Television-Operating-State Telemonitoring System in Caring for Elderly People Living Alone

K. Nakajima, H. Matsui, T. Motoya, and K. Sasaki

***Abstract*—We suppose that a television-operating-state (TVOS), *i.e.*, whether a TV is turned on (TV-on) or off (TV-off), expresses the consistency of the rhythms of the long-established everyday rituals of a dweller. We developed a low-cost TVOS telemonitoring system in caring for elderly people living alone. The system is comprised of both analog and digital circuit sections. The analog circuit section consists of a current sensor and amplifier, and outputs the TVOS. The digital circuit section consists of two computers with an Internet connection. The computer at the family's end requires the data from the computer at the elderly person's end to be transmitted via the Internet every minute, receiving the TVOS data with a one-minute delay. Two healthy volunteers, a 79-year-old female living alone and a 21-year-old bachelor, participated in this study. Changes in the TVOS were monitored for over five weeks, and the data was found to coincide with the aged subject's record of TVOS and showed the consistency of the daily rhythms of the TVOS.**

I. Introduction

IN developed countries, 20% of the current population is aged 60 years or over, and by 2050 that population is projected to be 32% [1]. Europe is fast becoming its oldest region [2], and 26 states in the USA are projected to double their 65-and-older population between 2000 and 2030 [3]. Meanwhile, Japan, as of 2005, is the most aged society in the entire world [2]. The Japanese population of 65 and over is 21% and in 2005 had already surpassed 25% in 12 prefectures [4]. Due to this, the number of elderly people living alone is increasing rapidly as the aged population increases. The Japanese population of elderly people living alone has increased substantially, this segment constituting 23% of the population of those 65 and over in 2005 [4]. The proportion of women aged 65 and over living alone in private households was over 40% in Great Britain, the Netherlands, Sweden, the USA, Germany, and Austria in 2002 [5]. As elderly women who live alone are considered at greater risk for loneliness, depression, and decreased mobility [6], the elderly living alone may need health and social care. Thus, the growing number of elderly people in the population is the biggest consumers of health and social care [7]. This gives rise to the problem of who will pay the cost of this population segment's health and social care. Telemonitoring at home is an interesting solution compared to health facility institutions for the elderly, since it improves the patient's comfort and reduces hospitalization costs, patient travel, time off from work, and overall cost [8, 9]. Moreover, a telemonitoring system could help elderly people to live independently by providing them with improved safety and security in their homes [7]. Telemonitoring systems involve the use of sensors such as passive infrared sensors [10, 11], light sensors, door sensors, water valve sensors [12, 13], and temperature detectors [14]. This kind of intelligent monitoring system creates profiles of the daily activities of the dweller, which then can be used to identify deviations from the individual's normal activity patterns, indicating that the person is in need of assistance [7]. We suppose that a television's operating-state (TVOS), *i.e.*, whether a television (TV) is turned on (TV-on) or off (TV-off), expresses the consistency of the rhythms of the long-established everyday rituals of a dweller. We reported that a subject, 78-year-old female who lived alone, watched TV at roughly fixed times when she was healthy, and a deviation from the normal pattern was identified in the TVOS profile when she was sick [15]. The overall goal of our research is to allow elderly people living alone to be monitored unobtrusively by their family using a telemonitoring technique. In this study, we developed an Internet-based low-cost TVOS telemonitoring system to detect deviations from regular daily activity targeting those who are independent in ADL, free of dementia, and live alone.

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II. Methods

A. Outline of Telemonitoring System

We suppose that a user of the system we developed have a computer with an Internet connection before we install the system. In other words, we borrow a user's computer, and partly embed it into the system, so that the both initial cost and running cost are reduced. Fig. 1 shows a schematic illustration of the entire system.

The system is divided primarily into two ends, identified as the elderly person's end (EPE) and the family's end (FE). Each end has a computer connected to the Internet. In this system, the TVOS is transferred from the EPE to the FE via the Internet. The TVOS indicates the private, everyday rituals of the elderly [15], therefore, the TVOS data have to be protected when it is transferred via the Internet. In regard to automatic and secure data transfer, UNIX provides advantages. However, we employed Microsoft Windows® in this study because it is currently the most popular

