Development of System to Support Diabetes Treatment

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Abstract: The number of diabetic patients is increasing worldwide. Although treatments, such as medical diet, therapeutic exercise, and pharmacotherapy, are available to patients, they fail to show effectiveness with some patients. Some of the patients lack in daily exercises and 60 percent of the patients forget to take medicines on time. In order to solve such problems, a database system was developed to support the nursing of diabetic patients through using mobile phones. However, this system fails to function as expected due to the reason that patients are required to keep in mind of the amount of exercise they are doing daily. In the past, we developed some systems to help remind patients to take medicines on time, but they don’t deal with the problem of daily exercise. In this study, we proposed a new system to support diabetes treatment by using acceleration sensor. This system can record the amount of exercise of the user automatically, and offer advice accordingly. By using photo detector, this system can also recognize the situation of medication, and suggest the correct medication to the user. Furthermore, this system also demonstrates capacity to administrate the situation of the patients’ exercise, which is considered more effective than the previous model.

Keywords: System to support diabetes treatment, Exercise, Medication, Acceleration sensor, Photo reflector

1. Introduction

In recent years, there have been changes in lifestyle, such as lack of exercise and increasing intake of high calorie diet [1]. If energy intake is higher than consumption, it is stored in the body as a subcutaneous or visceral fat [2]. Diabetes patients and obesity patients have been increasing worldwide [3]. According to “2007 National Health and Nutrition Survey” of Ministry of Health, Labor and Welfare in Japan, the number of diabetes patients in Japan is estimated to be approximately 8.9 million people [4]. Including prediabetes patients, it is estimated to be approximately 22.1 million people. Approximately 20 percent of Japanese is diabetes. The number of diabetes patients is expected to increase in the future [5].

Treatments, such as medical diet, therapeutic exercise, and pharmacotherapy, are available to patients [6]-[10]. Medical diet is a therapy to a proper diet in order to improve the metabolic abnormalities of diabetes [6] [7]. In therapeutic exercise, blood glucose levels decreases by moderate exercise[6][8][9]. Various symptoms of diabetes can be improved in therapeutic exercise. In pharmacotherapy, drug lowers blood glucose levels [6][9][10]. Methods of pharmacotherapy are the injection of insulin and the oral hypoglycemic agents. It is also important for physicians to understand the status of implementation of these therapies. In therapeutic exercise, it is important to continue daily moderate exercise. However, according to “2007 National Health and Nutrition Survey” of Ministry of Health, Labor and Welfare in Japan, the percentage of people who exercise always are reached only 63.5 percent. Some of the patients lack in daily exercise [11]. On the other hand, it is important to take medicines on time. However, over 60 percent of the patients forget to take medicines on time [12]. If patients do not take medicines on time, the effect of medicines is insufficient. In addition, it may make the state of illness worse.

In order to solve such problems, a database system was developed to support the nursing of diabetic patients through using mobile phones [13]. This system is intended to support the communication of nurse and patient. The patient can report the amount of diet, exercise, and usage of drugs. However, this system fails to function as expected due to the reason that patients are required to keep in mind of the amount of exercise they are doing daily. To avoid forgetting to take medicines, nurses need to always check the status of the patient medication, but this is difficult. In the past, we developed some systems to help remind patients to take medicines on time, but they don’t deal with the problem of daily exercise [14][15].

In this study, we propose a new system to support diabetes treatment by using acceleration sensor. This system can record the amount of exercise of the user automatically, and offer advice accordingly. By using photo detector, this system can also recognize the situation of medication, and suggest the correct medication to the user. Furthermore,
this system also demonstrates capacity to administrate the situation of the patients’ exercise, which is considered more effective than the previous model.

2. System to Support Diabetes Treatment

2.1 Structure  The structure of the system to support diabetes treatment is shown in Fig. 1. This system consists of the supporting unit for exercise and the supporting unit for medication. Each unit is described in subsection 2.2 and 2.3.

2.2 Supporting Unit for Exercise  The structure of the supporting unit for exercise is shown in Fig. 2. The supporting unit for exercise records the exercise amount of the user and advises the user depending on the exercise amount.

(a) Exercise Sensor  The exercise sensor consists of a three-axis acceleration sensor and electrical circuits. Three-axis acceleration sensor can detect the three-axis acceleration. The fluctuation of acceleration by moving (Frequency of about 0.1-30 Hz) is extracted from the output of each axis of the acceleration sensor. In order to obtain the acceleration in all directions, three outputs are added after envelope detection.

