on this basis, this paper describes three main functions' designs which are step count function, history query function and health test function. . This paper also describes the implementation and results of this application design and proves the design's feasibility and correctness.

Keywords-Android; Sensor; Steps Calculation Principle; Pedometer

I. INTRODUCTION

In thousands of years ago, walk was called "man's best medicine" by Hippocrates who is the father of medicine, and the World Health Organization explicitly pointed out that "the world's best sport is to walk." in 1992. With the development of society, people pay more attention to making life healthy, and walking tools-pedometer is becoming more and more popular. At present, many entitative pedometer equipments have already appeared in the market, such as Citizen, Omron and so on. Nowadays, such entitative pedometers are mainly divided into two kinds--mechanical and electronic [1]. Mechanical pedometer makes use of the vibration generated by human walking to make pedometer internal spring lamination or elastic ball vibration to produce electronic pulse. And then, internal processor judges the electronic pulse to achieve count steps function. The cost of this mechanical pedometer is lower, but its accuracy and sensitivity are very low. Electronic pedometer make use of the acceleration sensor[2] made by the new technology which is the combination of MEMS[3] and CMOS[4], such as ADXL330, ADXL340, measure the acceleration of the human walking to count steps.

With development of mobile network, people want to achieve more tools software implementation on mobile phones for convenience. Android[5] mobile phone platform is open enough to meet the requirements.. The existing Android platform pedometer usually uses the single acceleration sensor to count walking steps. According to the human body walk process, Pedometer establishes count steps model through analyzing the regularity of acceleration change in the gravity direction. But only using the acceleration data collected by single sensor is difficult to accurately reflect acceleration changes in the gravity direction. This paper discusses a pedometer application making use of both of the orientation sensor and the acceleration sensor, in which orientation sensor maps acceleration to the gravity direction to achieve the accurate gravity acceleration change.

II. ANDROID PLATFORM PEDOMETER OVERVIEW

A. Android Overview

Announced by Google in November 5, 2007, Android is an open-source mobile operating system based on Linux platform. This platform is composed of the operating system, the middleware, user's interface and application software. At present the latest version is 3.0. The greatest characteristic of Android is open-source which makes application developers master the development details more accurately, and develop higher level and more discriminating applications.

Android platform uses software stack structure which is mainly divided into three parts. The bottom layer is Linux kernel. The middle is called middleware layer. The top is application software layer.

Compared with other mobile operating systems, Android has a broader market. Such as Microsoft's Windows Mobile, The operators should to pay license fees to Microsoft. However, Android breaks certain restrictions by open-source. In addition, Google is also responsible for setting up Open mobile phone Alliance [6](Open Handset Alliance) to support and help Google to develop Android system and its application software. In view of the above advantage, Android gradually becomes the mainstream platform of mobile development, and, as a result, many personalized Android applications are generated.

B. Sensor Overview

The sensor is defined by the national standard GB7665-87 as: "Sensor is which can feel the specified measured signal which is converted into usable signal according to certain rules. Sensor usually is comprised of sensitive components and conversion components". Sensor is a detection device, which can feel the measured information, and can transform the information to electrical signal or other required formal information. It is the

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primary step to implement the automatic detection and automatic control.

According to the working principle, sensor can be divided into physical sensor and chemical sensors: Physical sensor application is based on physical effects, such as piezoelectric effect, away from the polarization, thermal power, and photoelectric, magnetic and electric effect and so on. Chemical sensors include chemical adsorption, electrochemical reactions sensors.

Most of the sensor is based on physical principles to operate. The most common physical sensors are pressure sensitive and force sensor, position sensor, the liquid level sensor, the energy consumption sensors, acceleration sensor etc. The pedometer application described by this paper is based on the intelligent mobile terminal sensor chip on Android platform, which provides the walking information, to realize count steps function.

C. Android Platform Sensor

The special of the development on the Android platform is that Android can let developers expediently access to the low-level hardware. Android SDK provides for hardware oriented characteristics.

At present, the Android platform which can support the sensor to be visited [7] includes: orientation-sensor, accelerometer-sensor, light-sensor, magnetic-field-sensor, proximity-sensor, temperature-sensor etc. But not all of the devices support all sensors defined in Android development platform. If a sensor can't be used in certain equipment, then the related applications also can't be used on this device.

