Technical Note

Development and Experimental Evaluation of Activity Detection System using Single Point Sensor for Observing Daily-Life of Elderly People

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Abstract: A new support system is proposed for monitoring and advising elderly people. The proposed system uses a single microcomputer with various sensors to collect data in a room of the house where the elderly is living alone. It detects a gradual change of activity of the elderly by extracting general pattern of the activity from the measurement data (especially, time series data of sound strength) of the sensors. When the activity patterm markedly changes from the general model, notifications and advice are sent to not only the elderly but also their family with the aim of maintaining the good physical condition of the elderly and encouraging them to perform health-aware activities. As a first step of the study, the feasibility of behavior estimation from the collected sound data was evaluated. The evaluation results clarified that the measured sound data can be used to estimate the behavior of elderly people.

Keywords: sensor network, cloud server, daily-life activities

1. Introduction

In recent years, the increasing number of elderly people, particularly those living alone and apart from the rest of their family, has become a serious problem [1]. Monitoring those people is effective but difficult and a burden on their family [2]. Serious situations, including life-threatening ones, often occur as a result of this problem. This problem can be solved by having the family keep track of the health condition of their elderly relatives. As a means of monitoring health conditions from a remote location, an IT-based system is an important candidate. Furthermore, it can not only monitor health conditions but also give advice (in the form of health-aware information) to elderly people.

In this study, a monitoring and advising system – using a sensor network to monitor daily living activities – is proposed. This system collects data from several kinds of sensors, and sends it for analysis on a cloud server in order to learn the subject activities. From the analysis, it detects a gradual behavior from a learning pattern and measurement data. In the proposed system, the time series data of the sound strength is especially observed by using a single microphone, and is deeply analyzed. As a result, the general pattern of the getting up time and going-out interval of the elderly family member is extracted as the learning model, and the system alerts when the pattern markedly changes from the model. In the case a change is detected, the system notifies the family in question that the behavior of their elderly member has changed, and it will also advise the family to check a condition of that member.

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2. Related Works and Objectives of This Study

2.1 Related Work

With the downsizing of the recent sensors and microcomputers, monitoring systems for elderly people have become a reality [3]. As a result, many products and systems have been developed for the purpose of monitoring elderly people. However, most of them aim to confirm that a person is alive. For example, the existing systems detect the usage of an electric kettle [4] or the usage of gas [5]. Another detects an elderly person falling by monitoring their behavior [6], [7], [8]. However, these systems can detect the falling, but cannot prevent the problem at the time of detection (e.g., the person may have died or be in a critical condition).

On the other hand, other systems try to analyze behavior patterns of elderly people by using a plurality of sensors [9], [10], [11], [16]. In this case, it is necessary to install many sensors in the homes of elderly people. The sensors used, for example, are motion sensors and door sensors (to detect opening and closing). One problem is the need for a lot of installation points, leading to high costs.

Another kind of system monitors actions of elderly people by using a camera or microphone [12], [13], [14], [17], [18]. This method makes it possible to gather detailed information about an elderly daily activities and their types. Such a system can be configured by installing fewer installation points compared to motion sensors. However, it tends to be disliked since the installation of cameras and microphones leads to privacy concerns. Similarly, the detailed behavior of the person should not be identified using the behavior recognition algorithm even if the direct measurement using the camera/microphone has not been used.

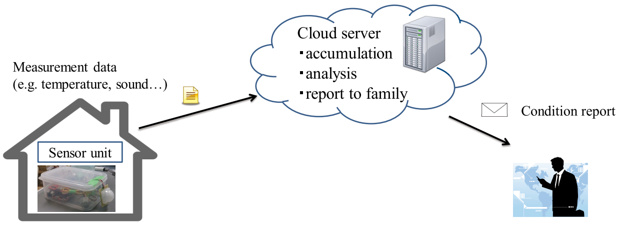

Fig. 1 Overview of proposed system.

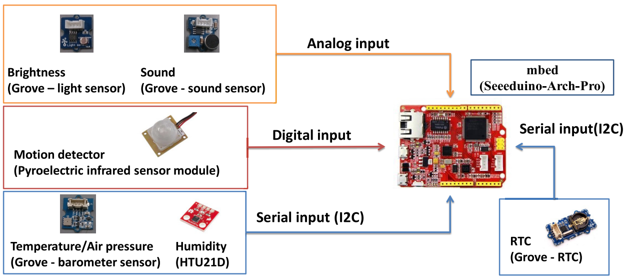

Fig. 2 Various sensors.

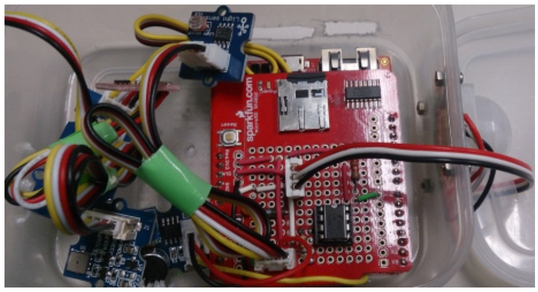

Fig. 3 Experimental sensor unit.

