Multimodal Data Enabled Motion Detection and Recognition in Exercise Social Networks

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Abstract—With the stress of working and living increasing day by day, a fairly large number of people have been in the state of sub-health. Therefore, in developed countries, health problems have become a social focus which cannot be ignored. In this paper, we utilize rich functions of smart phones, make them as social terminals providing daily convenient fitness services for the users. Users are connected by the exercise social network and can compete and treat their exercise points for coupons or games, etc. By processing multimodal data from three axis accelerator, gyroscope, direction sensor, together with pattern recognition, users can do body exercise through specified training motions such as raising dumbbells, deep crouch, sit-up, running recognized which will be identified and recorded for social usage. Our system leverages multimodal data processing to fit individuals so that we can get better accuracy no matter what the person's habit is or what device he is using.

Keywords- Multimodal data; social network; motion recognition; smart phone; sensor

I. INTRODUCTION

With the accelerated pace of life and increased social pressure, people's health has become an issue which cannot be ignored, especially in the developed countries and cities. According to the survey, in China, about 70% of its population is in sub-health state, 15% of them in the unhealthy state, and only 15% of people are healthy. Especially those IT workers, lack of exercise, excessive use of brains, with long-term adverse emotional impact, whose healthy balance are broken, remain at the sub-health state. Some work [1][2] has proposed to use smart phones which encourage people to participate in physical exercises since it‟s convenient and funny. Furthermore, to have social contact and competition included, it will bring more fun [3][4].

Currently, there are a variety of smart phone operating systems in the market, while the largest market share is the Android operating system, which released by Google in 2007. Android [5] is based on Linux kernel, and provides a lot of distinctive interface: Sensor System, speech recognition technology, Google Map, and widgets of desktop. Where the sensor system is built in, Android phones usually contain a very useful acceleration sensor, and through it, the phone supports the gravity sensing, to determine the direction of other functions.

Due to the openness of the Android system, it provides support for many hardware devices, such as acceleration sensors and gyroscopes. Therefore, we propose a multi-functional fitness software based on Android smart phones, intend to design a mobile application for the busy working groups. In spare time, the users can set up exercise targets based on their own physical condition, and then the system automatically generates the schedule of exercise program. Using smart phones‟ built-in sensors to sense the motion of phones, the software can recognize some simple exercise, such as simulated dumbbell, deep crouch, sit-ups, running. At the same time, it records statistics of the amount of exercises, and calculates the actual energy consumption, and thus assesses the physical condition. The exercise results will be recorded in the form of a diary at local, and also can be synchronized share on twitter, facebook and other social networking sites to communicate with friends, to achieve the interaction between users.

Ref. [6] shows that motion detection could be done using accelerators. As all these sensors become very popular in smart phones, using embed sensors to detect movement of smart phones is quite feasible nowadays [7][8][9].

Compared with other fitness methods, this study has proposed a lower cost way for fitness, without requiring additional expensive equipments. To enhance accuracy, multimodal data from different sensors are processed in a data mining manner [10]. By using only of leisure time users can achieve the purpose of physical exercise. In addition, it provides fancy interface, personalized exercise program, interaction between users, which increases the fun in the exercise, so as to achieve the effect of blending practice in the music, allowing users to gradually improve the physical condition in the relaxed course.

II. SYSTEM ARCHITECTURE AND FUNCTIONALITY

We design our system on Android operating system, the function flow of the whole system is shown in Fig .1, and the major functional parts are described as following:

A. *Customized exercise plan*

The system takes each individual‟s needs and characters into account. When a new user starts registration, he or she will be asked to answer some simple questions. By analyzing these questions (including height and weight, activity habits, physical condition), we could estimate the health level of users and then automatically generate a scientific customized exercise program for users together with workout schedule, and provide exercise reminders.

B. Real-time exercise detection

Thanks to multiple sensors and processing of multimodal data, the system embeds a variety of motion patterns in the software, such as lifting dumbbells, running, deep crouch and other. When users perform a certain motion pattern, the data of the acceleration and other sensor is dynamic sampled. All data are analyzed to see which pattern they are meet. The corresponding motion will be added by one. At the end of the exercise, according to proposed algorithms, the amount of exercise and intensity of exercise will be converted into the energy consumption, in units of calories presented to the user, and recorded into the user's database to generate exercise log.

