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A Novel IoT System for Health-Monitoring and Advice-Offering on Diet and Exercise

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Abstract

This article is about building a system that is capable to deal with health problems since people become speed-favored instead of nutrients-favored nowadays and they do not have time to do more sports. A brand new IoT system to monitor users' health information and offer advice on diet and exercise will be described. Along with that, its innovative reminder function would assist the user to complete the provided plans that would not be done only by the system. This would enable the data to interact through IoT devices and feedback to the cloud and terminal.

Keywords

IOT system; Monitor; Diet; Exercise; Advice; Reminder.

1. INTRODUCTION

Unlike the injuries and cancers, the diseases like obesity, hypertension and diabetes can be effectively controlled and treated. These diseases even can be prevented if people can live with a healthy lifestyle, such as regular sleep, balanced diet and proper exercise.[1] Now, people can easily access their healthy index such as glucose, blood lipids, blood pressure and so on. Also, people can learn all kinds of information of the general healthcare knowledge, but it is not easy for them to make good use of these index and information in that everyone is special, and everyone's physical condition is also different. Though there are all kinds of information related to people's health, it is too difficult for people to use this information effectively. So, it is necessary to develop a diet and exercise management system to help people use this information and give people the recommendation of diet and exercise guidelines.

Since in the earlier research works, though there are many diet and exercise management systems, most of them require users to submit their own data and give people their own recommendation of diet and exercise guidelines. Also, most of the systems are not intelligent enough. They will only provide people with their health assessment reports, telling people what nutrients they lack, what foods they should eat, and what exercise they should do. We design an IoT System for Health-Monitoring and Advice-Offering on Diet and Exercise. Our system can combine users' own preferences and environmental conditions to provide users with practical and convenient suggestions.

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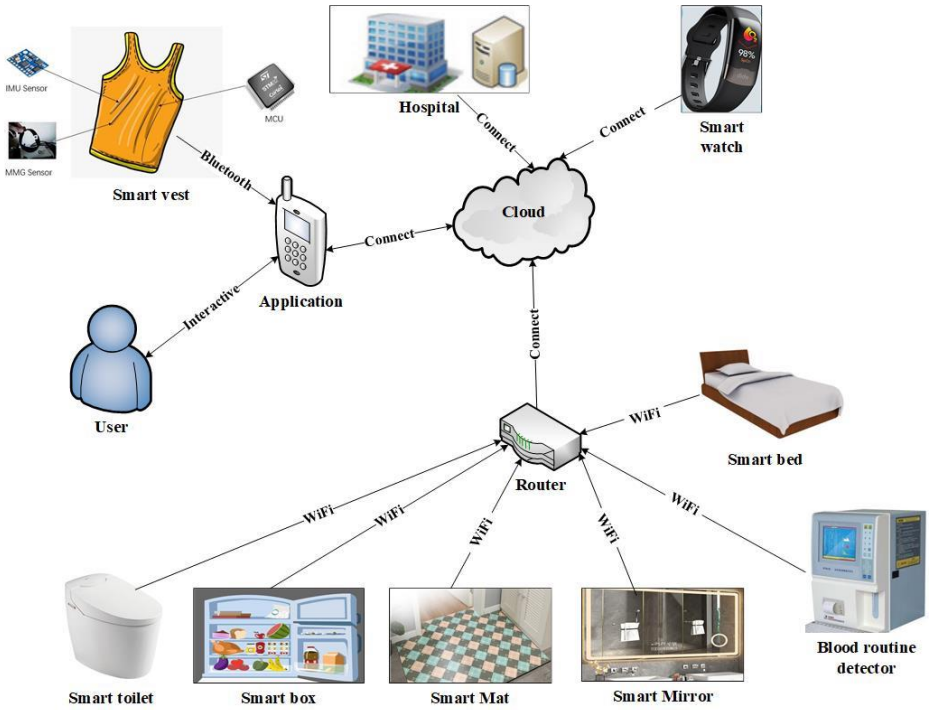

Figure 1. System Structure (Device) [2]