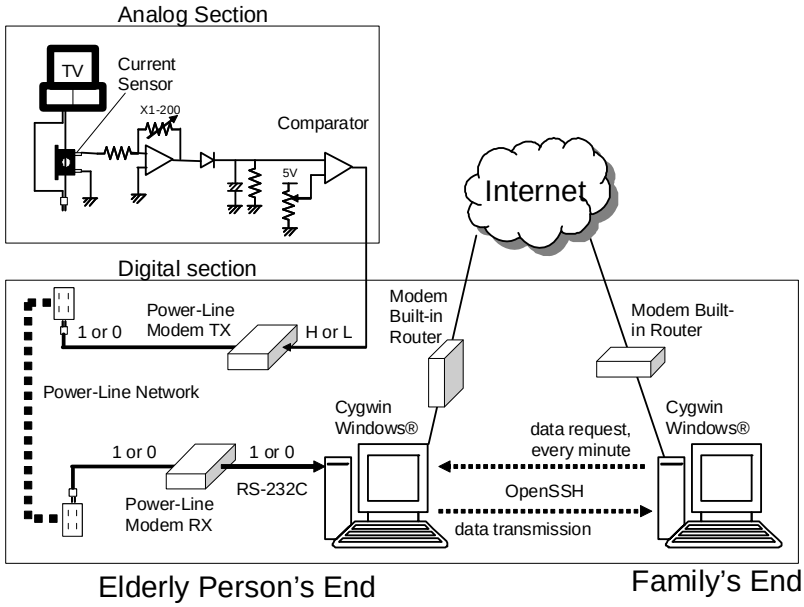

Fig. 1. Schematic illustration of the entire TVOS telemonitoring system.

operating system (OS) for home computers. Therefore, Cygwin, a free software, was installed onto Windows 2000 (SR4) to allow the use of two UNIX programs: 'sshd', a remote access program for security, and 'cron', a demon program for automatic data transfer on the PCs at both the EPE and the FE.

B. System for Elderly Person's End (EPE)

On the EPE, the system is comprised of analog and digital circuit sections, as shown in Fig. 1. A current sensor, a solenoid coil (CTL-6-S-Z, U.R.D. Co. Ltd., Yokohama, Japan), is attached to the power line of the TV. The current sensor produces an AC signal, and its amplitude is in proportion to the amount of power current used by the TV. The AC signal of the current sensor is fed to an inverting amplifier. The amplified AC signal is rectified with a single diode and goes through a smoothing circuit to obtain a DC voltage. The gain of the inverting amplifier is adjusted to obtain 4 volts of DC signal when the TV is on. The DC signal is compared to the reference voltage of a comparator that produces a logic signal, high 'H' or low 'L', so that the output signal indicates if the TV is on or if it is off. The reference voltage of the comparator has to be adjusted because of variations of the standby power of each TV. The logic signal is fed to a transmitter of the power-line modem (BPLM-100B, Busicom, Tokyo, Japan). The digital circuit section consists of a pair of power-line modems and a computer equipped with an Internet connection. The pair of power-line modems is used instead of a signal wire to allow transfer of the TVOS from the sensor to the computer. The computer acquires the TVOS from a receiver of the power-line modem via an RS-232C interface. The last TVOS is overwritten each minute as a text file in the computer's hard disk. An Internet service provider (ISP) assigns an Internet protocol (IP) address to a built-in router of the Internet modem.

Fig. 2. Upper and lower windows indicate on the computer at the family's end. Upper window: TV-on; Lower window: TV-off.

An Internet connection with a fixed IP address assigned to a computer is significantly expensive than a dynamic one. Two volunteer was participated in this study, they contracted a dynamic IP address assigned service with a ISP. Because IP address will be changed when the computer restarts the OS, the system employs a dynamic domain name system (DDNS). DiCE, a free DDNS software, seeks an IP address from a static host name of a computer.

C. System for Family's End (FE)

The computer at the FE requires the transfer of TVOS data to the computer at the EPE each minute via the Internet by using the IP address that is ISP-assigned to the built-in router at the EPE. The 'cron' command 'rsysnc', which

provides a very fast method for synchronizing remote files, is executed every minute by the ‘cron’ command ‘crontab’. Therefore, the computer at the FE receives the text file of the last TVOS from the computer at the EPE with a one-minute delay. Transmitted data are enciphered by the remote access program 'OpenSSH protocol 2' of 'sshd'. Public-key cryptography was used when the TVOS data was transferred. When the TVOS is TV-on, a picture on the TV’s screen is indicated on the computer screen at the FE as shown in Fig. 2.

III. Trial

Two healthy subjects, a 79-year-old female living alone (Subject A) and a 22-year-old bachelor (Subject B), participated in the present trial. They were not actually members of the same family, but for the purposes of the experiment we designated Subject A to be the aged person and Subject B to be Subject A’s family. The two subjects lived approximately 4 km apart. Both of the subjects used the same ISP service of Yahoo! BB 12M (Yahoo Japan Corp., Tokyo, Japan). Subject A had a TV in each living room and in her bedroom. We installed the sensor in the TV of the living room for the purpose of determining Subject A’s daily living habits.

When we installed the system in Subject A’s home, we confirmed the IP address that was assigned by the ISP. We then gave the confirmed IP address to ‘crontab’ on the computer in Subject B’s home. Installation time was about 30 min in each of the homes. The trial was conducted during a period of over five weeks, for 37 successive days, from the afternoon of June 16 (Thursday) to the afternoon of July 22 (Friday), 2005. We gave a notebook to Subject A to record her TV use with a time resolution of 5 min. We explained the purpose of this study to the subjects before starting the trial, and they provided us with their written informed consent.

