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Original Article

Personal Healthy Diet and Calorie Monitoring System using Fuzzy Inference in Smart Phones

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The increasing popularity of dining out has led to a rise in obesity and a reduction in exercise among adults. In addition, the increasing consumption of refined foods is resulting in unbalanced diets and elevated risk of various chronic diseases. To reduce these risks, much attention is being paid to methods of weight loss in Taiwan, and there is increasing awareness of the need to monitor caloric and nutrient intake, as well as an emphasis on the healthiness and balanced nature of food intake. Hence, we developed the "personal diet and caloric intake monitoring system" for use on smart phones, which is based on the fuzzy inference method. In this system, a QR code is used to save information regarding nutrients, including calories, protein, fat, carbohydrates, and sodium. Using the data stored in the QR code, the proposed system calculates the total nutrition from individual sessions of food intake. Next, it determines whether the number of intake-calories and intake-nutrition value go beyond the daily recommended allowances. In addition, this system applies the G-Sensor available on most smart phones to measure the rocking motion of users during exercise. Fuzzy inference method infers number of calories burned. The success rate of the system was 90% in terms of the accuracy of calorie burning calculations. Based on comparisons with Nike+ sensor, the calorie-burning value measured by the proposed system was closer to that calculated by the standard calorie-burning formula. In summary, this proposed system was able to help users make food selections and monitor calories, regardless of gender or goal whether it be losing weight or monitoring diet. Users are able to adjust nutritional intake and measure calories burned during exercise to eventually balance nutrients and control caloric intake.

Key words: Smart phones, Calories, QR code, Fuzzy inference, G-Sensor

Introduction

An increasing number of people are dining out and experiencing abnormal dietary intake. This has led to consumption of an unbalanced diet and an increase in obesity among Taiwanese. Obesity is a risk factor for many diseases[1] and, therefore, is of great concern. Statistics released by the World Health Organization (WHO) reveal that over 150 million adults are overweight[2]. In general, weight loss[3] is a measure taken to reduce the impact of obesity, with reduction in body fat topping the list of goals. Exercise and diet control together are considered the most effective methods losing weight[4]. An extensive number of studies have shown that regular exercise can adjust the physical state, promote health, control weight[5], reduce risk of chronic disease, and improve life quality. To achieve weight loss, caloric intake must fall below the calories[6] burned by the body. Nonetheless, the

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daily caloric intake should be sufficient to maintain the basic nutritional needs of the human body, with a minimum daily caloric intake of 1600Kcal recommended. Effective control of caloric intake can also prevent cardiovascular and other chronic diseases[7-9].

Food that is sold in the market usually comes with a label that lists nutrient content. Convenience store chains are increasingly making use of QR codes to store nutrient content information. This facilitates integration with our system. Eason et al.[10-14] proposed the QR code as a matrix symbol first developed by Denson-Wave in Japan in 1994. The camera function in smart phones is used to scan the QR code to open a website and display video or text and hyperlinks are provided via drawing text. Eason et al.[10-11] noted that the QR code is widely used in e-commerce, advertising and product information. Rohs et al.[12] suggested that the QR code can be applied to electronic screens, including computer, television and small portable device screens. QR code performs better than 1-dimensional barcode and its function and characteristics consist of large data capacity and small data area, storing 4296 alphanumeric or 7089 numeric characters. It can be used for quick scanning and is free from directional constraint. In the case that half of the QR code is damaged, the data can still be retrieved.

In an era of increasing smart phone use, the G-Sensor, which is built into most smart phones, can be used to determine motion intensity during exercise. Then, the fuzzy inference method can be applied to determine the number of calories burned. Over the past 30 years of development[15] the scope of application of fuzzy theory has become quite extensive, ranging from engineering technology to the humanities and sciences. Volosencu[16] indicated that when the input of the controller has undergone fuzzification, synthesis operation must be carried out according to the touch control rules to infer the desired output and yield a concise outcome[17]. It is necessary to know a person's weight and activity schedule to be able to calculate his/her daily caloric needs and monitor whether the daily caloric intake exceeds the recommended daily allowance.

