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A Touchscreen-Equipped Medicine Case as a Medical Interface for Assisting an Elderly Person in Medication Management

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***Abstract*—In this paper, we propose a new intelligent medicine case with a home medical interface (iMec G2) to assist an elderly recipient in taking his/her medicine adequately. A touchscreen was equipped in the front surface of the iMec which was tilted backward. The home medical interface for self-medication support was displayed on the touchscreen and handled by the recipient's fingers. The elderly recipient could confirm the information related to his/her prescription by touching a virtual medicine and could contact a recipient's caregiver by clicking an icon if necessary. The new iMec recognized medicine in its storage cartridge by an improved image processing method and evaluated the adequacy of dosage and dosing timing. By an experiment, we verified that the iMec G2 was able to create the home medical interface correctly and indicate a particular medicine which should be taken.**

I. Introduction

In advanced countries, medical spending has been increasing due to their aging populations. Self-medication is one of the best solutions, but it is too difficult for an elderly recipient to keep his/her health condition well. Accordingly, we proposed an intelligent medicine case (iMec) and its system to assist his/her caregivers in telemonitoring: the iMec detected a sign of incorrect medication and then warn the caregivers of the risk.

A home medical interface is necessary for assisting in medication management because the self-medication support system must warn the elderly recipient to prevent incorrect medication. A medicine case has a strong relationship with medication in the recipient's home, so we believe that the iMec is the best object to be equipped the interface. Therefore, in this paper, we develop a new intelligent medicine case with a medical interface (iMec G2). The new iMec provides a simple-to-understand and easy-to-use interface by using a touchscreen in order to assist the recipient in taking his/her medicine correctly.

Some medicine cases with indicators (e.g. LEDs) have been developed, but a medicine case with an interactive device has not been developed yet. Additionally, most conventional medical interfaces were designed for caregivers (doctors, nurses, care workers, etc.), not for an elderly user whose physical ability declined.

Before we introduce the new iMec, we illustrate the design concept of our self-medication support system in the following section.

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II. Self-Medication Support System

In order to keep the recipient's medication compliance well, our self-medication support system must evaluate the adequacy of the recipient's medication condition and must help the recipient based on the result of evaluation.

The caregivers use a medicine case to check whether an elderly recipient have taken his/her medicine when they visit the recipient's house. Most commercial medicine cases have 28 divided storage spaces (i.e. 4 times for 7 days). Each divided storage space is specified a specified dosing timing. Therefore, we propose an iMec (intelligent medicine case) and an iMec-centered medication support system (iMec System). The medicine case has input-output devices for setting correct dosing timings into its divided storage spaces, sensors for recognizing that the elderly user picked up medicines from correct divided storage space, and a computer for evaluating the adequacy of dosage and dosing timing.

There are some medicines that should be taken during a predetermined time period (e.g. between 7 a.m. and 9 a.m.), but most medicines should be taken according to the recipient's present behavioral condition (e.g. after eating breakfast). Hence, the iMec must estimate the present behavioral condition and evaluate the adequacy of dosing timing precisely by comparing the correct dosing timing to the estimated present behavioral condition.

In addition to the intelligent medicine case, we use wireless sensor devices to collect the information needed for dosing timing evaluation because the iMec cannot gather sufficient information only by using the internal sensors of the iMec. The group of the sensor devices is called the Ubiquitous Sensors. Since common dosing timings are related to eating and sleeping behavioral conditions, we place the sensor devices around kitchen, dining, bed, bath, and toilet rooms.

The medication support system must advise on usage and warn against inappropriate medication so that the elderly recipient can take his/her correct medicine at correct timing. Since the iMec System can detect some signs of incorrect medication based on If-Then rules, it can notify the recipient of the risks by using a home medical interface. Besides, the home medical interface is also necessary for self-medication support in order that the recipient can check the information related to his/her prescription. By using the interface, the elderly user could take medicine without any mistakes.

Moreover, when the recipient is likely to take incorrect medicine, medication support system must also convey the risk of inappropriate medication to the caregivers, because monitoring is considerable important for medication support. After receiving the warning, the caregivers can rush to the recipient's house or make phone calls to reduce the risk. We place a server computer so that the caregivers can monitor the recipient's medication history anytime and anywhere. The server computer is called iMec Server. The computer has a mail server function for sending emergency emails.

The configuration of the iMec System is shown in Fig. 1. The iMec is placed somewhere (e.g. on the dining table) in the recipient's house, and the Ubiquitous Sensors is placed on various places. The iMec Server is placed and managed somewhere (e.g. in the recipient's pharmacy). The iMec communicates with the Ubiquitous Sensors via radio waves and with the iMec Server though the Internet.

