Proposal of Sensors for Robot Supporting to Take Medicines on Time

Yuhki Kitazono, Xianglan Zheng, Shota Nakashima, Shiyuan Yang, Seiichi Serikawa

Kyushu Institute of Technology, 1-1 Sensui-cho, Tobata-ku, Kitakyushu-shi, Fukuoka 804-8550, Japan
(Tel : 81-93-884-3282; Fax : 81-93-884-3015)
(kitazono@boss.ecs.kyutech.ac.jp)

Abstract: Patients sometimes forget to take medicine. It may make recovery of patients slow down. In this study, we propose a new robot supporting to take medicines on time using medicine sensors and a chewing sensor. When medicines are put into medicine sensor, the electric capacity of the medicine sensor will be changed. According to the value of capacity of the sensor, this robot can easily judge whether medicines are in the medicine box or not. The chewing sensor is made up of an ear wearing device and a unit which consists of a photodiode and an infrared LED. The infrared rays from the infrared LED irradiate a mandible. Using reflected light received by the photodiode, the chewing sensor can judge whether foods have been taken or not. By using the medicine sensors and the chewing sensor, the robot can bring the user medicines on time and have following function. If medicines are not taken at time to take medicines, the robot announces to the user. In case of medicines taken before meals, the robot warns the user to take medicines if the user is chewing before taking medicines.

Keywords: Robot supporting to take medicines, Medicine sensor, Electric capacity, Chewing sensor.

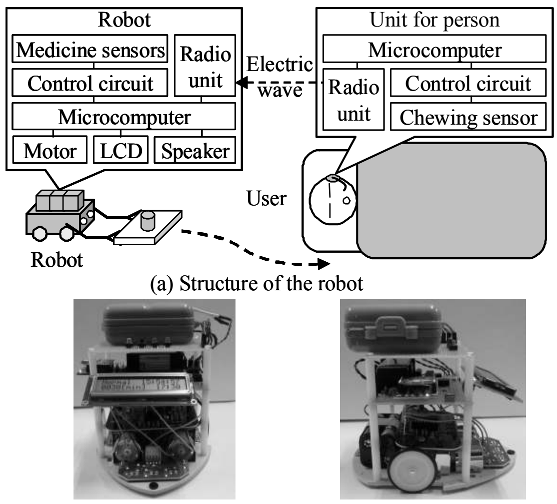
I. INTRODUCTION

According to National Livelihood Survey 2008, the ratio of the patients to Japanese people was 0.3336[1]. If medicines are prescribed for most of patients, over 30 percent of Japanese take medicines. However, over 60 percent of the patients forget to take medicines on time[2]. If patients do not take medicines on time, the effect of medicines is not enough. In addition, it may make the state of illness worse. For this reason, methods to prevent forgetting to take medicines are necessary and helpful to patients[3]. There are several kinds of systems that announce the time of taking medicines to a patient[4]~[6]. However, these systems cannot accurately judge whether a patient takes medicines or not, and cannot judge that the patient takes medicine before meals or after meals. Many chewing sensors are used to detect that, but most of them are uncomfortable in direct contact type. There is also non contact-type using an infrared sensor, but it needs to be fixed on glasses and needs to be adjusted[7]. Thus, the solution of these problems is needed. In addition, a robot that brings medicines is more useful for patients of bedridden than the systems only of the announcement.

Therefore, a robot supporting to take medicines on time is proposed. In this paper, new medicine sensor and chewing sensor for the robot are developed. Regardless of size and shape of medicines, the robot can accurately judge whether medicines have been taken out or not from the medicine sensors. The robot can also accurately judge whether a user is chewing or not by the chewing sensor. By using the medicine sensors and the chewing sensor, the robot can bring medicines to a user and announce to take medicines on time.

II. ROBOT SUPPORTING TO TAKE MEDICINES ON TIME

A robot supporting to take medicines on time is structured as shown in Fig.1 (a). The picture of the experimental robot is shown in Fig.1 (b) and (c). A unit for person judges whether a user is chewing or not from a chewing sensor, and transmits the result to the robot. The robot judges whether medicines have been taken out or not from medicine sensors. If medicines are not taken at time to take medicines, the robot announces to the user. In case of medicines taken before meals, the robot warns the user to take medicines if the user is chewing before taking medicines.