The concept of fuzzy theory was first put forth by Zadeh in 1965, who proposed the concept of Fuzzy Set with emphasis on describing the level of nature of things in real life using fuzzy logics to make up for shortcomings in traditional sets of descriptions using two-valued logic. In 1974, Mamdani successfully proved the superior performance of a fuzzy logic controller for automatic control of stream automobile, which later led to a wave of research studies of its applications in a considerable number and variety of fields, including control systems, pattern recognition and decision analysis. In particular, a large number of scholars have studied the application of fuzzy logic controller to control systems in recent years.

According to one previous study[18], fuzzy inference plays an important conceptual role in fuzzy logics. In general, fuzzy inference aims to infer the propositional if-then rules of new fuzzy logics. The result obtained from fuzzy inference then has to be defuzzified. The purpose of defuzzification is to take the result yielded from fuzzy inference and convert it from fuzzy set to output of clear value through reasoning and appropriate calculation. Common methods used include center of gravity defuzzification, center of sum defuzzification, and height defuzzification. In this study, we used center of gravity defuzzification.

There are many similar smart phone Apps available[19]. For example, there are Apps for calculating caloric intake and for calculating the number of calories burned. Users can check whether the caloric intake per day is suitable for controlling or losing weight. However, there are very few Apps that can simultaneously calculate caloric intake and number of calories burned. The proposed system combines these two features. Users can know how many calories they have consumed in a meal. If there is excessive intake, a warning message will be sent. If users exercise, the proposed system provides data about the number of calories burned.

As smart phones can be used to record caloric intake and number of calories burned, we developed a system to record daily nutritional content using data stored in a QR code. Our proposed system can use these nutrient data to perform analysis and processing, and transmit these data into a remote database. The proposed system can also be integrated with G-Sensor within smart phones for measuring the number of user's jumps and the intensity of jumps to determine the calorie-burning value of daily exercise. The proposed system can notify the user if he/she has exceeded the daily-recommended caloric. The values of caloric intake and calories burned are used to remind the users of the deficiency or in excess of caloric intake or exercise at any time.

The purpose of this paper was to develop a system for personal diet and caloric intake monitoring. It can be implemented in smart phones and its functions include calculation of calories burned during exercise, caloric intake and nutrients including sodium and protein.

This paper is divided into three sections. The first section is methods, which introduces the our proposed system architecture, system processing flow, and the processing procedure of the system to explain the calculation of calorie intake and the sum of nutritional content as well as the process of inferring calorie burning using fuzzy interference technology. The experimental results of the system are noted in the second section which also includes an explanation of the operational interface. The third section is the conclusion.