2. BASIC STRUCTURE

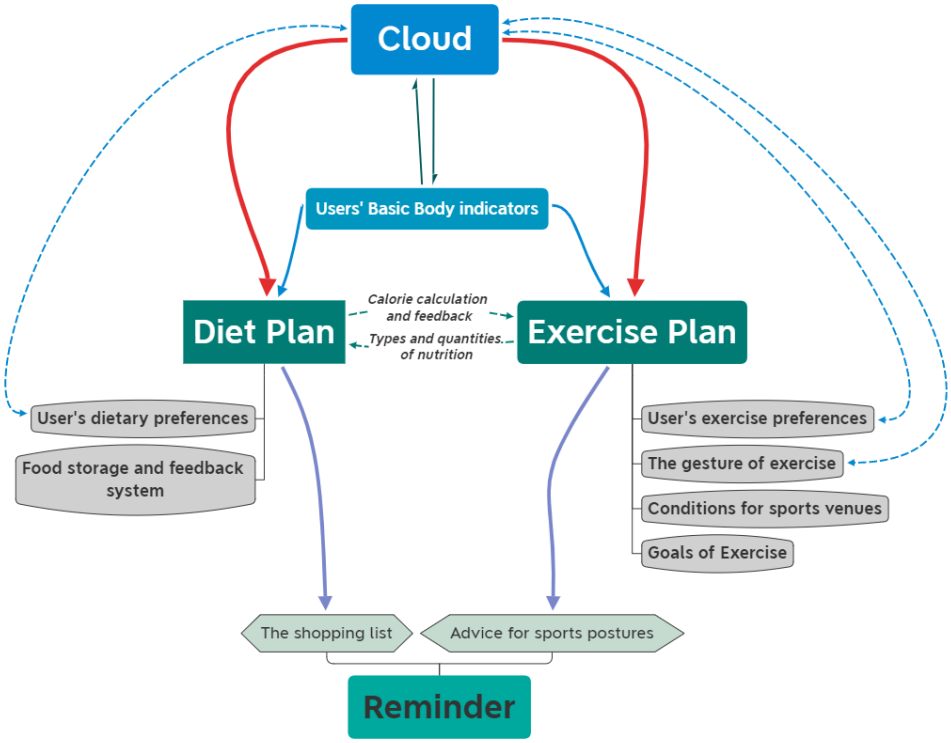

Figure 2. System Structure (Functions)

The system has a cloud for algorithmic operations. The main diet plan and exercise parts of the system generate interactive data by collecting user preferences and habits in the early stages. The basic user physical data required in the operation of the system is collected in the subsystem database through physical devices. Body data and process data are uploaded to the

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cloud for data processing and data feedback. There may be food storage problems and user movement pose problems in the process, data processing through the cloud after real-time generation reports sent to the user's mobile platform or system fixed terminal.

3. FUNCTIONALITIES

3.1. Diet Planning

For people's health, the diet is of vital importance and this module is an important part of the whole system. This module could monitor changes in the user's basic information (the user's health indicators), judge what nutrients the user lacks and provide the corresponding recipe to the user. For example, If the user's blood glucose data in the database rises beyond the normal range, the server in the cloud will determine that the user's blood glucose level is higher than the normal[3], and finally returns to the user a diet recommendation that helps to lower the user's blood glucose like the recommended recipe will include onions which contain the Xanthurenic Acid, which can enable cells to make better use of sugar, thereby reducing blood glucose. To realize such functions, many user's health indicators like user's glucose are needed to be collected and details of the user's health indicators are described in the next chapter.

As shown in the Figure 3, the first step is to analyze the user's basic information (the user's health indicators) collected in the database. The server will determine whether the user's data is abnormal by comparing the data with the normal range of the values. Regardless of whether the data is normal or abnormal, the server will provide the user's health risk assessment report. This report contains the results of comparing the user's data with the normal range, what nutrients the user lacks and whether the user is in good health. Then the server in the cloud will offer a corresponding recipe to the user. As shown in the Figure 4, there are three main considerations in the formulation of the initial recipes. The health risk assessment report is the top priority, and the user's dietary preference and food storage are the second priority. Besides, considering that user can eat well while maintaining his health, user's dietary preference and food storage are given a certain weight in the second layer respectively. Dietary preference accounts for 70% of the weight, and food storage accounts for 30% of the weight.