(b) Recording of Exercise Amount  The output image of “Exercise” and “Stop” is shown in Fig. 3. Microcomputer gets the output of the exercise sensor every 1 second. If the output is higher than the threshold voltage $V_E$, this unit considers the state of this moment as “Exercise”. Otherwise, this unit considers the state of this moment as “Stop”. The threshold voltage $V_E$ is determined in 3.1. This unit calculates the total time of “Exercise” every 1 minute. This total time is defined as “Exercise Amount” on the 1 minute. The range of “Exercise Amount” of 1 minute is 0-60. This unit continues to record “Exercise Amount”.

(c) Display of Exercise Amount  By connecting this unit to a computer, it is possible to display a graph of “Exercise Amount” every 1 minute. Patients can check the status of their own “Exercise Amount”. Since physician can be confirmed visually “Exercise Amount” of the patients, physician can treat the patients appropriately.

(d) Advice for User  Diabetes patients should exercise for 30-60 minutes continuously [16][17]. This unit measures the duration of “Exercise Amount”. Consider the stop for about 1 minute, this unit recognizes that exercise continues if the total “Exercise Amount” exceeds 100 for 3 minutes. This unit advises the following from “Exercise Amount”. Therefore, this unit can encourage the proper exercise to the diabetes patients.

i If the user exercised for 30 ~ 60 minutes continuously, this unit advises to continue the same level of exercise daily because the user exercised properly.

ii If the user exercised more than 60 minutes continuously, this unit advises that the user may reduce the exercise duration because the user exercised enough.

iii If the user exercised less than 30 minutes continuously and the total time of exercise was more than 30 minutes, this unit advises to exercise continuously for a long time more because the exercise duration was short.

iv If the total time of exercise was less than 30 minutes, this unit advises to exercise more because the user was a lack of exercise.

2.3 Supporting Unit for Medication  The structure of this supporting unit for medication is shown in Fig. 4. The supporting unit for medication recognizes the time of taking medicine. If the user does not take medicine at the correct time, the supporting unit for medication announces to the user.

(a) Medication Sensor  The medication sensor is an improved product of the sensor that we have previously developed [13]. In the previous system, the structure such as wiring was complex because the LED mounted on the lid. In a new medication sensor, the lid is not attached to anything electronic components. A LED and a photo detector are set at the bottom of the medication sensor. To avoid the influence of the surround lighting, the light from the LED is modulated. The photo detector receives...
the reflected light from the LED. From the output of the photo detector, only the modulated frequency element is extracted by using the band pass filter. In this study, the duty ratio of laser’s On/Off is set to 0.5 simply. The modulation frequency is set to 10 kHz that are very higher than the frequency of power supply (50 or 60 Hz) that is the main turbulence.

(b) Recognition of Medication
A medicine falls down to the bottom automatically when it is put into the funnel shaped holder as shown in Fig. 4b. The light from the LED is reflected by the medicine. The photo detector receives the reflected light. The reflected light is strong because the distance from the LED to the medicine is close. If there is no medicine in the holder, the light from the LED is diffused. A part of the reflected light is received by the photo detector. Thus, by the presence of the medicine, the intensity of the light received by the photo detector is different. If the output is higher than the threshold voltage $V_M$, this unit recognizes there is a medicine in the medication sensor. Otherwise, this unit recognizes there is no medicine in the medication sensor. The threshold voltage $V_M$ is determined in 3.2.

When the sensor is placed upside down, the unit cannot accurately determine the presence of medicine. While there is no opening and closing of the lid, the presence of medicine does not change. By attaching a magnet to the lid, the unit recognizes the opening and closing of the lid by using a magnetic sensor. This unit only recognizes the presence of medicine immediately after the lid is closed. Therefore, this unit can recognize the presence of medicine correctly because the sensor is not upside down immediately after the lid is closed. It is sufficient to light the LED only after the lid is closed. This function also contributes to energy savings of this unit.

(c) Announcement about Medication
The start and end time of taking medicine is input by the user. This unit announces the following from the output of the medication sensor and the time entered. Therefore, this unit can encourage the proper medication to the diabetes patients.

i In the start time of taking medicine, this unit announces that there is the time of taking medicine now.

ii If the user tries to take medicine before the start time of taking medicine, this unit announces to stop taking medicine.

iii If the user does not take medicine after the end time of taking medicine, this unit announces that the user has forgotten to take medicine.

3. Experiment
3.1 Experiment of Supporting Unit for Exercise
The supporting unit for exercise was tested in this experiment. Three-axis acceleration sensor module (Kionix Inc., KXM521050) was used for the exercise sensor. Experiments are shown below.