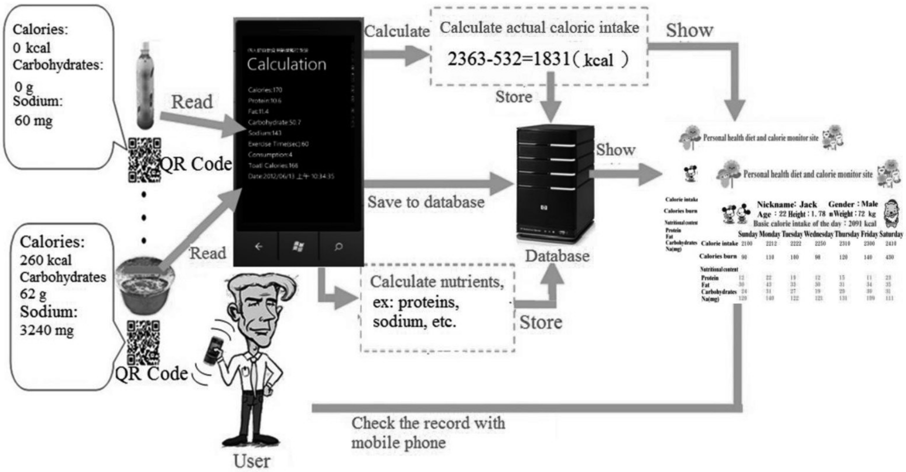

Fig. 1. System architecture

Materials and Methods

Fig. 1 shows the architecture of our proposed system. The system framework is divided into three parts. The first part is for data reading of the QR code labeled on food packages to record caloric and nutritional content. The data within the QR code include calories, protein, fat, carbohydrates, and sodium. The second part involves data transmission, access and calculation, with transmission of data to a remote database for storage through wireless transmission technology. We also use the G-Sensor installed in most smart phones to detect the amount and intensity of exercise. These data are incorporated into an exercise formula to calculate the calories burned, followed by calculation of the total caloric intake per day. Finally, the third part displays the final results on the smart phone or on a website that we have designed so that users can check detailed information and historical records in real time.

The proposed system is specifically designed for patients suffering from chronic diseases who must pay attention to their diet, giving them reminders of excessive nutritional content. For example, for patients with cardiovascular disease, the system gives warnings regarding sodium control and a message window pops up in case of excess.

Fig. 2 shows the flowchart of proposed system processing. It is divided into three parts. First, the user enters personal data, including gender, age, height, and weight. Next, the proposed system automatically calculates the total calories and nutrients from daily food intake by reading the data contained within the QR code on food packages. All of the information is transmitted to a remote database via wireless transmission technology. With regard to the calculation of nutritional content, let's use sodium

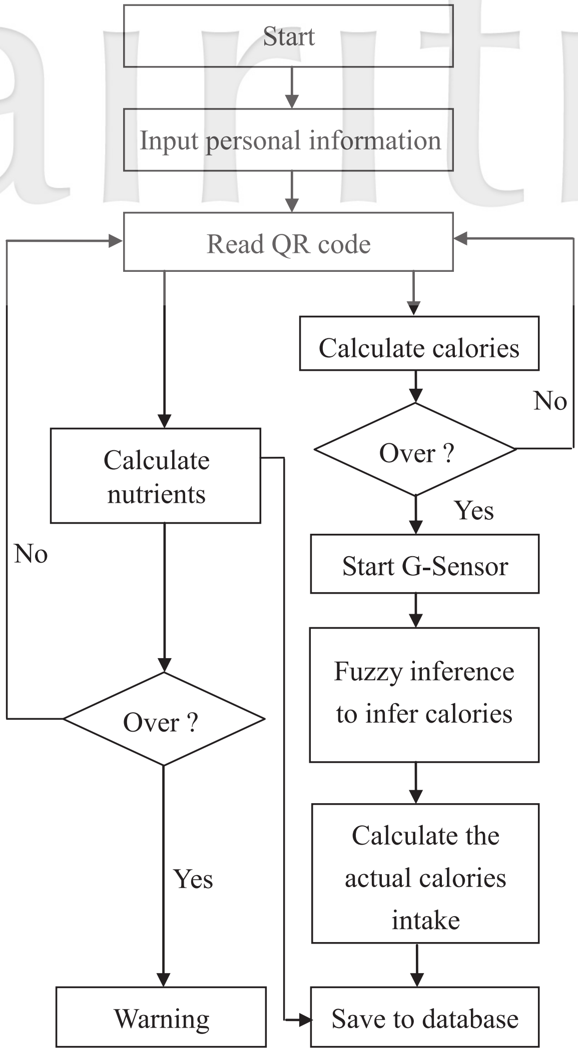

Fig. 2. Flowchart of system processing

intake as an example. Sodium intake should not exceed 2400 mg per day. If the amount of sodium exceeds this standard, a message window pops up to remind the user to cut back on sodium. In the beginning, in order to understand personal health condition, personal basic data, including height and weight, are entered into the proposed system. Then, the daily recommended caloric intake for that user is calculated. If the caloric intake exceeds the recommended allowance, the system automatically informs the user and recommends exercise. Here, the proposed system launches the G-Sensor to obtain the number of jumps by the user. The fuzzy inference method is used to infer the calories burned by the user during exercise. Finally, the total caloric intake and number of calories burned in one day is calculated to produce the actual caloric intake. The data are then stored in a database.

