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Recreation Activity Monitoring System Using Proximity Sensors

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***Abstract*—This paper describes a recreational-activity monitoring system that records the existence of tools (removed or not from a predefined place) that are used in the recreation activities. The system is composed of three types (infrared, ultrasonic, and RFID) of proximity sensors to adapt to various sizes of the target object. The timings of when the target object was removed and returned are monitored. Simple experiments showed that the detectable range of the system was approximately 60~100 mm, and concluded that the infrared and ultrasonic sensors were useful for relatively large objects, and the RFID technology was suitable for small objects.**

I. Introduction

MONITORING daily activities of people suffering from chronic diseases such as hemiplegia due to stroke or other causes will be useful for evaluating not only the status but also the effectiveness of physical and occupational therapy. The activeness of people may change depending on their health and mental conditions, and low activeness and staying indoors for a long time should be avoided from a point of view of the disuse syndrome.

The total daily activeness including indoor and outdoor activities can be easily evaluated by the Actigraph (Micro-Mini RR type, Ambulatory Monitoring, Inc.), and the relationship among the activeness, the health conditions, and the effectiveness of the physical and occupational therapy has been revealed thus far [1]. However, the details of the activities (e.g., what type of activities were being performed at the time) could not be estimated from the information of the Actigraph. Nevertheless, such information will be useful for understanding the status of the people and the future therapy program in detail.

Daily activities include housework such as washing, cleaning, cooking, and buying things, and recreational activities include Japanese croquet, knitting, and Bonsai (raising dwarf trees), etc. Thus far, by introducing a variety of sensor technologies, many noninvasive indoor activity monitoring systems have been developed [2–7]. These systems have been useful for evaluating activities related to housework; however, it is difficult to monitor and distinguish the recreational activities by using these systems.

In this paper, a recreational-activity monitoring system that records how often the tools for the recreational activities were used has been proposed. The system records the existence of the tools (target objects) in the predefined place using three types of proximity sensors (infrared, ultrasonic, and RFID) for ensuring the recording. The times when the tool is removed and returned are monitored; these indicate the begin time and the end time of a recreational activity. The frequency of the recreational activity is evaluated by keeping a track of either of the timings, and the time duration can be calculated from these two timings.

II. System Structure

The proposed system is composed of three parts; a data logger PC, a data sampler module, and sensor units (Fig. 1,

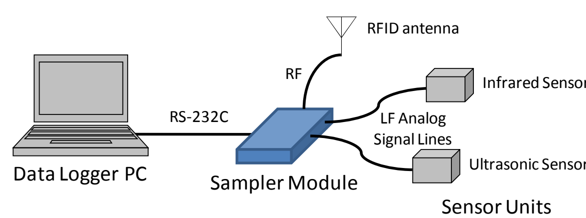

Fig. 1. System structure

TABLE I
SPECIFICATIONS OF THE MONITORING SYSTEM

Item	Specification
(Data Logger PC)	
Hardware	Notebook Computer (Toshiba Dynabook Satellite 2750)
OS	Linux (Fedora 10)
Data format	CSV
(Sampler Module)	
Microprocessor	PIC16F877 (Microchip Technology Inc.)
Sensor channels	8 channels (maximum)
Sampling resolution	10 bit (maximum)
Sampling cycle	1 min
(Sensor Units)	
Infrared	940/800 nm (RPR-220, Rohm Co., Ltd)
Ultrasonic	40 kHz (T40-16, R40-16, Nippon Ceramic Co., Ltd.)
RFID reader	Series 2000 (low frequency; 134.2 kHz, Texas Instruments, Inc.)

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Tab. I).

In this study, three types of proximity sensors were introduced to adapt to various sizes of target objects. Infrared and ultrasonic sensors were used for relatively large objects such as shoes for walking, bag for Japanese croquet (set of stick and ball), and toolbox for Bonsai or knitting, and the RFID technology was used for relatively small objects such as a cordless phone and scissors.

The data sampler module consisted of a PIC microprocessor and an RFID reader module. The microprocessor controlled the timing of data sampling and RFID data reading, and output the obtained value to the data logger PC. The sampling cycle was set to 1 min, and the sampling resolution of the analog sensors (infrared and ultrasonic) output was set to 8 bits. In the RFID system, a glass transponder (Texas Instruments, Inc., RI-TRP-RR3P, length 23 mm, φ 3 mm), small MoM (Mount-on-Metal) transponder (Texas Instruments, Inc., RI-TRP-R9VS), and ferrite-cored stick antenna were used. The transponders were placed onto the target object, and the antennas were placed near the transponder.