Table 1 List of sensors connected to mbed for monitoring daily-life activities.

	Sensor	Activities of Daily Living
Environmental Change by The Action	[1] Air Pressure Temperature	Status of Air-Conditioner
	[2] Humidity	Opening and Closing Window
	[3] Brightness	Lighting the Room Lights
Human Action	[4] Sound	Sounds such as TV
	[5] Motion Detector	Indoor Movement

2.2 Objective of This Study

In consideration of the situations described in the previous section, a monitoring and advising system – which utilizes a combination of sensors and a cloud server – is proposed. The proposed monitoring and advising system gives elderly people advice about leading a healthy life.

The proposed system aims to achieve low installation costs and data collection with consideration for privacy. Accordingly, it collects data without imposing a burden on the elderly person in question and detects activity patterns of the elderly on the basis of the collected data.

3. Overall Structure of Proposed System

3.1 Overview of Proposed System

An overview of the proposed monitoring and advising system for elderly people is shown in **Fig. 1**. The system provides assistance for elderly people to help them live a healthy life. The assistance is given by monitoring the daily-life activities of elderly people. The system is composed of a sensor unit and a cloud server. The sensor unit collects data, which is accumulated and analyzed in the cloud server.

The sensor unit is overviewed in **Fig. 2**. It is installed in one room of the house of an elderly. After installation, the data measured by the sensor unit is automatically collected and sent to the cloud server via the Internet. The configured measurement unit is shown in **Fig. 3**.

The cloud server is accessed via the Internet. It saves the data received from the sensor unit in a database. The stored data is used to learn life-style patterns and determine the condition of the elderly people. In addition, the cloud server notifies the family of the elderly person when patterns other than steady conditions are detected.

3.2 Sensors for Monitoring Daily-Life Activities

Various kinds of sensors and their intended applications are listed in **Table 1**. The sensor unit records the daily-life activities of the elderly people by using these sensors. The sensors can be divided into two groups. The first contains environmental sensors for capturing changes in an indoor environment. The second contains human sensors for directly capturing the behavior of elderly people. The sensor unit measures these elements every second.

The environment sensors are used for estimating the status of air-conditioning equipment, windows, etc. and detecting changes in brightness of the room. For example, temperature and humidity can be used to estimate the status of air-conditioning equipment and windows (i.e., open or closed). Brightness can be used to estimate the status of indoor electric lights (i.e., "on" or "off"). Air pressure can predict a change in the weather. The environment sensors are also used to detect changes in a person's usual behavior pattern. An example of a different pattern is the case that an elderly person is in bed all day with a cold. In such a case, indoor temperature and humidity show a change from the normal days.

The human sensors are used to estimate a person's movement and continuing presence in a room. An example of the status to be detected is watching television. The sound of the television in a room can be used to estimate that a television is being watched in that room. The infrared motion detector can be used to estimate the motion status of the elderly people.

The sensor unit uses the "mbed" development platform as a microcomputer. With the mbed, it is possible to perform an advanced process (such as multi-threading) while maintaining low power consumption. Furthermore, the mbed comprises an Ethernet connector and can access the Internet. However, mbed cannot record a time when the power is disconnected. Moreover, its battery cannot be attached to the body. To solve these problems, the proposed system uses a real-time clock IC with a battery.

3.3 Analysis of Sensor Data by Cloud Computing

The cloud server, installed on the internet, stores the data measured by the sensors and analyzes patterns of daily-life activities. Using a cloud server makes it possible to use the data from multiple sensors in large quantity in the analysis. Furthermore, parallel processing in the cloud server makes it possible to process a large amount of data.

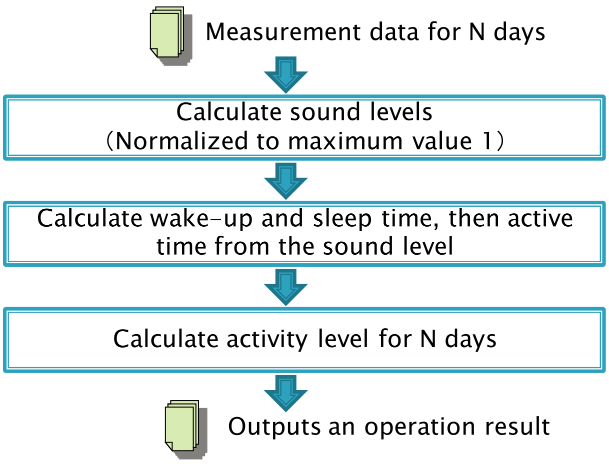

Fig. 4 Proposed algorithm for estimating indoor activity.