QR code replaces the traditional barcode to store the nutrient data of food. Users can read all of the information contained in the QR code on the food package using their smart phone. The proposed system automatically calculates personal caloric and nutrient intakes. Below is a detailed explanation of the process:

A.Fuzzy inference to infer calories

Caloric consumption is calculated by the following equation:

$$\textbf{\textit{Consumption}} = \mathbf{1/2} \times \textbf{\textit{Times}} \times \textbf{\textit{BMI}} \times \textbf{\textit{Tp}} \qquad (1)$$

The unit of consumption is cal. The variable, Times, represents the number of jumps, and its unit is times/hr. The variable, BMI, represents body mass index, and its unit is kg/m^2. The variable, Tp, represents the amount of time of exercise, and its unit is hr.

According to the results calculated from the calorie burning equation, (1) does not tolerate much change and is absolute, while contradicting the human thinking model. To better comply with human expectation, we use a fuzzy inference method. Fuzzy inference simulates logic using fuzzy message or incomplete data. It makes a correction without undergoing precise and complicated calculation. Fuzzy inference is incorporated into the calorie calculation equation to infer a calorie-burned value that is more in line with human cognition.

A precise result is inferred by fuzzy inference method based on a small quantity of data. In general, there are four steps to fuzzy inference, including the fuzzification of the input variables, rule evaluation, aggregation of the rule outputs, and defuzzification. Hence, we first define the membership functions of inputs and outputs, as shown in Fig. 3 (a) to (d):

Fig. 3 (a) to (d) are the membership functions of input and output variables. According to these membership functions shown in Fig. 3 (a) to (d), we can define the following rules of fuzzy inference:

R^1: if Times is S and *BMI* is S and *Tp* is S then

C is S.

R^2: if Times is M and *BMI* is S and *Tp* is L then C is L.

R^3: if Times is M and *BMI* is L and *Tp* is M then C is L.

In the context of the linguistic variable jumping times, BMI, exercise time and caloric consumption, we define three terms: small, medium and large. The 324 rule membership function curves are shown in Fig. 3. These rules were reduced or selected by an expert, leaving us with 250 rules. Next, we used center of gravity (COG) defuzzification method to defuzzify. The COG equation is shown as equation (2).

$$X^* = \frac{\sum x \times \mu_{calorie}(x)}{\sum \mu_{calorie}(x)} \qquad (2)$$

From the real values of number of jumps, BMI, and exercise time, we obtain the value of calories burned using the fuzzy inference method. In the following section, we calculate actual caloric intake using inferred calorie burning value.

B. Actual caloric intake

With regard to caloric intake, users can use their smart phones to read the QR code on a food package and the system can calculate the total calories and total nutritional content of food consumed in one day. The number of calories burned in one day is obtained by the fuzzy inference method. Finally, the number of calories burned is subtracted from the caloric intake to obtain the actual caloric intake in one day. Hence, the system can effectively monitor user intake and number of calories burned.

The equation is shown below:

Caloric intake = total intake per day - total calories burned per day (3)

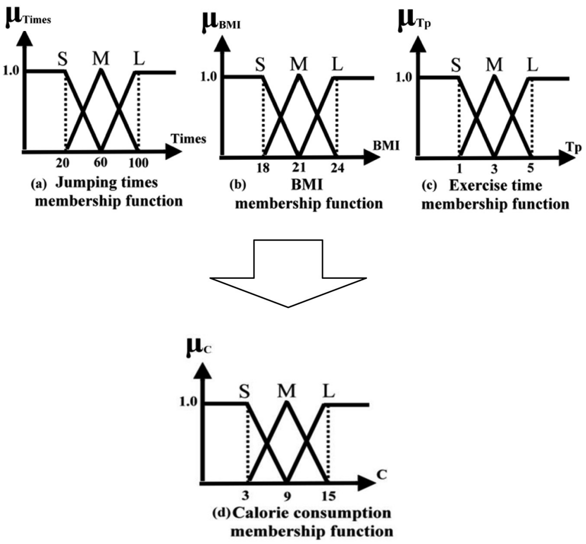

Fig. 3. (a) to (d) are the membership functions of input and output variables.