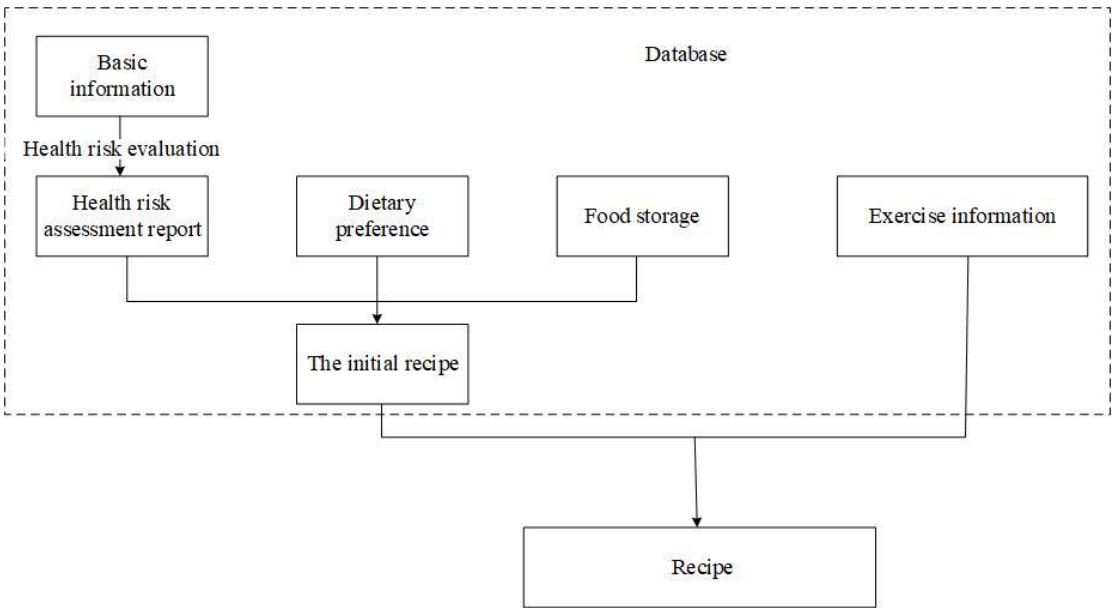

Figure 3. Diet Planning - Process Diagram

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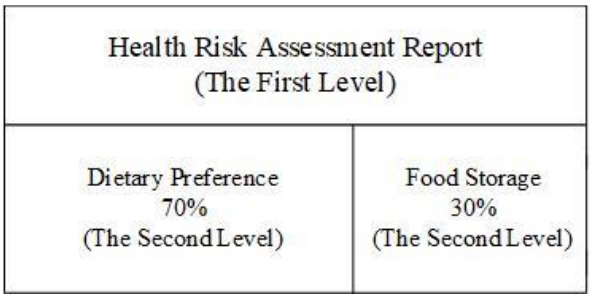

Figure 4. Weight distribution in the formulation of the initial recipe

In addition to the health risk assessment report, dietary preference and food storage, the formulation of the recipe also needs to take into account the user's exercise information. For example, if the user has a lot of exercise intensity and needs to supplement protein, some protein-rich foods such as beef and eggs would be added to the recipe.

3.2. Exercise Planning

People may suffer from some diseases caused by their inertial habits like sitting in front of the computer too long, like arthralgia, which can have a long-time effect on human body. When given exercise plan, it is hard for people to track if they really follow the plan. The feedback and sports plan giving module are built up to solve these kinds of problems.

The function of this module is to give suggestions on how to exercise based on three parts. The first part is user's conditions, including BMI, sex, and the user's sports venue. The second part is the user's sedentary time, which is how much time the user spends sitting on the chair and habitual gesture. The third part is the motion data monitored when one is exercising such as running time, mileage and muscle restriction. In making suggestions, the first part is the basis of the suggestion, all suggestion needs to base on the user and user's sports venue. Then, the suggestion will be made to solve the potential problem made by one's habit like sitting for too long, and to make people stay healthy. The items in the plan are changeable, catering to user's preference and the previous sports data, like exercise amount and injury. Preference will be analyzed online. All the devices needed are listed below.