(a) Decision of Threshold Voltage $V_E$ of Exercise Sensor
At first, the threshold voltage $V_E$ for the recognition of “Exercise” and “Stop” was decided in this experiment. Walking was used as “Exercise”. Subjects with the exercise sensor walked and stopped. Each work was performed over 5 seconds. The output of the exercise sensor was measured. It was not determined...
how to hold the sensor. Two people were tried this experiment 5 times each. An Example of the output of the “Exercise” and “Stop” is shown in Fig. 5. It was confirmed that there was a clear difference in the output. According to the results, the recognition rate of 100 percent was obtained at the range of 0.55 ~ 0.7 V of $V_E$. Therefore, $V_E$ was decided 0.65 V.

(b) Recording of Exercise Amount

Next, “Exercise Amount” was measured. Subjects with the supporting unit for exercise walked and stopped. Each work was performed over 10 minute. In addition, after subjects stopped about 30 seconds, subjects walked about 30 seconds. In each condition, “Exercise Amount” of 1 minute is measured. It was not determined how to hold the sensor. Two people were tried this experiment 30 times each. Fig. 6 shows “Exercise Amount” of 1 minute. As a result, “Exercise Amount” is all 0 when subjects stopped, that is almost 60 when subjects walked, and that “Exercise Amount” is about 30 when subjects walked about 30 seconds after subjects stopped about 30 seconds. Therefore, it is confirmed that the supporting unit for exercise was able to detect almost exactly “Exercise Amount” as time of exercise.

(c) Display of Exercise Amount

Here, the display of “Exercise Amount” was confirmed. After a subject with the supporting unit for exercise walked and stopped randomly over 1 hour, “Exercise Amount” was displayed. The display of “Exercise Amount” is shown in Fig. 7. Thus, the state of exercise of the user is confirmed visually.

(d) Advice for User

Finally, the advice from this supporting unit for exercise was confirmed. The experiment was performed in the following 4 conditions.

i The user walked about 45 minutes continuously.

ii The user walked about 70 minutes continuously.

iii The user was repeated 4 times walking about 10 minutes continuously.

iv The user walked about 5 minutes.

As a result, this supporting unit for exercise advised as follows.

i This unit advised to continue the same level of exercise daily.

ii This unit advised that the user may reduce the exercise duration.

iii This unit advised to exercise continuously for a long time more.

iv This unit advised to exercise more.

Therefore, it is confirmed that this supporting unit for exercise advised the user according to the situation of the exercise.

3.2 Experiment of Supporting Unit for Medication

The supporting unit for medication was tested in this experiment. The photo-reflector (ROHM Co., Ltd., RPR220) was used for the medication sensor. Experiments are shown below.
Development of System to Support Diabetes Treatment

33

Figure 8: Medicines used in the experiment.

Figure 9: The output of the medication sensor.

(a) Decision of Threshold Voltage of Medication Sensor
At first, the threshold voltage $V_M$ for the recognition of medication was decided in this experiment. The output of the medication sensor was measured when medicine is put into the sensor. The output of the medication sensor was also measured when there was no medicine in the sensor. Four types of medicines with different sizes and shapes are used as shown in Fig. 8. It was tried 10 times for each condition. Figure 9 shows the average output and the range from minimum to maximum. According to the results, the recognition rate of 100 percent was obtained at the range of 3.1 $\sim$ 3.8V of $V_M$. Therefore, $V_M$ was decided 3.4V.

(b) Announcement about Medication
Next, the announcement from this supporting unit for medication was confirmed. In advance, the user put a medicine in the medication sensor and inputs the start and end time of taking medicine. The experiment was performed in the following 3 conditions.

i The user took medicine between the start and end time of taking medicine.
ii The user tried to take medicine before the start time of taking medicine.
iii The user did not take medicine after the end time of taking medicine.

As a result, this supporting unit for medication announced as follows.

i In the start time of taking medicine, this unit announced that there is the time of taking medicine now.
ii This unit announced to stop taking medicine.

Therefore, it is confirmed that this supporting unit for medication announced to the user according to the situation of the medication.

4. Conclusions
In this study, we proposed a new system to support diabetes treatment by using acceleration sensor. In this system, we developed a supporting unit for exercise and a supporting unit for medication. This supporting unit for exercise was able to record the amount of exercise of the user automatically, and offer advice accordingly. By using photo detector, this supporting unit for medication was able to recognize the situation of medication, and suggest the correct medication to the user. Furthermore, this system also demonstrates capacity to administrate the situation of the patients’ exercise, which is considered more effective than the previous model. Therefore, this system is useful in the treatment.

As future prospects, we are planning to develop a new system to consider pharmacotherapy.

References


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