C. Nutritional intake

The nutrient data of each food item is stored inside the QR code. Users can use their smart phone to read the data. Then, this proposed system makes a judgment. The system sums up the nutritional content so that users can find out the total amount of each type of nutrient consumed per day.

Additionally, this proposed system automatically detects user intake of each nutrient and determines whether the daily recommended allowance has been exceeded. Below are several illustrations:

R^1: if Sodium> 2400mg then intake exceeds daily recommended allowance

R^2: if Carbohydrate>75g then intake exceeds daily recommended allowance

R^3: if Fat > then intake exceeds daily recommended allowance

D. Detection of jumps

To allow users to do simple exercise anytime and anywhere and to understand how many calories have been burned, the G-sensor in smart phones is used to detect user jumps. Users can shake the phone up and down to burn calories. They can also place the phone at their waist and jump up and down to burn calories. When the smart phone is held still in the hands, it can tell users the relative direction of the smart phone in relation to the earth using the G-sensor. The goal of detection of jumps is to obtain the relative information regarding number of calories burned such as number of jumps and distance, etc. During the jumps, the high or low of accelerator value resulting from smart phones moving upwards in the opposite direction of gravity defines a critical value that can be used for calculating the number of jumps. The detection method is according to equation (4).

$$c = (c + 1) \text{ where } Y > 1 \,||\, Y < 1 \,\&\&\, X == 0 \,\&\&\, Z == 0 \quad (4)$$

X, Y and Z represent the X-axis, Y-axis and Z-axis, respectively, and c represents the number of jumps.

E. Website design and database building

Open web development environment is bound to be the mainstream of the future. Fig. 4 shows the architecture of our designed website. PHP technology is the main tool used.

The system offers a storage function to store information regarding caloric intake, nutritional content and calories burned in a database. PHP, a web design language, was used to design a website that offers users the function of remote query of personal caloric intake and calorie burning data.

Fig. 4 shows that the website is divided into 6 parts, including the homepage, sitemap, dieting information, health control, links to related websites, and member area. Users can read up-to-date news on dieting, health, and exercise on the homepage. This website provides users with health and dieting information, as well as self-evaluation methods. The site is designed with authority in that users must become members to track total personal caloric intake, total nutritional content and calories burned after login to the website. Moreover, user intake is displayed to make the user aware of any excess or deficiency. Users are notified to supplement or reduce certain types of intake or to increase or decrease exercise. Finally, the website offers links to domestic and international health and dieting websites to provide users with as much information as possible regarding health, dieting, and exercise.

Subsequently, we built a database which is composed of three tables, including caloric intake table, caloric consumption table, and decision table by MySQL. The data from the smart phone are saved by wireless transmission technology. Long-term information recorded in the database can be used to analyze an individual's physical condition.