III. Android Platform Multi-Sensor Pedometer Application Design

The so-called multi-sensor is relative to the single sensor. Now, Android pedometer application mostly used a single acceleration sensor to collect data, to extract features and to implement count step function. This paper presents an Android platform's pedometer application design and bases on the acceleration sensor and the orientation sensor.

A. Single Sensor Pedometer Implementation Principle

The realization of single sensor is mostly based on the following pedometer principle: When people are walking, there is a up and down process with starting point and stamping point states, that is, the acceleration of gravity acceleration value will present up and down. Through the analysis of the acceleration changes, people walking pace can be identified, so as to realize the project function.

From the hardware sensor to identifying human steps, the whole process can be divided into three stages:

1) *Data collection*--Using the Android platform interface to visit hardware collects the sensor data. Here the sensor mainly includes acceleration sensors, and this paper adds the orientation sensor data collection to make count step more accurate and can reflect the states of the mobile phone.

The collection frequency is determined by general features of human walking. Generally speaking, the human walk 0.5 ~ 2 steps per second , at most, no more than 5 steps, that is walking frequency is 0.5 ~ 5 HZ ac [1]. According to the Shannon theorem, collection frequency should be at least 2 * F_{max} (maximum frequency), that is 10 HZ ac, and considering the accuracy and efficiency of application, frequency was selected as the 20 HZ ac.

2) *Steps characteristics extraction*--According to formulizing the data collected above, the regular characteristic of acceleration changes during human walking can be got. Usually, according to the starting point and stamping point states existing in the human walking, if the formulation is appropriate, the result is that the acceleration mutative curve is similar to sine curve, which results in concluding the characteristic of steps to build a model to count steps.

3) *Build Steps Model*--The feature extraction of the wave will produce a top (bottom) of the wave in a step. Through the screening of the top (bottom) acceleration the step can be confirmed. Screening conditions are:

(1) The top (bottom) of acceleration waves should meet certain threshold because any movement of mobile phone may cause the changes of the acceleration. Using the threshold can filter these data interference.

(2) The consecutive count step time interval must be 0.2 ~ 2 seconds, which accord to human general frequency of walking.

There are two methods to determine threshold. One way is by the number of test data to determine the fixed threshold, and the other method is through the real-time data collection, determine the dynamic threshold, etc. The top (bottom) of waves meeting the above two conditions can be identified a step.

B. Multi-Sensor Pedometer Design

Multi-Sensor Pedometer application makes acceleration mapped to the gravity direction using orientation sensor, and gains accurate gravity acceleration changes. This method is more joint theory support and more accurate in practice.

Multi-sensor pedometer similar to the single sensor pedometer is also divided into three processes including: Data collection based on multi-sensor, Steps characteristics extraction based on multi-sensor, Build Steps Model based on multi-sensor. Each process design is as follows:

1) *Data collection based on multi-sensor*

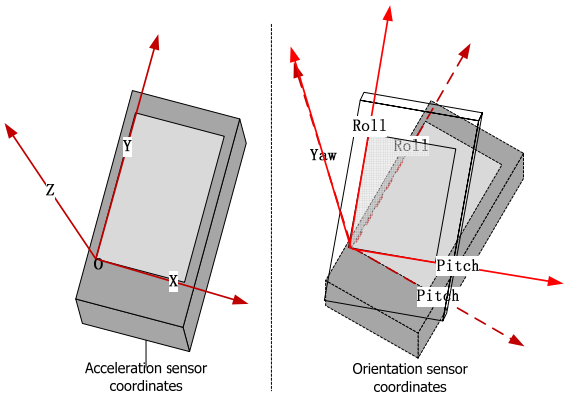

Figure1. Sensor Coordinate System

➢ Acceleration-sensor

The main effect of acceleration sensor is to obtain the movement of the mobile phone and this sensor acquires three parameters. They are the acceleration components which are separately equal to the accelerations of the coordinate system

X, Y, Z axis minus the components of gravity acceleration in the corresponding axis. The relationship between the acceleration coordinate system and mobile phone screen coordinate system is shown in figure1.

Different from the mobile phone screen coordinate system, the sensor's takes the left bottom as the origin, and the X axis is left to the right along the screen, the Y axis is down to up along the screen, and the Z axis is always perpendicular to mobile phone screen from down to up. The changes relationship of sensor data is as follows:

Mobile phone screen upward horizontal placed:

(x,y,z) = (0, 0, -10);

Uplift the top of the phone: the value of Y is reduced, and is a negative value;

Uplift the right of the phone: the value of X is reduced, and is a negative value;

Mobile phone screen upward horizontal placed: z= -10.