Exercise and diet are two inter-related parts, when giving exercise plans, the diet data should also be considered. The most important thing is the type of nutrient and calorie intake. All this data come from the database. For example, when making exercise plan, database showcases that the user consumed too much fat last week, then, in this week's exercise plan, more aerobic sports will be included.

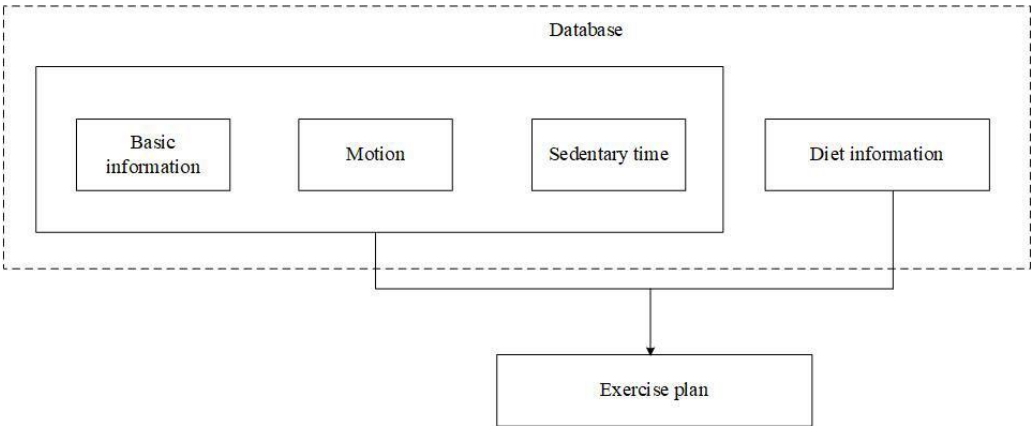

Figure 5. Exercise Planning - Process Diagram

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3.3. Reminder

In that users may have some bad habits that would affect their health, like sweet-food preference and wrong gesture of push-ups, which would not be monitored or given suggestions by diet and sports plan parts, a reminder is a great assistant to solve these problems. Also, since the food storage would be short for certain kinds of food for the diet planning part to produce proper recipe, the reminder would also be a way to notify the user by generating a shopping list. It functions much like a mother that always be there to tell you to adjust the bad habits on you and write the shopping list when going to the market. Having such a figure around the user could better monitor the march of the plans suggested and adjust the bad behaviors as well.

Through data like BMI, motion and food sugar level, which would be collected by the devices listed below in the next chapter, the system would analyze and show if the food containing certain components is not suitable for the user, or the gesture of the user is not right when doing certain sports. Then, no matter the food or the gesture is appropriate, the system would send a notification showing the components of the food that the user is going to take or the right gesture of the sports that the user is going to do. If the one is not quite appropriate, the report would be sent along with the notification indicating that the food or gesture should be replaced. For the shopping list, the system notifies the storage shortage from the diet planning system, and then push this message to the user[4]. The user would be able to see the shopping list through the nearest devices and purchase the commodity without overbuying and wasting.

4. DATA

4.1. Basic Information

Height & Weight

The users' height and weight information would be used to calculate BMI, the Body Mass Index[5], which is for determining the fat rate of the user. For users with different BMI, the suitable food would be various in sugar levels, and the gesture would differ for different levels of sports for different users, like different time length of planking.

The device which can measure the user's weight is a smart mat. The smart mat would be placed in the front of the door and measure the user's weight when the user comes back and stands on the mat. Besides, the bathroom would be equipped with a smart mirror, which can measure the user's height when the user washes in front of the mirror.

Since the height and weight would not various in and out of home, the sensors could be at a permanent place in the users' house. Thus, to be more stable to upload the data, the devices would be connected through Wi-Fi instead of using Bluetooth that needs mobile phones to be a gateway, which is of high mobility and not for stability.