The data logger PC logged the outputs of the sampler module to a CSV formatted file, and displayed the values to increase the reliability of the installation.

Note that at least one sensor unit must be used for one target object, and the sensor should be placed to where the target object is usually placed.

III. Experiments

To assess the practicability of the proposed system, three simple experiments were carried out; evaluation of the detectable range of the three types of sensors, dependency evaluation of the rotation angle of the target object, and short-term monitoring.

In the assessment of the detectable range, the output voltages of infrared and ultrasonic sensors were measured at intervals of 2 mm from the object to the sensor unit. In the case of the RFID system, the success rate (error rate) of RFID data reading at each measuring point was evaluated.

In the evaluation of the rotation angle dependency, the sensor output voltages of 11 different situations were measured (10 "exist" situations with different positioning and rotation angles and 1 "removed" situation). The output voltage was evaluated 10 times (at different times). The signal to noise ratio (SNR) based on the output voltage of when the target object was removed was calculated.

The short-term monitoring experiment was performed in a laboratory as a simulation on the basis of the assumption that the shoes were selected as the target object. The sensors were placed in the shoe cupboard near the targeted shoes.

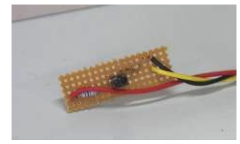
IV. Results and Discussion

Fig. 3 shows the evaluation results of detectable range of each sensor. The output voltage of the infrared sensor was 0.28~0.49 V, and the baseline of the 0.07 V seemed to be affected by the ambient light. The output voltage of the ultrasonic sensor ranged from 0.14 (110 mm in distance) to 0.56 (1 mm) V, whereas when the target object was removed, the output voltage was approximately 0.025 V. The detectable ranges of the analog (infrared and ultrasonic) sensors were approximately ~110 mm. The detectable range of the RFID system was approximately 60~100 mm depending on the type of RFID transponder. The detectable range indicated the tolerance of the positional shift of the target objects (tools).

Table II shows the evaluation result of the dependency of the rotation angle and positional shift of the target object. The SNR and the standard deviation were calculated from the average sensor output voltage of each "exist" situations based on the average voltage of "removed" situation. The sensor

(a) Cordless phone with RFID proximity sensor

(b) Toolbox used for sewing (a target object)



(c) Infrared sensor settled behind the toolbox (prototype)

Fig. 2. Target objects and proximity sensors

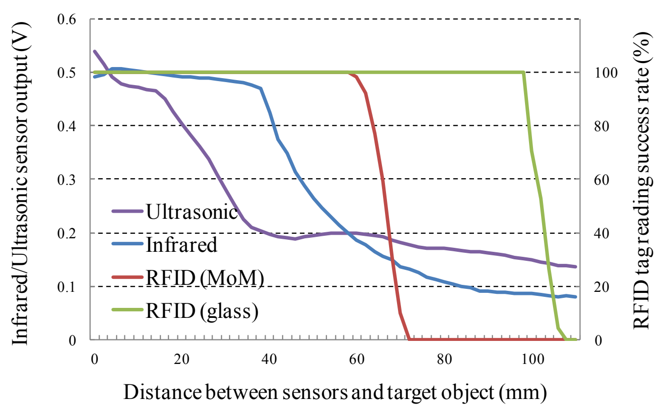


Fig. 3. Detectable range of infrared sensor and RFID system

TABLE II
SIGNAL TO NOISE RATIO OF EACH SENSOR

	S/N [dB]
Infrared Sensor	8.39 ± 3.82
Ultrasonic Sensor	5.25 ± 1.52

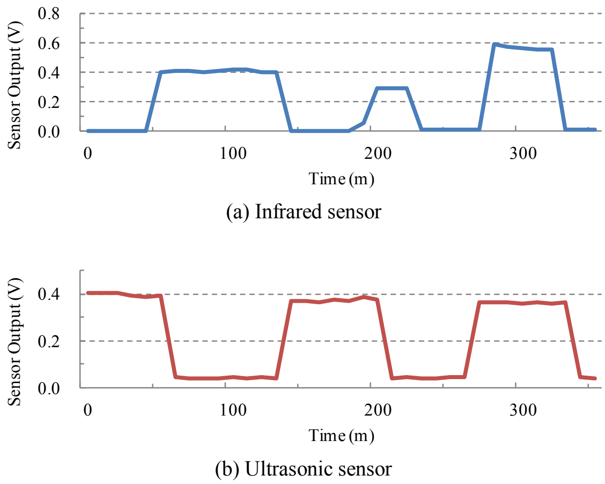


Fig. 4. Result of monitoring experiment (dark environment)