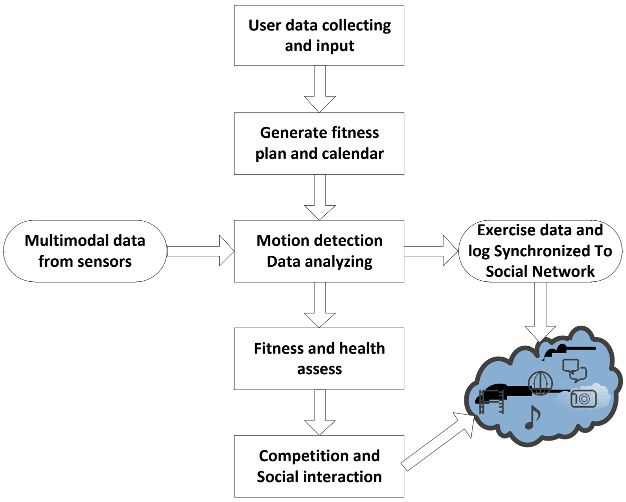

Figure 1. Function flow of proposed system

C. Exercise Statistics

Exercise analyzing and reporting is very important to users. When a user finishes a period of exercise, the system will record exercise data in this period, and take a series of related evaluation which is to determine whether the user has reached the expected target or not, and to give a comprehensive evaluation. To make the best out of the data, the user interface is enhanced by interesting animation, intuitive charts and so on. Meanwhile, the system writes the data into the database and amends the plan accordingly.

D. Social interactions

To encourage users to use the system, social networking is utilized to enrich user experience. The exercise results can be synchronized and shared on Twitter, Facebook and other social networking sites, and exchange of experience with good friends. Furthermore, users can compete with each other. The accumulated points can also be used to exchange for coupons or gift cards.

III. DESIGN AND IMPLEMENTATION

User interface is the first step before user can be attracted to use the system

A. UI Design

1) The main user interface.

As the entry of the system, the user can easily find the entrance to all functions in the main UI, and can view the current status of the target completion and physical health status, shown in Fig .2. When the body is in good condition, smiley face will appear on the left, while in poor health, the face will show crying, in order to motivate users to adhere to physical exercise.

2) The exercise user interface

When users start exercising, and select the motion pattern, the program will jump to exercise UI, shown in Fig .3. In the exercise UI, real-time duration of current exercise and the total number will be displayed. The exercise ends when users click the button of END, and then displays the results of the exercise. The exercise result can be shared on Twitter, Facebook and other social networking sites.

Figure 2. Main UI Figure 3. Exercise UI

3) The exercise plan UI

This UI will display each exercise plan in chronological order, shown in Fig .4. When the user clicks the ADD button to add an exercise program, then clicks on the exercise program drop-down menu to select the name of the exercise program, in the input box, enters the amount of exercise and time. Users can also click the delete button to delete one of programs. Finally, when the users have finished setting each program, then he can click the save button to generate an exercise plan. In addition, there is a button to generate an exercise plan automatically based on the user's status. When the exercise time comes, the software will prompt the user for the appropriate exercise.

4) The exercise statistics UI

Exercise statistics user interface, shown in Fig .5, there are two labels can switch between the exercise chart and energy consumption chart. In the exercise chart label, users can browse every day exercise statistics, and graphically presents in an intuitive way. Users can also browse the exercise history by clicking left or right button. In energy consumption chart label, it displays the energy consumption in this month. Users can also browse the history of energy consumption chart.

B. Database Design

In the system, a user profile will be created for each user which allows them to set their own training programs.

During the exercise process, there will generate the user's personal data. These contents will be stored in the corresponding database, which provides feedback exercise results to the user.

Through analysis, we should establish the following entities: user, exercise plan, exercise results, specifically described as follows:

User (id, name, password, health, latest login);
ExercisePlan (id, pTime, pType, pNumber);
ExerciseResult (id, aTime, aType, aNumber, aCalorie).

Figure 4. Exercise Plan

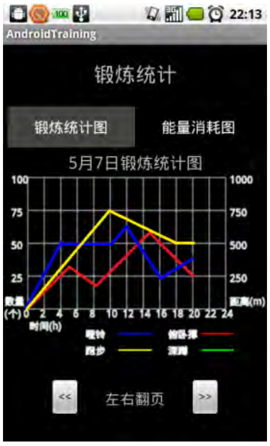

Figure 5. Exercise Statistics

In summary, we obtain the logical structure of the database model includes the following three tables:

TABLE I. USER

No	Field	Data type	Description
1	id	INTEGER	User ID, Primary Key
2	name	TEXT	User name
3	password	TEXT	User password
4	health	INTEGER	Health status
5	last	INTEGER	Latest exercise time

TABLE II. EXERCISE PLAN

No	Field	Data type	Description
1	id	INTEGER	User ID, Primary Key
2	pTime	INTEGER	Exercise alarm, P. Key
3	pType	TEXT	Exercise type
4	pNumber	INTEGER	Exercise number

TABLE III. EXERCISE RESULT

No	Field	Data type	Description
1	id	INTEGER	User ID, Primary Key
2	aTime	INTEGER	Exercise time, P. Key
3	aType	TEXT	Exercise type
4	aNumber	INTEGER	Exercise number
5	aCalorie	Real	Calories

C. Motion Detection and Recognition

In order to better analyze the sensor data and to extract the motion patterns of each motion, first we have to train the algorithm and analyze the data locally on PCs.