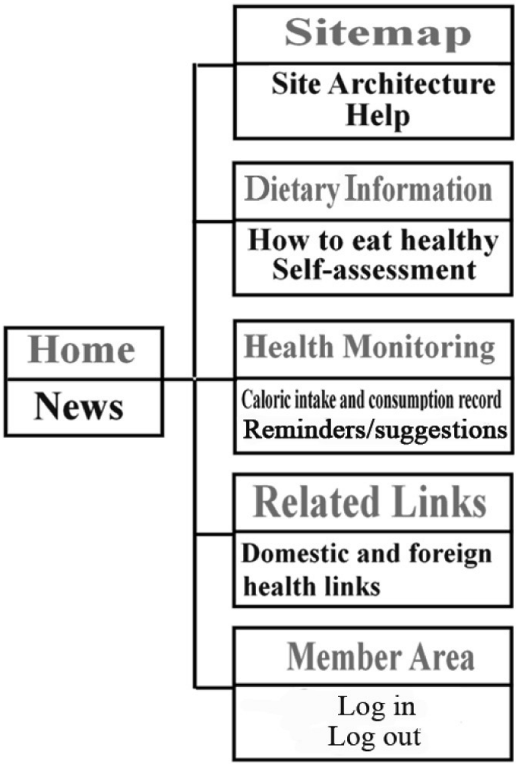

Fig. 4.The architecture of the designed website

In Table 1, the records of nutrient intake are saved to the database. In this table, nutrition information, including the type of food, calories, protein, fat and carbohydrates, is listed. These data are obtained from the QR code.

In Table 2, the number of times the user shakes the smart phone during exercise is recorded and the number of calories burned is calculated based on the number of jumps.

In the decision table shown in Table 3, the actual caloric intake is stored and the user's daily total caloric intake minus the total calories burned is used to determine this value.

Table 1. Caloric Intake Table

Number	Food	Calories	Protein	Fat	Carbohydrate	Sodium
1	Cookies	170	1.9	8.3	21.9	165

Table 2. Caloric Consumption Table

Number	Number of jumps	Calorie consumption
1	30	6

Table 3. Caloric Consumption Table

Number	Total caloric intake	Total calories burned	Caloric intake
1	1400	200	1200

Results

In this paper, we used fuzzy inference technology to infer actual number of calories burned and compared the accuracy of the proposed system with the Nike+ sensor sold in the market. We invited 20 subjects, consisting of 11 men and 9 women, to test the system. The users were aged between 20 and 37 years. All of the subjects carried a smart phone at the waist and exercised by jumping. The G-sensor of the smart phones was used to measure the number of jumps, in which the time allowed for jumping was 1 minute and approximately 0.02 hours. The jump height had to be at least 14 cm from the ground, which is equivalent to two thirds of a 700cc mineral water bottle. Any height below this value could not be accurately measured and therefore could not be included in the calculation of the number of calories burned. The basic data of the 20 users are shown in Table 4.

We also requested the same users to attach the Nike+ sensor to their foot to measure the calories burned during exercise. The calories burned as measured by the proposed system was compared

Table 4. User basic data

Subjects	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Age	22	20	21	24	23	21	25	22	20	21
Height(m)	1.79	1.72	1.8	1.77	1.71	1.74	1.73	1.79	1.72	1.8
Weight(kg)	70	68	60	65	59	62	66	70	68	60
BMI	22	23	19	20	20	20	22	22	23	19

Subjects	M11	F1	F2	F3	F4	F5	F6	F7	F8	F9
Age	22	20	21	21	20	21	24	20	21	21
Height(m)	1.79	1.6	1.62	1.68	1.72	1.8	1.77	1.6	1.62	1.68
Weight(kg)	70	51	50	54	68	60	65	51	50	54
BMI	22	20	19	19	23	19	20	20	19	19

Table 5. Experimental results of our proposed system

Subjects	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Nike+ record calorie-burning (kcal)	4	4	3	5	4	5	3	4	4	3
Mobile phone record jumping times	31	30	32	31	30	33	32	30	30	28
Mobile phone record calorie-burning (kcal)	6.8	6.9	6.4	6.2	6	6.6	7	6	5.7	5.3
Standard calorie-burning function(kcal)	7.8	7.9	6.8	7.1	6.8	7.0	7.6	6.4	6.1	6.4

Subjects	M11	F1	F2	F3	F4	F5	F6	F7	F8	F9
Nike+ record burning calorie (kcal)	4	4	4	3	4	3	5	4	5	3
Mobile phone record jumping times	31	30	30	28	30	32	31	30	33	32
Mobile phone record burning calorie (kcal)	6.8	6	5.7	5.3	6.9	6.4	6.2	6	6.6	7
Standard calorie burning function(kcal)	7.8	6.4	6.1	6.4	7.9	6.8	7.1	6.8	7.0	7.6