- Orientation-sensor

The main effect of orientation sensor is to obtain the orientation changes of the mobile phone and acquires three parameters. They are the rotation angles of Yaw axis, Pitch axis and Roll axis. The relationship between the orientation coordinate system and mobile phone screen coordinate system is shown in figure1.

The direction of Yaw axis is the negative direction of gravity direction and it keeps unchanged. The direction of Pitch axis changes through the mobile phone rotating along Yaw axis and keeps 90 degree Angle from Yaw axis. The direction of Roll axis is down to up along the mobile phone screen and keeps unchanged.

According to the application programming interface, Android platform provides data that can be collected are defined as follows:

TABLE I SENSOR DATA TABLE

Sensor type	data	description
Acceleration-sensor	X	Acceleration value of X axis
	Y	Acceleration value of Y axis
	Z	Acceleration value of Z axis
Orientation-sensor	Yaw	Rotation angle of Yaw axis
	Pitch	Rotation angle of Pitch axis
	Roll	Rotation angle of Roll axis

Using the hardware access interface provided by the Android platform to achieve the above sensor data, the data collection function can be realized.

2) *Steps characteristics extraction based on multi-sensor*

The steps feature extraction of the single acceleration sensor is to analyse the absolute values of the acceleration to determine the wave crest (wave troughs). The definition of acceleration the absolute values are as follows:

$$G_a=\sqrt{X^2+Y^2+Z^2}$$ [8]

Different from the above method, the method of combining the orientation sensor is to make acceleration mapped to the gravity direction using orientation sensor. Here, take components of X, Y, Z acceleration in gravity acceleration direction respectively as the variable a_y, a_x, a_z.

$$a_x = X \times Sin(roll)$$

$$a_y = Y \times Sin(pitch)$$

$$a_z = Z \times Cos(roll) \times Cos(pitch)$$

$$G_v = a_x + a_y + a_z$$

The acceleration waveform contrast diagram calculated using the above two ways is as follows:

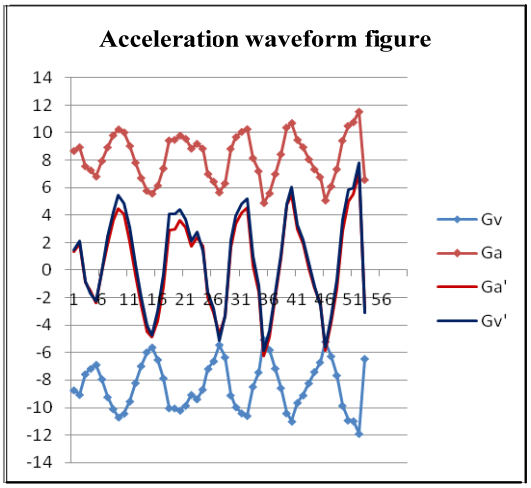

Figure2. Acceleration Waveform Figure

In the figure above, Gv is multi-sensor waveform figure, and Ga is for the single sensor. The figure shows the wave trend of the two methods is approximation but is not completely equal. Gv representing acceleration in the gravity direction is more according with the principle of rise and fall of human walk and is more accurate than Ga. In the figure2, Ga' and Gv' respectively equal to the value of Ga and Gv minus initial acceleration value and compared with the waveforms of the Ga' and Gv', the difference between the acceleration values is more obvious which embody the advantage that Gv reflects the gravity acceleration value.

3) *Build Steps Model based on multi-sensor*

Based on the principle, the steps are calculated by determining the effective wave crest (trough). The so-called factor that the effective crests values should consider is that the sensitive sensors are possible to produce numerical changes for small movement. This kind of accidental data is the invalid wave value. The application adopts dynamic threshold method to filter the invalid wave value. Through the observation of experimental data, the different value between effective step wave crest and the average acceleration is usually greater than 1. In view of 20 HZ sample frequency, imaging the application can go into normal state in five seconds, this application designs a length of 100 storage queue to store acceleration values. The formula for calculating the Real-time dynamic threshold—Th is as follows:

$$Th=\sum_{i=1}^{100} Gvi \div 100 + 1$$

When the value of the crests Gv > Th, the crests is effective and the count of steps should be added 1.