1) Dumbbell pattern #1

At first, flexing arms, while holding the phone in the hand, the main screen of phone facing out. Then, arms drooping naturally, bending to the shoulder, try not to move the upper arm, and gently down, then repeat the above actions.

Before the analyzing the sensor data, it needs to know several related concepts, (1) Sensor coordinate system: acceleration coordinate system is the same as mobile coordinate system, as follows: place the mobile on the desktop, the X axis is horizontal and points to the right, with a red line, and the Y axis is vertical and points up of the screen, with green line, and the Z axis points towards the outside of the front face of the screen, represented by the blue line; (2) Vector sum is $\sqrt{x^2 + y^2 + z^2}$, with a white line. Then using written test program to test the above actions, the result is shown in Fig .6, the unit is m/s^2.

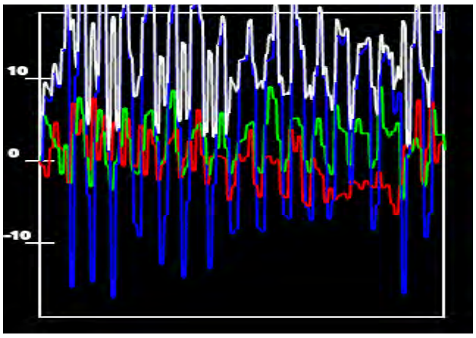

Figure 6. Dumbbell pattern #1

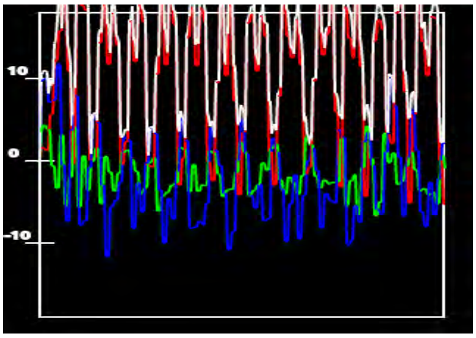

Figure 7. Dumbbell pattern #2

From analysis of Fig .6, when dumbbell pattern #1 is performed, the Z-axis direction has the larger amplitude, while X-axis and Y-axis has relatively small amplitude. So regard the Z-axis as a monitoring axis, vector sum as an auxiliary judgment. We also set two thresholds: a high threshold with $15m/s^2$ and a low threshold with $-5m/s^2$. Once data exceed the high threshold for some time and suddenly fall to the low threshold and maintain a short period of time, the action will be as recognized as valid data.

2) Dumbbell pattern #2

Raise arm in a horizontal and lateral manner, while holding the phone in the hand. The main screen of phone faces downside. Arms droop naturally. Handheld phones will move to the side of the arm and shoulder level, palms facing downside, and then gently let down, repeat the above actions.

The result is shown in Fig .7, which shows that the amplitude of the X-axis and Z-axis has special characteristics that when X-axis reaches the highest point, Z-axis is in the lowest point. According to this characteristic, the X-axis is regarded as a monitoring axis, and Z axis as an auxiliary judgment. We set high threshold is $15m/s^2$, low threshold is $4.5m/s^2$. Use a method similar with dumbbell pattern #1 for motion recognition.

3) The deep crouch pattern

Put the phone in pocket or in hand, when you squat, pause preferably no more than a second, and then stand up, which achieves a count.

The test result is shown in Fig .8. Since the direction of the phone is uncertain while doing deep crouch, any single axis can be used as the monitor axis, so that only the sum of three-axis vector $\sqrt{x^2+y^2+z^2}$ is to be judged. And Use a similar method with dumbbell pattern for motion recognition and the high and low threshold are $12m/s^2$, $8m/s^2$, respectively. If the vector sum breaks high threshold for a period of time, and suddenly falls to a low threshold and maintain for a short period of time, the action will be treated as valid data. The count increases.