The device of measuring this has been already various in the market. The user can still use their own devices if these are compatible with the system if they want. Or the device could be anything that is normal in life and the user would have no sense to be measured. For example, the mat in the restroom could embed a kind of weight sensor, which could easily measure the user's weight with the user having no conscious on it. Also, the mirror in the restroom could be a tool to measure the user's height. Hence, when users need to go to the restroom, like brushing teeth, the weight and height of the user would be measured and uploaded to the cloud.

Since the height and weight would not various in and out of home, the sensors could be at a permanent place in the users' house. Thus, to be more stable to upload the data, the devices would be connected through Wi-Fi or wires that is small, like an optical fiber or ultrathin cat-6 wires (ethernet), instead of using Bluetooth that needs mobile phones to be a gateway, which is of high mobility and not for stability.

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Age & Sex

The measurement range of health indicators is different for people of different ages. The same is true for sex. The information of age and sex is of vital importance to the system.

The "Healthcare" application is of vital importance to collect this information. Through the application on the smart phone, user can fill in the age and sex. Also, the information about age and sex only needs to be filled in once.

Since the smart phone acts as an intermediary between the user and the application, we use the cellular network as the data transmission network for the smart phone.

Electronic Medical Record

The system obtains users' electronic medical records by connecting with systems of major medical institutions and hospitals. Every time the user goes to the hospital for a comprehensive physical examination, the user's physical examination report will be uploaded from the hospital to the user's database in real time. In addition, the diagnosis and severity of the disease in the hospital will also be uploaded to the database to recommend the best diet and exercise guidelines for users.

Blood routine, Urine routine & Stool routine

These data of users are an important basis for judging users' health.

The device for measuring blood routine is the blood test instrument located at home and there is a smart toilet in the bathroom. The smart toilet can collect part of the user's urine and excretion and analyze it to get the routine data of urine and stool.

Since these devices are located at home, so these devices transmit the information to the database through Wi-Fi.

Blood Pressure, Blood Glucose & Heart Rate

The user needs to wear a smartwatch which can monitor the user's blood pressure[6], blood glucose and heart rate.

The smart watch can get access to the Internet easily, so data collected by the smart watch can be transmitted to the database through Wi-Fi.

4.2. Dietary Data

Food Storage

Since the food stored in each user's home is different, in order to better recommend a practical recipe to the user, it is necessary to obtain the information about the food storage in the user's home.

First, in order to access the information of the food, each food is accompanied by a special bar code, which stores information about the source, type, production date and shelf life of the food.

Second, the kitchen will be equipped with a smart box which is used to place the food. The box includes the bar code scanner, weight sensor and camera. The box has the function of identifying bar code, measuring the weight of food and monitor the changes of food in the box. The box can obtain the information about the type of food by scanning the bar codes and obtain the weight of the food through the weight sensor. In addition, When the user puts in or takes out the food, the camera and weight sensor in the box will work. The camera will identify what food is put in or taken out and then the weight sensor will judge the added or missing weight of food.

Because the information is collected at home, so the smart box transmits this information to the database through Wi-Fi.

Dietary Preferences

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Everyone has their own dietary preferences. So, collecting information about user's dietary preference can better recommend the food recipe.

The "Healthcare" application is of vital importance to collect this information. Through this application on the smart phone, user can fill in the dietary preference. Also, user can change this information in real time.

Because the smart phone acts as an intermediary between the user and the application, we use the cellular network as the data transmission network for the smart phone.

4.3. Exercise Data

Motion

The motion data includes sporting time, intensity, and joint injury. This module is to make people stay healthy, so the exercise plan must be moderate, which means that the module needs to know the condition of human body. For example, the joint injury data is collected. When making sports plan, all the items included inside the plan will not make the injured joint move vigorously. Only a changeable plan can best make the user have a good exercise effect. When the user doesn't go to run for enough time or the user runs too much, the module will know through devices and make changes, either increasing the exercise amount next period or reducing. The exercise plan can be personal only in this way.

The device that can monitor one's anaerobic sports amount and time is a smart watch. The GPS inside the smart watch can know whether the user goes to some venues, like swimming pool for enough time. When one is running or do other aerobic sports, the smart watch can know the mileage and the heart rate, which can show the body condition accurately. For aerobic exercise, the smart vest is capable of recognizing user's behavior and detecting joint injury. The action recognition can be done by IMU[7], which is a small and easy chip based on MEMS. The MMG [8] sensors, which can be just a rubber string, can test the muscle restriction and friction of joint.