IV. ANDROID PLATFORM MULTI-SENSOR PEDOMETER APPLICATION IMPLEMENTATION

A. *Android Platform Pedometer Implementation Architecture*

Android platform system structure is divided into four layers. This application how to make use of these layers is described as follows:

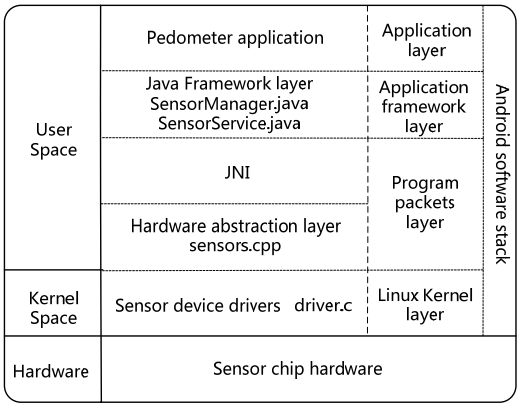

Figure3. Pedometer Implementation Architecture Figure

Pictured above, the layers of the Android software stack bottom to up respectively are Linux kernel layer, program packets layer, application framework layer and application layer. The application described presents in the application layer at last, but its implementation depends on the interaction of sensor hardware and the underlying architecture of Android platform.

The process of realizing the pedometer application can be described as follows:

1、 The sensor driver in Linux kernel layer controls sensor hardware chip to obtain the acceleration, direction changes.

2、 Hardware abstraction layer makes use of the open(), read() and write() functions to interact with the underlying layers to obtain data.

3、 JNI layer completes a task that is realizing the transforming from c++ language to java language and provides a series of API for Java Framework layer.

4、 Application framework layer provides all kinds of classes about various sensors for developers.

5、 Application layer makes use of the API provided by the application framework layer, according to the principle of multi-sensor pedometer, to realize the pedometer application.

Considering the functional and practical for application, the application designs three functions which are step count function, history query function and health test function.

Among them, Step count function completes counting step and inserts the step records into database per hour for history query function.

History query function makes use of the Embedded SQLite[9] date base to store the step data in a month. Users can view the 24 hours data (bar chart) and each week data (line chart).

Health test function mainly provides all kinds of calculator related to health. It includes BMI calculator, calorie calculator and so on.

The interaction of each layers of the Android platform is described in the following figure. In the figure4, middleware is stand for the layers from hardware layer to application framework layer.

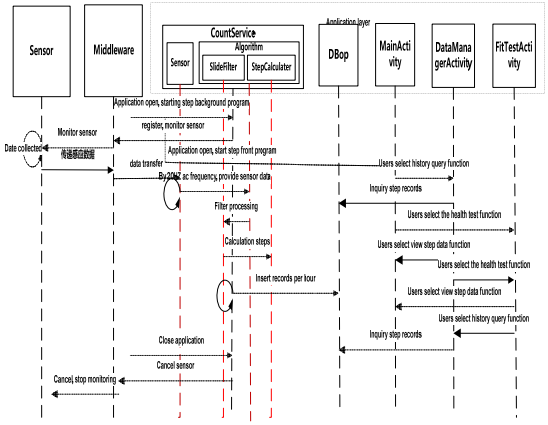

Figure4. Application Interaction Figure

The figure above shows that when the application open, the application layer first registers and monitors the sensors through the API on the Android platform and then the hardware sensors get the step data transmitted to middleware and the middleware transmits the data to the pedometer application. In the figure4, the implementation of the step count is the combination of the front module and background module, which can make the application keep running when the front pages are closed. At last, when users close the application, application first stops monitoring the sensors and then stop steps, and last closes the application.

B. *Results show*

The results of this design are as follows:

Step Count Function History Query Funtion

Figure5. Application Results Figure

Step count function figure is the front module to shows the steps data about walking. In the figure above, there are some buttons on the bottom of the page which is used to jump to the other functions.

History query function figure is the page of DateManagerActivity. In the figure, the bar chart shows the hours data and the line chart shows the month data.

V. CONCLUSION

This paper presents an Android platform's pedometer application design which is based on the acceleration sensor and the orientation sensor, and compares the single acceleration sensor pedometer with the multi-sensor pedometer. The feasibility and the advantage of the multi-sensor pedometer are proved in this paper. The advantage is that the multi-sensor pedometer is more accurate than the single sensor pedometer and i can provide the attitude of the mobile phone to be used to optimize the characteristic extraction. According to this design, the paper describes the implementation and the results of the design and introduces the structure of the Android platform. All in all, this paper completes the design and the implementation of the multi-sensor pedometer and at the same time proves the feasibility of the design.

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