(a) Structure of the robot

(b) Front view of the robot (c) Side view of the robot

Fig.1. Robot supporting to take medicines

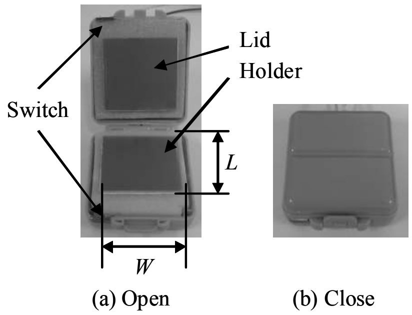


Fig.2. Picture of medicine sensor

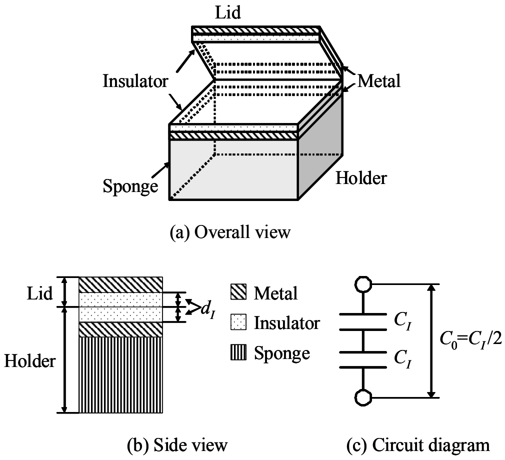


Fig.3. Structure of inside of sensor box
in case of no medicine

1. Medicine Sensor

The picture of medicine sensor and the structure of sensor box are shown in Fig.2, 3 and 4. Two pieces of metals are set on the inside of the lid and the holder, and insulators are put on the metals. A sponge is set between the metal and the bottom of the holder. This is used instead of spring. When there is no medicine in the sensor, the distance between the metal of the holder and that of the lid is $2d_I$ (Refer to Fig.3 (b)). The circuit diagram is shown in Fig.3 (c). The electric capacity of each insulator is assumed C_I. The combined electric capacity is C_0 (=C_I /2). When there is a medicine in the sensor (Refer to Fig.4 (a)), the distance between the metal of the holder and that of the lid is $2d_I$+d_M (Refer to Fig.4 (b)). The circuit diagram becomes Fig.4 (c). The electric capacities of medicine and air between the insulator of the holder and that of the lid are assumed C_M and C_A. The electric capacity of each insulator in part of air is assumed C_{IA}. The combined electric capacities of C_a, C_m and C_1 are as shown in Fig.4 (c). These are represented as followings.

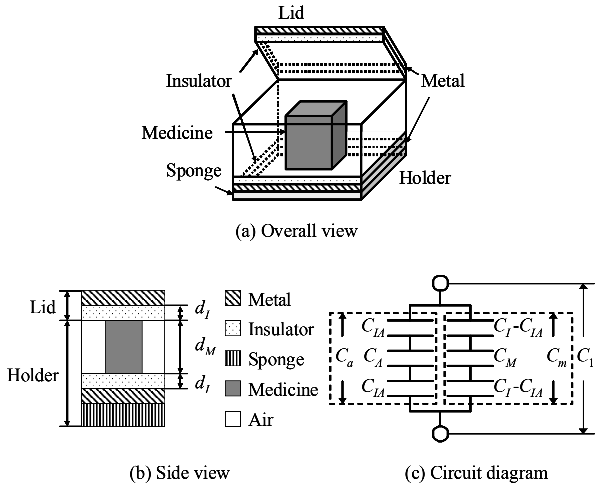


Fig.4. Structure of inside of sensor box
in case of medicine

$$C_a = \frac{1}{1/C_{IA} + 1/C_{IA} + 1/C_A} = \frac{C_{IA}}{2 + C_{IA}/C_A} < \frac{C_{IA}}{2} \qquad (1)$$

$$C_m = \frac{C_I - C_{IA}}{2 + \left(C_I - C_{IA}\right)/C_M} < \frac{C_I - C_{IA}}{2} \qquad (2)$$

$$C_1 = C_a + C_m < \frac{C_{IA}}{2} + \frac{C_I - C_{IA}}{2} = \frac{C_I}{2} = C_0 \qquad (3)$$

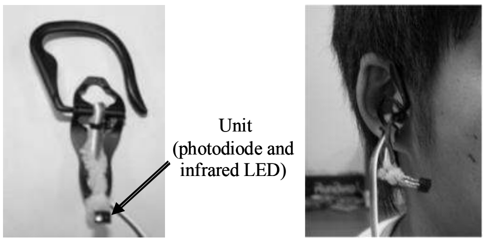
Then C_1 is lower than C_0 if C_M and C_A take a limited positive value. When there is a medicine in the sensor, the electric capacity of the sensor becomes low. Therefore, it can be judged whether medicines are in the sensor or not by measuring the electric capacity of the sensor.