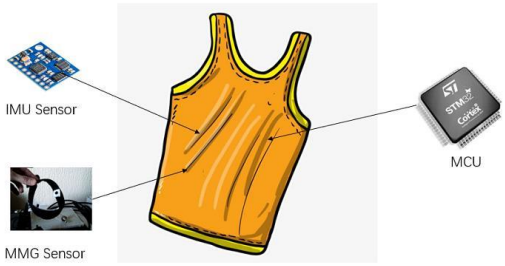

Figure 6. Instance: a smart vest [9]

Figure 7. Instance: a smart watch [10]

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The smart watch can get access to the Internet easily, so data collected by the smart watch can be transmitted to the database through WIFI [11].

The sensors inside the smart vest needs to be small and light, so the communication chip is very important. When one is doing aerobic exercise, the motion is vigorous as well. In order to overcome this problem, Bluetooth is used [12]. The sensors and phone are connected by Bluetooth. After the data is sent to the cellphone, the cellphone sends the data to the database.

Sedentary Time

The first is how much time one sitting on the chair or couch. Spending too much time sitting may cause cervical spondylopathy and make people easily to be fat, which is a bad sign for one's body condition. Both aerobic and anaerobic sports can make people fit and tighten the body. The amount of exercise should be neither too less nor excessive. So, this data is needed[13]. For example, if one sits on the chair for too much time, the stress point and sitting time will be sent to the database by devices, like a pressure gauge inside the chair through WIFI. The database can figure out the gesture based on the stress point and calculate the problem brought by it. Then, in the next exercise plan, some exercise will be included in specific to solve this problem, the amount of other exercise will be moderated to best mitigate the problem brought by the sitting time.

The key of the devices of this module is that the device can monitor people's behavior without causing attention, so devices need to small and combine with commodities. All the chairs, couch and bed are with a pressure gauge inside. The time and gesture can be monitored without people's attention. The pressure gauge can embed into an MCU. When people work in office, people always work with own PC, so inside PC, a camera is needed. Whenever the camera monitors that people's face is right inside the purview, the camera can realize that people is sitting. The camera can also recognize people's sitting gesture and calculating some angles. This data will be sent to the database and be processed there.

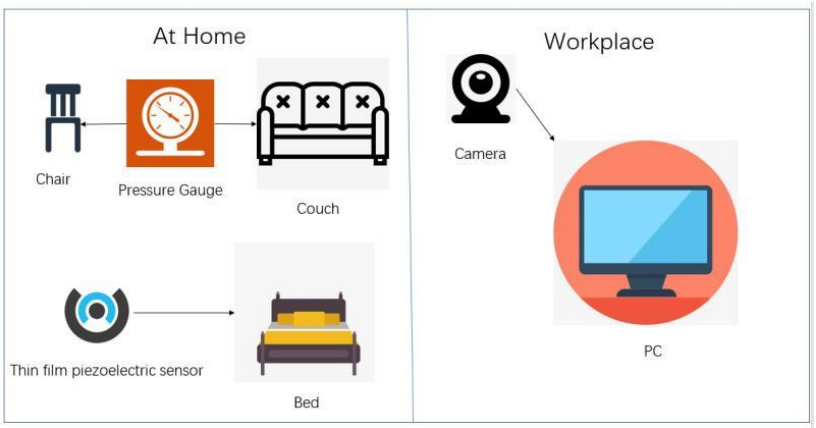

Figure 8. Instance: a monitoring system for sedentary time [14]

All the place people sit on will be inside the room, so the MCU can be connected with WIFI inside one's house easily through a chip like ESP8266.

Most workplace now has WIFI and the PC will be a station. So, the camera inside one's PC can send data to the database through WIFI of the workplace.