The operational procedure of the iMec System is described below. First of all, the caregivers set correct dosing timings into the divided storage spaces and then stock correct types and quantities of medicines in the spaces. The Ubiquitous Sensors always watches the recipient's behavior and sends measured data. After the iMec receives the data, it estimates the present behavioral condition by inference algorithm. The recipient takes medicine from correct divided storage space periodically. Every time the flap of the iMec closes, the iMec recognizes medicines in the spaces and then evaluates the adequacy of dosage and dosing timing. If the medication condition is bad, the iMec notifies the risk of the medication error to the caregivers. At the same time, the iMec warn the elderly recipient of the error, so the recipient can notice it. The caregivers restock other medicines every time the spaces empty.

A medicine case is strongly associated with medication management, so we believe that it is useful for medical interface. In the next section, a new iMec with a home medical interface is introduced.

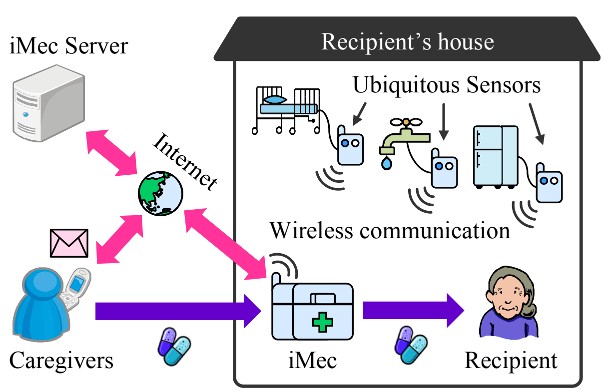


Fig. 1: The configuration of our medication support system (iMec System). This system consists of an intelligent medicine case (iMec), a group of sensor devices (the Ubiquitous Sensors), and a server (iMec Server).

III. Intelligent Medicine Case

A. Hardware Design

We developed the second-generation intelligent medicine case (iMec G2) as shown in Fig. 2. The new iMec was made of black acrylic boards. Its width, depth, and height are about 24, 38, and 26 centimeters respectively and its total weight is about 4 kilograms.

The iMec G2 has a compact computer (Endeavor NP12, Seiko Epson) for medicine recognition, behavioral condition estimation, and medication condition judgment. We connect a ZigBee receiver to communicate with the Ubiquitous Sensors and a mobile network transceiver to communicate with the iMec Server to the computer.

The four webcams (C910, Logitech) were placed on the bottom plate of the iMec. Each camera can capture a quarter area of the bottom surface of the storage space with some margin, that is, the iMec can obtain the bottom-side image by uniting 4 images: the upper left, upper right, lower left, and lower right images. As lights for the cameras, wide-angle white LEDs were also placed in the flap of the iMec. The light sources of these LEDs reach to the cameras through a smoked acrylic board in order to make a uniform background on a captured image. In addition to these LEDs, same LED was placed on the center of the bottom plate for camera calibration. The microcomputer (Arduino Nano 3.0, Gravitech), which connected to the compact computer, senses the open-close condition of the flap and control the brightness of all the LEDs.

A 10.1-inch LCD with a touch panel (LCD-USB10XB-T, I-O Data Device) was equipped in the front surface as an input-output device. With the user-friendliness of the device in mind, this touchscreen was tilted against the bottom plate; the recipient is easy to see and touch. The touch detection method of this touchscreen is a resistance film method, so it is resistant to dust and grease.

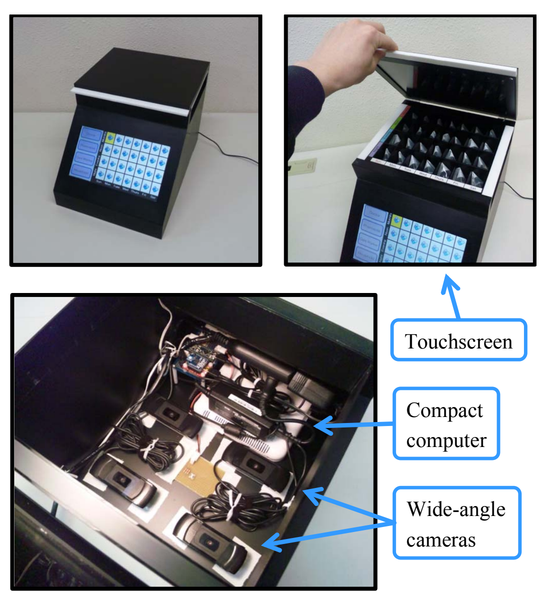


Fig. 2: The appearance of the second-generation intelligent medicine case (iMec G2). This medicine case has a touchscreen in the front surface.