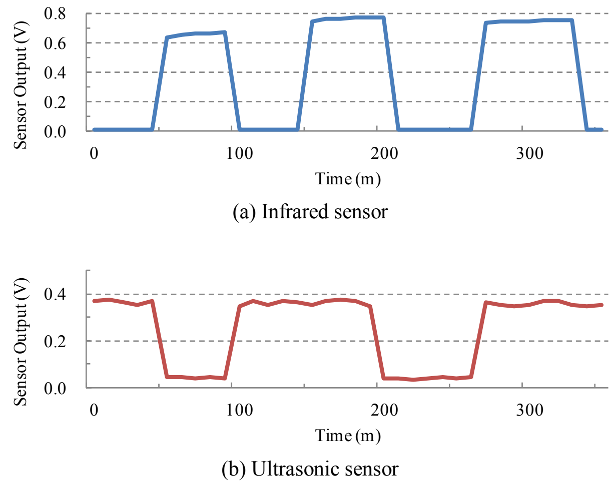


Fig. 5. Result of monitoring experiment (light environment)

outputs exhibited dependency; however, there are statistically significance between "exist" and "removed" states (One-way ANOVA and Scheffe's post-hoc test).

In the short-term monitoring experiment, the system successfully recorded the timing of when the target objects were removed and returned. However, the output voltage of the infrared sensor seemed to be affected by sunlight (mentioned as the baseline in the evaluation of the detectable range). Figs. 4 and 5 show examples of the monitoring experiment (Fig. 4 shows an example of a dark environment, and Fig. 5 shows an example of a light environment). Although the output voltage of the ultrasonic sensor was not considerably different in these two environments, the infrared sensor seemed to be affected by the light; the output voltage of the infrared sensor was higher including the baseline (minimum output) in the light environment. Therefore, it can be concluded that an ultrasonic sensor will be suitable for such a sunny place.

In this system, we chose to display raw values of the sensor outputs instead of indicating the existence of the target object by LED lights, etc., in the sampler module in order to avoid the on-site threshold setting problem. An appropriate threshold value could be estimated and applied after gathering the data.

The RFID technology will be very useful because it makes it possible to distinguish the objects in front of the antenna (target object or not) by reading the ID. However, large objects such as a bag are difficult to restore to the exact same place (original situation), and this results in the transponder's facing away from the antenna; this will cause the failure of tag reading. The other sensors (infrared and ultrasonic) have no ability to identify objects but will be useful for restoring the position of such a large object.

The system proposed in this study can be considered as one of the area monitoring system; several sensor units are installed into a residence. The main difference is that the proposed system focuses especially for the recreational activities while most systems focus indoor/housework activities. The housework activities are essential therefore many systems have been proposed, however the QOL of the elderly people and/or the people who have chronic diseases may be evaluated effectively from the recreational activities. Wearable devices such as Actigraph will be useful to obtain total daily activities precisely, but the aim of this study was developing the recreational activity monitor without disturbing their usual life (e.g. having or wearing special device).

V. Conclusion

In this study, a recreational-activity monitoring system that uses three types of proximity sensors was proposed. Simple experiments showed that each sensor had different characteristics (infrared sensor had higher SNR but was easily affected by sunlight, the ultrasonic sensor had lower SNR but was not influenced by the light, the RFID system will be helpful to identify whether the object placed near the sensor system is the target or not but will not be usable when the transponder attached to the object facing away to the reader), and suggested that an appropriate sensor should be selected according to the size and distance of the target object and the situation (e.g., sunny place). Considering the total cost of the system and its reliability, the ultrasonic sensor is the most appropriate sensor for use in the recreational-activity monitoring system because the ultrasonic sensor will not be affected by environmental noise. Long-term evaluation is now being carried out, and whether the detectable range of the sensors is sufficiently good will be evaluated in the future.

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