4.4. Information for Reminder

Motion

Since this part of system is to adjust the habit and monitor the march of the plans suggested, motion information is needed to judge the behavior of the user, like the open-and-close

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(chewing) speed of mouth when chewing food, the sitting or lying time, etc. Through these data, we can send notifications to the user, like "Stand up for a while since you have sat for a long time!", or "Do not eat too fast because this would damage your stomach!"

The device that can detect the motion should be like invisible or as a normal thing in the users' life without bothering them. For example, a smart vest with sensors could detect the motion the users are doing, like push-ups and sitting. Also, a smart glasses or braces would be used to determine the motions on face, like chewing and staring. These data would be sent to the server to be processed and feedback a notification on them, like "Move your eyes around to rest since you have stared at the screen for a long time!" The information could also be used to generate the sports and diet plan.

Because the motion data is not only collected at home or a permanent place, the data should be transmitted through a mobile gate to upload to the database. Thus, the device should use Bluetooth to connect with users' mobile phone to build connection with servers instead of Wi-Fi or Cellular Data.

Food Sugar Level

Many people may prefer sweet food or dessert, which may contain much more sugar than we need[15]. And this part of nutrition intake may not be covered by diet plan part of the system. However, this is so important that it would even directly affect the health condition of a man since high sugar level may lead to a fat related disease, such as high blood glucose and pressure. The data collected contains the approximate components of the food intake and the blood glucose level. Then the system would send notifications depending on the sugar level of the food, considering with the BMI, which is measured in home and for deciding if the user is overweight. If the user is overweight, the system would send notifications that prevent the user from eating any desserts. For the ones who is not overweight or healthy, it would be allowed to eat some dessert for a day, the notifications suggesting the sugar level of the food sent to the user.

The device that can detect the sugar level in the food should be non-puncturing, which means not equipped in the vein or under the skin, thus not bothering the user. For example, we can further develop the smart glasses in the motion detecting devices to make it able to detect the sugar level of the food which the user sees. Also, the smart braces would also be a great choice. The brace may have some sensors that can detect the food taken into the mouth and test the sugar in it.

Due to the same reason that this function needs mobility to test the sugar level, the smart device needs to use a gateway, which is usually a smart phone, to upload the statistics for analysis. The connection between mobile gateway and the device can be Bluetooth, or RFID as well since the device is always on the users' body and near the smart phones or gateways, with the data not enormous.

5. SUMMARY

The system is designed to monitor the user's daily life without influence, make people stay healthy and stay away from bad habits.

This system is able to monitor the user's body condition, like blood glucose, heart rate, etc. and user's daily habit including dietary preference and exercise amount in daily life without causing influence on user's daily life, no matter the user is at home, office or outside. All the devices are connected with the database in the cloud. The data is collected and analyzed in the database. In suggestion making, all the data is accessible and considered in hierarchy, the diet and exercise suggestion are moderate and personal. The suggestion is made to make people stay healthy.

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The system can also monitor the user's behavior and remind the user real-time. When the user is doing some unhealthy food, like eating too much sweet food, a notification will be sent. In doing this, the user may realize the bad habit and try to forsake bad habits.

However, there are still flaws in this system. The sensors that are used to monitor the user's daily life are too much to make the hardware structure easy and people are easy to be influenced by them. The shopping list provided by the system is useful, but the user still needs to find out where is the nearest and cheapest market at. Most importantly, one important physical indicator, which is sleep condition, is not included in this system.

6. EXPECTATIONS

Due to many reasons, our designed system could not achieve some functions contemporarily. There are some functions that we hope to be achieved in the future.

We hope that all the sensors can integrate into the surrounding environment. Just like the active badge system, we hope all the sensors job can be done only by a camera inside the house or the user's workplace. With identification technology, the camera can identify if the person is the user or not. In this way, the system can monitor user's behavior and habit in a more silent and undisturbed way.

We also hope that the system can contain the information about the infrastructure near the user's house and workplace, so that when the shopping list and exercise plan are made, the system can also inform the user of the market where the items on the list are cheap and where can the user go to finish the exercise.

We want to figure out how to monitor sleep data, how exercise and diet influence sleep condition for different ages of people. When giving suggestions, how to considerate the data from sleep, diet and exercise in order to give the best comprehensive suggestions is being waited to be solved.

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