The cloud server sends advice to the elderly people or their families if it detects an abnormal condition, namely, a change in the life-cycle pattern (in contrast to detecting whether a person is dead or alive). Currently, these functions are being individually tested. In the future study, it is planned to implement a cloud server that integrates them.

The proposed system analyzes sound data in order to estimate "indoor-activity level" of a person. The estimation algorithm consists of three steps as shown in **Fig. 4**. In the first step, the sound level is calculated by normalizing the strength of the sound between 0 to 1 (the maximum strength is mapped to 1). After that, in the second step, the algorithm detects the wake-up time when the sound level continuously exceeds the predetermined threshold (e.g., 0.01) at the beginning of the day, and detects the sleep time when the sound level continuously becomes lower than the threshold at the end of the day. The time interval from the wake-up and sleep time is defined as the active time. Finally, the ratio of the time interval when the sound level is larger than the threshold is assumed as the activity level in the third step. In the proposed system, the activity level is calculated for a long term (over *N* days).

4. Experimental Evaluation of Proposed System and Analysis of Sensed Data

4.1 Experiment Using Proposed System

The proposed system was experimentally evaluated in an actual house of an elderly couple. The experimental conditions are listed in **Table 2**. The location of the experiment was a town called Kawaguchi in the city of Nagaoka, Niigata prefecture, Japan. The experiment was performed three times.

4.2 Detection of Getting-up and Going-to-bed Habits

With the cooperation of the elderly couple, a sensor unit was installed and used to collect data. The unit acquired sound as an analog signal. The method for detecting the activity of the couple uses that sound data recorded every second. Each time the sound exceeds a volume threshold for 800 milliseconds is regarded as an activity. Therefore, the numerical value to be recorded was taken as an integer up to 800. Especially, the detection targets are get-up and go-to-bed habits. The detection procedure (i.e.,

Table 2 Experimental conditions.

Location	Kawaguchi Town, Nagaoka City
Date	(1) October 28, 2014 – November 24, 2014 (2) December 30, 2014 – January 16, 2015 (3) June 6, 2015 – August 23, 2015
Resident	Two Elderly People
Purpose	Data Measurement by Sensor Unit
Recording Method	Save to SD card

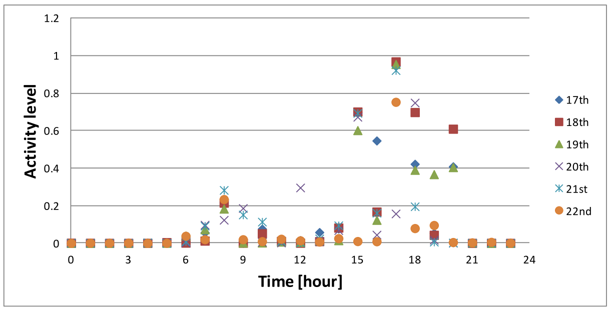

Fig. 5 Analysis of sound data.

"learning process") consists of three steps: the total value of the sound data is calculated every hour; the total value is divided by 3,600 (seconds) to determine the average; and the calculation result is converted to a value between 0 and 1 by dividing it by 800.

Converted data recorded from November 17 to 22 are shown in **Fig. 5**. This graph shows activities in a room (such as watching TV) when the activity value is close to 1.

Furthermore, the graph shows that the elderly people are active from 6:00 to 20:00. It shows that it is possible to detect the get-up and go-to-bed times, which can be monitored to detect changes in the long-term and gradual life pattern of the elderly couple. For example, the sleep time gets earlier from the 20th. Asking the elderly couple about this pattern change revealed that the elderly man had a cold from the 20th. The validity of the conjecture inferred from the monitoring results given by the proposed system was thus confirmed.

Moreover, the number of times the elderly go to the toilet at night can be counted. This can be done by checking the sensor data acquired during their sleep periods. In particular, the sound of entering and leaving the room is detected. In addition, it will also be possible to detect midnight prowling by the same method.

In short, it was confirmed that it is possible to detect get-up and go-to-bed time on the basis of sound data. Changes in that time can detect abnormalities in the life patterns of the elderly. In addition, the condition of the elderly can be inferred from nighttime activities. The proposed system can thereby prevent the elderly becoming sick by giving notice to their family if the pattern of detection results changes. At the same time, it advises the elderly in regard to staying healthy.