In order to avoid misjudging, a switch is set below lid of the sensor as shown in Fig.2. When the lid is opened, it may be misjudged because of the change of capacity of the sensor. The switch signal is used to stop the judgment while the lid opens.

In this robot, when there are medicines in a sensor, the capacity of the sensor is low. The robot judges whether medicine sensors contain medicines or not when all lids have been closed.

2. Chewing Sensor

The proposed chewing sensor is shown in Fig.5 (a). It is made up of an ear wearing device and a unit which consists of a photodiode and an infrared LED. The sensor worn on one ear needs to be fixed about 1 [cm] away from a mandible as shown in Fig.5 (b). The modulated (10 [kHz]) infrared rays from the infrared LED irradiate the mandible. The reflected light is received by the photodiode. Then, the signal goes through the circuit which consists of amplifiers and a band-pass filter. The microcomputer judges whether chewing or not by the output of the circuit.



(a) Picture of the sensor (b) Wearing the sensor

Fig.5. Chewing sensor

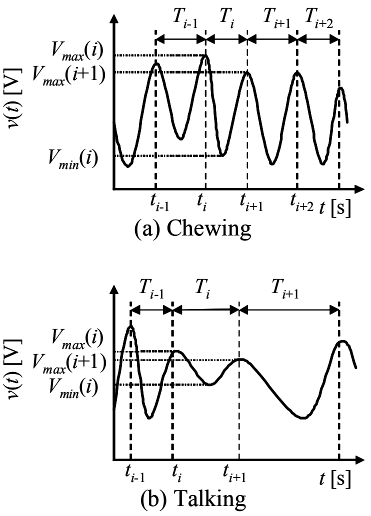


Fig.6. Shape of waves of chewing and talking

Talking and chewing can be distinguished from the shape of waves of the output as shown in Fig.6. In case of chewing, a similar shape of waves is repeated because of the similar movements of the mandible. However, in case of talking, the shape of waves is irregular. Using correlation of waves, it can be judged whether chewing or not. In addition, people normally chew 0.5~3 times in one second. Therefore, if the waves satisfy the following Eq. (4), (5), (6) and (7), it is assumed that they are "correlation waves".

$$\frac{V_{max}(i)+V_{max}(i+1)}{2}-V_{min}(i) \geqq V_{th} \quad (4)$$

$$|T_{i+1}-T_i| \leqq 0.3[\mathrm{s}] \quad (5)$$

$$R_i=\frac{\sum_{t=0}^{T} v(t_{i-1}+t)v(t_i+t)}{\sqrt{\sum_{t=0}^{T} v^2(t_{i-1}+t)}\sqrt{\sum_{t=0}^{T} v^2(t_i+t)}} \geqq 0.97 \quad (6)$$

$$T=\min(T_{i-1},T_i)$$

$$0.3[\mathrm{s}] \leqq T_i \leqq 2.0[\mathrm{s}] \quad (7)$$

A local maximum voltage and the following local minimum voltage are assumed $V_{max}(i)$ and $V_{min}(i)$ respectively as shown in Fig.6. The next local maximum voltage is assumed $V_{max}(i+1)$. The time from $V_{max}(i)$ to $V_{max}(i+1)$ is T_i, the time from $V_{max}(i+1)$ to $V_{max}(i+2)$ is T_{i+1}. Regularized cross correlation function from T_i to T_{i+1} is R_i. V_{th} is the threshold voltage. In this experiment, it is set 100 [mV]. If the correlation waves continually occur over 5 times, it is considered as chewing.

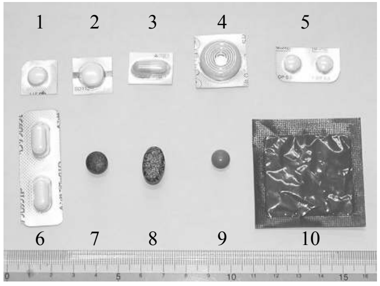


Fig.7. Medicines used in the experiment

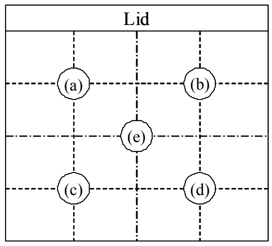


Fig.8. Positions of medicine in the sensor

III. EXPERIMENTS

1. Experiments of Medicine Sensor

In the part of experiments for medicine sensor, the metals with the area of 36 [cm^2] (W = 6 [cm], L = 6 [cm]) and the insulators (Glass-epoxy, Relative Permittivity: 4.5~5.2[8]) with thickness (d_I) of 1.6 [mm] are used. The sensor shown in Fig.2 is used in the experiments.