Fig. 5. Keying in of personal information

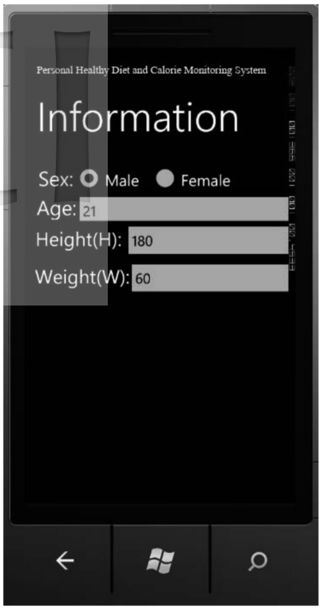

Fig. 6. List of chronic diseases

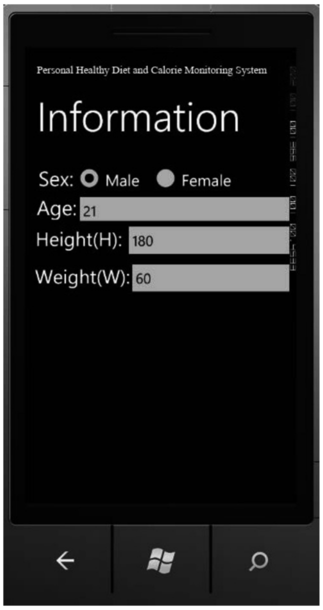

Fig. 7. Nutrition information

with the calories burned as measured by the Nike+ sensor, as shown in Table 5, using as the standard for calorie burning.

MET denotes the ratio of the metabolic rate in exercise to one at rest, which is used by most aerobic exercise equipment to display the exercise intensity and number of calories burned. For this paper, we used jumping as the exercise for burning calories, where MET=10. Table 5 shows that the number of calories burned as measured by the proposed system is similar to that measured by standard calorie burning equation and that the difference between the two falls below 1 kcal. On the contrary, the difference between the measurement by Nike+ sensor and standard calorie burning exceeded 2 kcal. Among the data from the system experiment in Table 5, the difference between the calories burned as measured by the proposed system and the standard calories burned by female 3 was 1.1 kcal which exceeded 1 kcal. This was regarded as a failure of our test and hence the system's success rate was 90%.

Next, we introduced the system UI. Users were required to input their personal basic data such as gender, age, and height into the system to calculate the recommended caloric intake per day, as shown in Fig. 5.

Users could use the drop-down menu to click on any chronic diseases which they might be suffering from, as shown in Fig. 6.

Next, the users were requested to read the QR code labeled on food package using a smart phone. Data included number of calories and nutritional content of food and were displayed on the screen, as shown in Fig. 7. The system also calculated the total calories and nutritional content of the foods consumed in one day, as shown in Fig. 8. Next, the data were stored in the database via wireless transmission so that users could review historical records.

According to professional dietitians, our proposed system was designed to provide reminders to avoid consumption of excessive nutritional content. For example, patients suffering from high blood pressure have to restrict sodium intake and are reminded when such intake exceeds recommended levels. For example, patients with high blood pressure should not exceed 2400 mg of sodium per day. Any value approaching this recommended value will cause the system to issue a message to remind users, as shown in Fig. 9.

Finally, the system contains a record storage function that displays all data to a website where users can review the caloric intake for that day or past days. Fig. 10 shows the website interface of the proposed system.

Fig. 8. The results of caloric intake and calorie burning calculations

Fig. 9. Message window showing a warning of excessive intake of sodium

Our results showed that the proposed system can provide a simple and convenient way to monitor nutrient and calorie intake at regular intervals. Through the accompanying website, the system can automatically transmit users' personal data. Meanwhile, all users can view each other's records on this website. Hence, our proposed system can provide personalized suggestions and comparisons of weight and general health details.