4.3 Long-term Analysis

This proposed system performs long-term analysis of changes in average activity patterns for each month. In other words, it estimates seasonal change of life patterns. The long-term analysis involves three steps. The first step calculates the activity level in the activity time. (Activity time is determined as the period between getting-up time and bed time.) The second step calculates

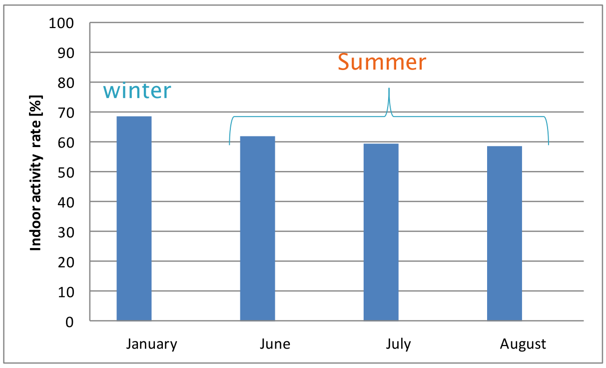

Fig. 6 Results of long-term analysis – 1: Ratio of indoor activities at activity time.

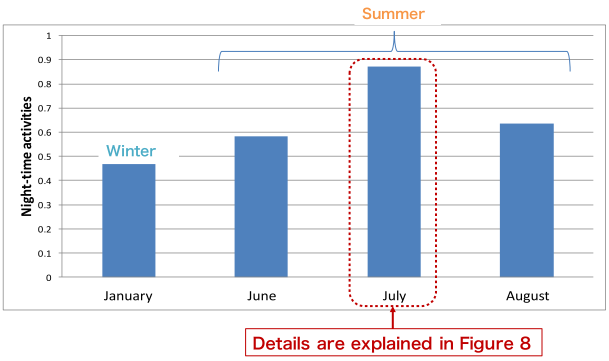

Fig. 7 Results of long-term analysis – 2: Indoor activities from bed time to getting-up time.

the average activity level per hour. The third step compares the change in activity levels for each month.

The activity level shows the frequency that the elderly people are in the room being monitored. Therefore, the system can estimate indoor-activity rate, which is determined by the proportion of activity levels in the activity time.

Indoor-activity rate is plotted in **Fig. 6**. If indoor-activity rate is high, the elderly are judged to spend a longer time in the room. If it is low, the elderly are judged to spend a shorter time in the room. If it does not become shorter in a specific summer, an alert will be triggered.

This system also estimates night-time-activity level, which is calculated from sound data during sleep time. It is calculated for each day and used for monitoring night-time activity (e.g., sleep-walking or going to the toilet). Monitoring changes in night-time-activity level is useful for disease prevention. Seasonal change of night activities are confirmed by calculating the average monthly value of night-time-activity level. Average number of night-time activities is plotted in **Fig. 7**. This result shows that night-time activity increases in summer because it is so hot the people cannot sleep well [15].

However, the night-time activity is smaller on August than July although August is the hottest month in the year. It is guessed that the main reason of the result is a use of an air conditioner. By hearing to the elderly people living in the room, we confirmed that the air conditioner started to be used from 13 July. Therefore, the average night-time activities before 12 July are compared with that after 13 July in **Fig. 8**. As shown in this figure, the night-time activities markedly reduced after starting to use the air

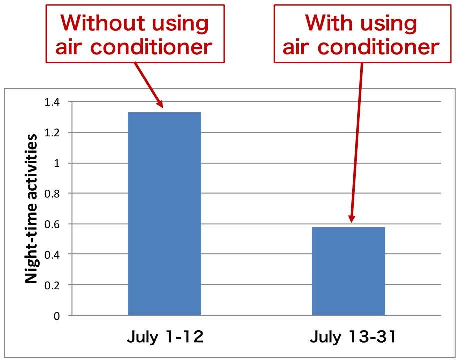

Fig. 8 Results of long-term analysis – 3: Effect of use of air conditioner on indoor activities.

conditioner. As a result, we can conclude that the difference of the night-time activities between July and August is due to a use of the air conditioner. Therefore, by monitoring the night-time activities in each day, we can check whether the air conditioner is appropriately used for keeping the room comfortable or not. If the night-time-activity level increases significantly in summer, an alert will be triggered.

5. Conclusions and Future Work

A monitoring and advice-giving system based on daily-life activities for the elderly people was proposed. The proposed system uses a combination of sensors with a microcomputer and a cloud server. In addition, a method for detecting the activity patterns of the elderly couple was proposed and experimentally evaluated by using the data collected in the house of an elderly couple. The results of the experimental evaluation revealed that it is possible to detect a seasonal change in the activity pattern by creating a learning model from the measured sound data. These results have shown that it is possible to detect the activity pattern of elderly persons from their action parameters in consideration of privacy and environmental data obtained in their home.

In future, detection algorithms for handling more-diverse activity patterns will be developed. In addition, short-term analysis for detecting a change in daily activities (e.g., being in bed with a cold) is being studied. Furthermore, an algorithm for advising elderly person on the basis of the activity pattern, an advising-giving function using a simple weather forecast based on air pressure, and high-speed data processing using parallel processing in the cloud server will be implemented. This study was partly supported by SCAT.

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