The variance of the output voltages of the sensor is confirmed for determine the threshold voltage (V_m) to judge whether medicines are in the sensor or not when medicine is put into the sensor as follows.

A.Influence of the Position of Medicine

In this experiment, the influence of position of medicine in the sensor on output voltage of the sensor is confirmed. The output voltage of the sensor is measured when the medicine (Refer to Fig.7, No.1) is put into the sensor. Five places where medicine is put (Refer to Fig.8, positions (a)~(e)) are tried. It is tried 10 times for each condition. The output voltages at each position and the output voltage in case of no medicine in the sensor are shown in Fig.9.

B.Influence of type of Medicine

In this experiment, the influence of type of medicine on capacity of the sensor is confirmed. The capacity of the sensor is measured when the medicine is put in the

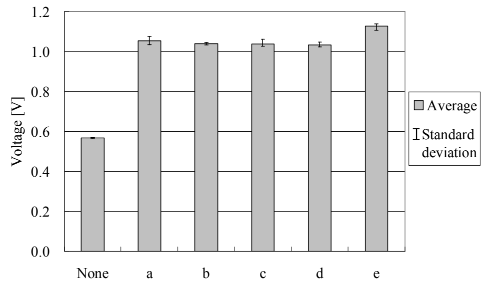


Fig.9. Influence of position of medicine on output voltage of medicine sensor

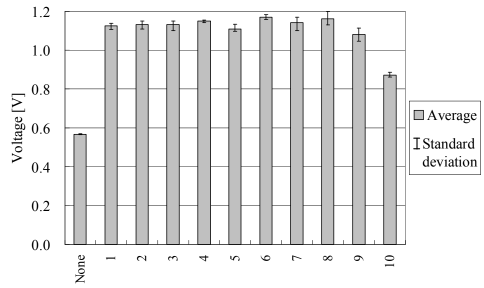


Fig.10. Influence of type of medicine on output voltage of medicine sensor

sensor. Ten types of medicines with different sizes and shapes are used 10 times for each of them as shown in Fig.7. A medicine is placed at the position of center as shown in Fig.8 (e). The result is shown in Fig.10.

If the output voltage is higher than V_m, it is assumed that medicines are in the medicine sensor. The recognition rate of 100 [%] is obtained when V_m is in the range of 0.57~0.86 [V]. Therefore, V_m is decided 0.70 [V]. It can accurately judge whether the user have taken medicines or not.

2. Experiments of Chewing Sensor

In the next part of experiments, chewing sensor shown in Fig.5 is used. Ten people (a~j) do the experiments of talking and chewing, and every people does those 3 times. As the result shown in figure 11, in case of chewing, continuous correlation waves are over 8 times. In case of talking, those are not over 3 times. Therefore, the recognition rate is 100 [%]. It can accurately judge whether the user is chewing or not.

3. Operation Check of the Robot

In this experiment, operation check of the robot is performed. Experimental conditions are three cases as followings. (1) User takes medicines on time. (2) User does not take medicines on time. (3) In case of medicines taken before meals, user is chewing before taking medicines. It is tried 10 times for each condition. As the result, the robot did nothing in the condition of (1). In the condition of (2), the robot brought the user medicines, and announced user to take medicines. In the condition of (3), the robot brought the user medicines, and warned user to take medicines before having foods. Thus, it was confirmed that the robot correctly brought, announced and warned.

IV. CONCLUSIONS

A robot supporting to take medicines on time is proposed in this study, and a medicine sensor and a

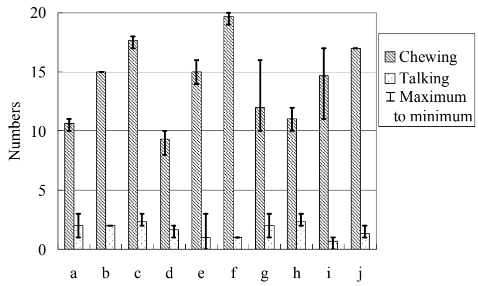


Fig.11. Numbers of continuous correlation waves relating to chewing

chewing sensor are developed. The robot can bring the user medicines on time. If medicines are not taken at time to take medicines, the robot announces to the user. In case of medicines taken before the meals, the robot warns the user to take medicines if the user is chewing before taking medicines.

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