The first-generation iMec can keep medicine for one week in its storage space. When its storage space is empty, a recipient's caregiver must stock medicine in the space again. In brief, the caregiver must visit the recipient's house at least once a week. Thus, we developed storage cartridges to reduce the burden as shown in Fig. 3. By using the cartridges, the recipient can easy to handle many medicines. Each cartridge can keep medicine for one week and thereby the second-generation iMec can keep a cartridge under the flap. The width, depth, and height of a storage cartridge are 238, 190, and 44 centimeters, so large-size medicines like SDP (Single Dose Package) can be stocked.

(a) Top Surface (b) Bottom Surface

Fig. 3: The appearance of a storage cartridge. The bottoms of plastic partitions were painted white for storage space recognition.

B. Medicine Recognition Method

We improved the conventional medicine detection method and also introduced a medicine recognition method in order that the iMec may distinguish correct medicines from the others (in particular, its empty packages). The procedure of image processing to recognize the presence of correct medicine was separated into 4 large parts. These parts are described as following.

Firstly, to approximate the camera distortion by a 7-degree equation, the iMec generated a distortion-less image from every captured image. For calibration, we used check pattern posted on the bottom of a storage cartridge. The distortion-less image was converted to a gray-scale image by the simple average method.

Secondly, the iMec recognized the divided storage spaces of a cartridge by the Hough transform because the plastic partitions were represented as straight lines in the gray-scale image without distortion. The iMec calculated the edge strength of a gray-scale image captured when there were no medicines in the cartridge (i.e. background image) by the Sobel filter, and then generates a binary image based on a constant threshold. Consequently, the iMec created an image that consists of the straight lines and recognized areas surrounded by the lines as the divided storage spaces.

Thirdly, the iMec recognized the presence of objects in each divided storage space by the background subtraction method. The iMec subtracted the gray-scale value of every pixel in the background image from the value in an image captured when the flap of the iMec closed. Since the background of every captured image is almost constant, the renewal of background image was not necessary. The iMec converted the subtracted image to a binary image based on a constant threshold. Additionally, the iMec applied contraction operation to the binary image for removing noise. As shown in Fig. 4, divided storage spaces that stocked some objects had many high pixels on the binary image.

(a) Captured Gray-Scale Image (b) Subtracted Binary Image

Fig. 4: A result of the background subtraction method. The white pixels in the subtracted binary image represent the presence of objects.

Finally, the iMec distinguished correct medicines from the other objects by using a support vector machine (SVM). Since there were a little differences in size, shape, and transparency between correct medicines and the others, correct medicines within each divided storage space were distinguished based on 6 kinds of feature quantities: the total number of high pixels in a subtracted binary image, the variance of the high pixels in the subtracted binary image, the total length of probable straight lines, the total length of probable curve lines, the average value of the histogram of the subtracted gray-scale image, and the variance of the histogram of the subtracted gray-scale image.

By the above algorithm written by C# Language, the iMec was able to recognize whether there is correct medicine in a particular divided storage space. The adequacy of dosage is checked based on the presence of correct medicine in the space. For example, the iMec could judge that dosage was correct even if correct medicine in correct space had been taken and then its empty package returned to the space.

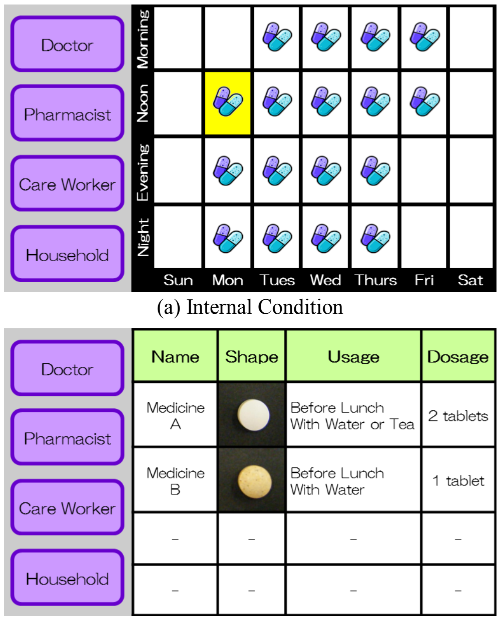
C. Home Medical Interface

Figure 5 shows examples of the home medical interface displayed on the touchscreen. The iMec normally expressed the internal condition of the storage cartridge. When an elderly recipient may forget to take his/her medicine, yellow/red divided storage space indicated the medicine that should be taken at the time.