Conclusion

The problem of obesity has gradually become more severe due to the popularity of eating out and long working hours leading to less exercise. Hence, we have developed a smart phone personal diet and caloric intake monitoring system using fuzzy inference method. Fuzzy inference employs three input fuzzy sets, including number of jumps, BMI, and exercise time, to infer a calorie burning value. The value conforms to human thinking. The system can be widely applied by both male and female genders, those wanting to lose weight, those with chronic disease who must pay attention to diet, and those who intend to maintain a balanced diet. Our proposed system can help users with food

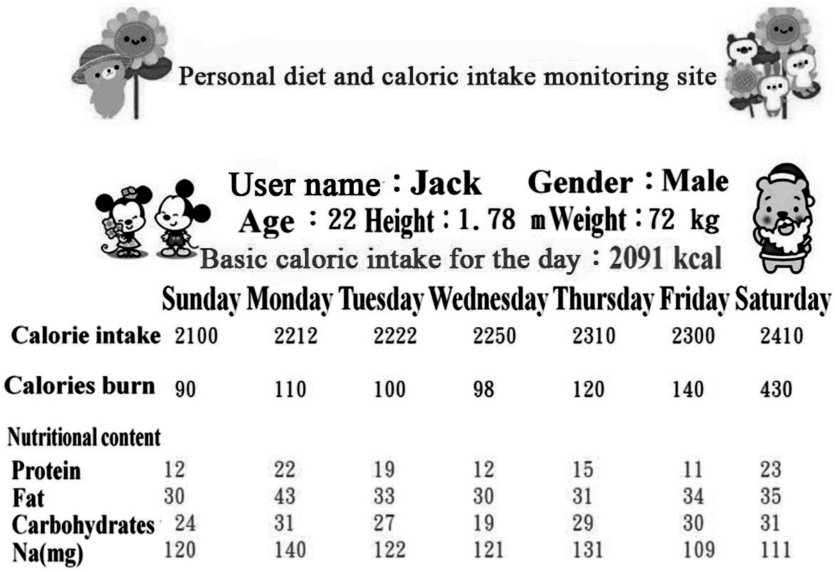

Fig. 10. The website interface

selection and adjustment of personal nutritional intake. Users can monitor their diet anytime and anywhere. We expect users to gain a better understanding of their physical state through this system and maintain balanced nutritional intake so that ultimately they will gain a sensitivity regarding good nutrition.

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Original Article

應用於智慧型手機的個人健康飲食與熱量監控系統使用模糊推論

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由於現代外食族的普及、肥胖人口的增加、成年人運動 少且加上飲食 緻化，造成飲食不均衡面臨健康危機，使得減重成為目前國人重要關注的議題之一，因此開始越來越關心熱量及營養成份的攝取，開始重視自己所攝取的食物是否健康及均衡營養，所以我們開發出一套「應用於智慧型手機的個人健康飲食與熱量監控系統使用模糊推論」。我們利用智慧型手機的可攜性、方便性與不受距離限制的特性，並且利用QR code的便利性和資料儲存量大等特點來開發出一套結合模糊推論（Fuzzy inference）技術之系統，系統會讀取QR code中的營養成份，包含食物的熱量、蛋白質、脂肪、碳水化合物和鈉，接著利用手機中的重力感測裝置（G-Sensor）來測量使用者運動時的搖晃程度，算出使用者運動時消耗的熱量，最後計算個人攝取營養成份的總量，藉以判斷是否有超出標準量。實驗結果的部份，本系統成功率90%，本系統與Nike+ sensor做比較，所測量出來的消耗熱量，以本系統和標準消耗熱量公式較為相近。所以不論是想瘦身的男性或女性、必須注意飲食的慢性病患者、發育中的孩童或者是需要均衡飲食的壯年人，有一套可以讓他們輕鬆選擇食物的系統，如此可針對不同的族群調整適合自己的營養吸收量，同時還能利用本系統來運動消耗熱量，達到均衡營養與熱量控制的目的。

關鍵詞：智慧型手機, 熱量,模糊推論, 重力感測裝置

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