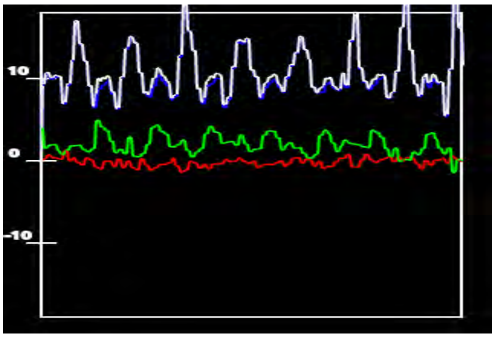

Figure 8. deep crouch pattern

4) The running pattern

Users put mobile phones in the pocket, and begin to run; the test result is shown in Fig .9. We can see the graphic is mixed and disorderly. As the previous algorithm cannot fulfill the function of monitoring of the running, here we bring forward a new algorithm. Its idea is roughly through the amplitude and frequency of vector sum to infer the intensity and distance of running.

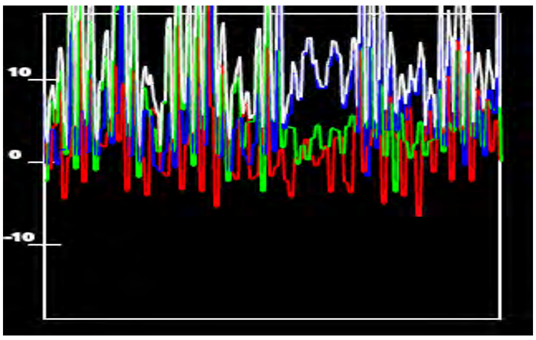

Figure 9. running pattern

In this paper, we develop the following formula, which can estimate running motion distance per second with the acceleration:

$$distance = (aixs\_amp \times step\_length \times count) / aixs\_scale$$

Among them, the parameter distance is the running motion distance per second, unit is meter. The parameter Aixs_amp is for the maximum acceleration in this second minus the minimum, namely the acceleration amplitude, unit is m/s^2. Step_length is the step length for users, the unit is cm. The count refers to the frequency with acceleration from the highest to the lowest, can be understood as steps per second. Aixs_scale is a proportional coefficient, values can be 0.03 ~ 0.05.

According to the formula above, we set a timer in the program, call the function once per second to calculate distance, constantly accumulate, then can display real-time running away.

Integrate the above function into an Android app, after the start of the motion, open the phone built-in gravity accelerate sensor, constantly read data, call the motion recognition function. If meet the pattern, the counter is increased until the user reaches the end of exercise or manually press the end button, the specific process shown is in Fig .10.

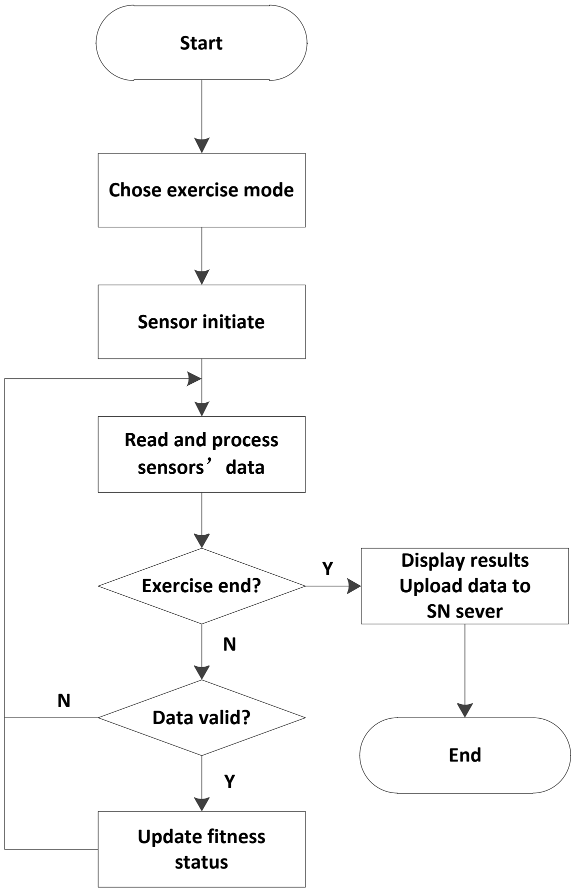

Figure 10. The flow chart of motion pattern Recognition

IV. CONCLUSION

In this paper, we develop a system that uses multimodal data from sensors built in a smart phone. It can act as an exercise tool any time anywhere. Through internet connection, these smart phones can be connected as terminals of social network which enables user to earn points and compete with each other.

The functionality includes customized exercise plan, real-time monitoring, exercise statistics. Through experiments, most exercise modes keep low error rate. However, there are different mobile phones and different usage habit. Therefore, in the future, self-adaptation will be major topic to deal with.

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