Moreover, we assume that an elderly recipient is difficult to understand the dosage and usage, so the iMec displayed his/her prescription simply when the recipient touched a virtual medicine. To keep the information current and correct, a pharmacist managed the data on the iMec Server.

The iMec always showed icons in the left side on the home medical interface. If the elderly recipient pushed an icon, he/she can make a phone call to a particular caregiver. This function was realized with the help of Skype application.

Like the conventional iMec, the LCD blinked with yellow or red according to the risk level of medicine in order to warn the elderly recipient of incorrect medication. After the flap of the iMec opened, the interface returned from warning mode to normal mode.



(a) Internal Condition

(b) Recipient's Prescription

Fig. 5: Screenshots of the home medical interface.

IV. Experiment

To evaluate the recipient's medication condition and show the internal condition of the storage cartridge, the iMec must recognize medicine correctly by image processing. Hence, we conducted experiments to verify the accuracy of the proposed medicine recognition algorithm.

In this experiment, we used PTP (Press Through Package) and SDP (Single Dose Package) medicines. The storage space of the iMec G2 was divided into 28 small storage spaces. These spaces were recognized before an experiment. We put the medicines into all divided storage spaces one by one, and then picked the medicines up from these spaces one by one. This procedure was repeated five times and then the average rates of correct detection per medicine.

As a result, the PTP and SDP medicines were detected 95 and 100 percent by the proposed detection process. We obtained a notable result that the rate of PTP was worse than the rate of SDP. This result might be caused the difference of background area on captured images; the PTP medicines were smaller than the SDP medicines, so the PTP medicines were more susceptible to background change. Incidentally, the iMec didn't recognize that some objects were stocked in a divided storage space when the space was empty.

Next, we evaluate the accuracy of the medicine discrimination process. In addition to the PTP and SDP medicines, these empty packages were also used in this experiment because these are the most similar objects in the recipient's house. We tried 50 times per medicine: the correct medicine was 20 times, an incorrect medicine was 10 times, the empty package was 10 times, and a condition when there were no objects in a particular divided storage space was 10 times.

In the case of the PTP medicines, the accuracy, which equals the number of correctly-classified instances divided by the number of all instances, was 82 percent; the result was not extremely good, but it is a sufficient level for management support. On the other hand, the accuracy of the SDP medicines was 64 percent; this result was not so good. We confirmed that the straight and curve lines of PTP medicines were detected successfully, however, these of SDP medicines were not detected well because the iMec detected only true circles, not ellipses.

The false negative rate, which equals the number of incorrectly-classified true instances divided by the number of all true instances, was calculated as around 0.2. This result was serious; the iMec cannot evaluate the adequacy of dosage precisely, namely the iMec was apt to judge that there is correct medicine in the space regardless of the presence and absence of correct medicine.

V. Conclusion

In this paper, we proposed the iMec G2 which permitted an elderly user to confirm his/her prescription, contact his/her caregivers, and check his/her medication history for self-medication support. Naturally, the new iMec was able to inform the elderly recipient of appropriate timing and warn the recipient of incorrect dosage like the old iMec. Moreover, the new iMec System could also send emergency emails to the caregivers when the iMec detected some signs of incorrect medication. Since the medicine recognition algorithm was improved, our medication support system became a practical level.

We verified that the iMec G2 was able to show the internal condition correctly, so we will evaluate the usability of as a future work. Additionally, we are also going to make short movies to attract the recipient's attention and to warn the recipient effectively.

Acknowledgment

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References

[1] G. Eysenbach, "What is e-health?", *Journal of Medical Internet Research* (*JMIR*), Vol.3, No.2, e20, 2001.

[2] A. Agarawala, S. Greenberg, and G. Ho, "The Context-Aware Pill Bottle and Medication Monitor", *ACM Proc. of 6th Int. Conf. on Ubiquitous Computing* (*UBICOMP2004*), video, 2004.

[3] V. Fook, J. Tee, et al., "Smart Mote-Based Medical System for Monitoring and Handling Medication Among Persons with Dementia", *ACM Proc. of the 5th Int. Conf. on Smart Homes and Health Telematics* (*ICOST2007*), pp.54-62, 2007.

[4] T. Suzuki and Y.Nakauchi, "Dosing Monitoring System Using iMec and Ubiquitous Sensors", *IEEE Proc. of the 31st Annual Int. Conf. of Eng. in Med. and Biology Society* (*EMBC2009*), pp.6163-6166, 2009.

[5] R. Beer, R. Keijeers, et al., "PMD: Designing a Portable Medicine Dispenser for Persons Suffering from Alzheimer's Disease", *Proc. of the 12th Int. Conf. on Computers Helping People with Special Needs* (*ICCHP2010*), pp.332-335, 2010.