IV. Results

Telemonitoring of the TVOS was performed for 37 successive days without any malfunctions. Fig. 3 shows the TVOSs obtained from the system and those from Subject A. In the period of this trial, the number of instances of TV-on in total was 107 according to the system’s record and 104 according to Subject A’s record, respectively. The system recorded TVOS with a time resolution of 1 min, while Subject A was asked to record it with a time resolution of 5 min, as mentioned. Although differences of a few minutes are seen between the system-recorded data and the subject's records because of the time resolution differences, the data almost coincide. An average period of TV-on was 372 ± 130 min (mean ± SD) per day by the system record and 363 ± 129 min by Subject A’s record, with a coincidence rate of 88.6 ± 18.0 % in the TV-on period. There were several discrepancies in the records of short term TV-on and TV-off, especially from June 26th to 29th. After the trial, we interviewed Subject A about these discrepancies, and confirmed her missing records. Excluding her missing records, the obtained TVOSs from the system and Subject A corresponded perfectly.

Based on information obtained in our interview, Subject A usually comes to the living room at around 8:00 and goes to her bedroom at 22:00, and regularly watches some TV programs including news programs in the morning, at noon, and in the evening. As shown in the recorded TVOS in Fig.

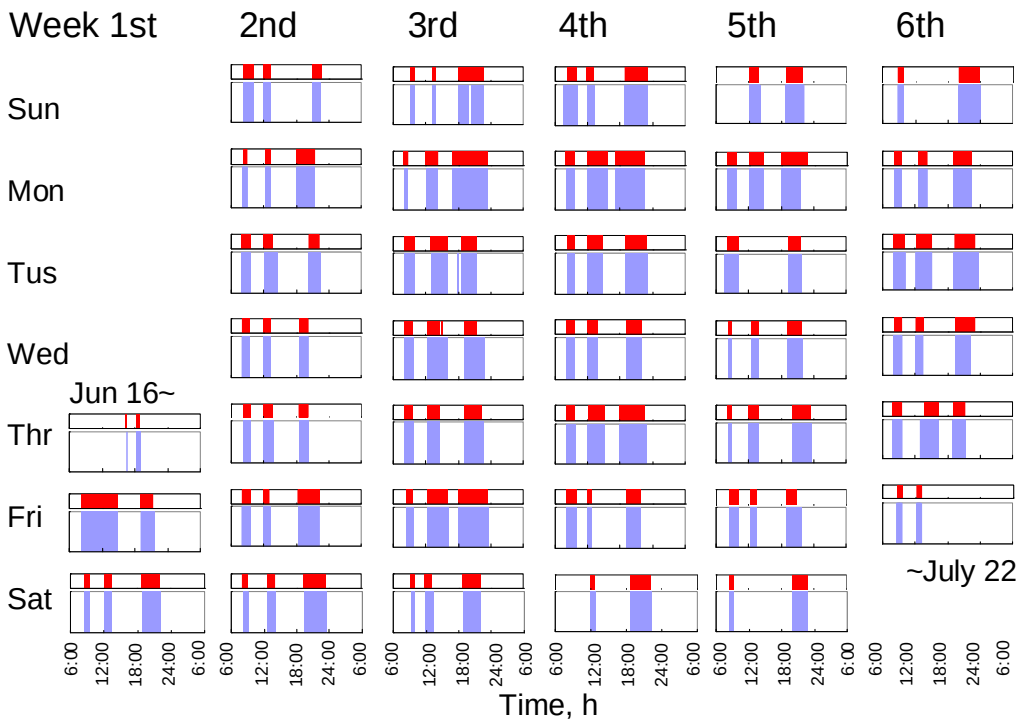

Fig. 3. TVOS records of 37 successive days. The upper short (red) and lower long (blue) bars indicate Subject A’s record of use and the system’s record, respectively.

3, the TVOS indicates the regular on/off state of the TV in the morning at around 8:00 to 9:00 excepting in July 9th and 10th. The TV was also turned on at around noon regularly everyday excepting in July 12th, 16th, and 17th. In the evening, the TV was turned on at around 19:00 and was turned off by 22:00. The data shown in Fig. 4 and 5 support the data provided by the interview. Frequencies of TVOS were recorded according to days of the week (Fig. 4). The number of the days was five, *i.e.*, from Saturday to Wednesday. Six Thursdays and Fridays were included in the trial period. Subject A used the TV three times in a day, and no typical difference between usages was seen each day. Fig. 5 shows the frequency of the TVOS over the successive 37 days. Three clear peaks were seen in the morning, at noon, and in the evening.

V. Discussion

In this study, a telemonitoring system was developed and we confirmed the subject's daily living habits based on the consistency of the rhythms of the TVOS. Normally, the home contains many electric appliances and we can acquire many types of data from electric appliances whose frequency of use can express many types of domestic habits. In fact, in one of our previous studies we installed monitors on electric appliances and door latches in the home of an elderly person living alone [15]. Suzuki *et al.* [13] reported a single-subject feasibility study demonstrating that the total count of output from binary sensors could be an index of indoor activity. We attempted to analyze the data we acquired in the above studies to extract helpful information regarding an individual's health condition, but found that most of the data have no correlation to each other. We found that this kind of analysis cannot constitute a global method because the number and kind of sensors vary in each home and the habits of daily life differ from subject to subject. In our attempt to develop a health status indicator based on these data, we confirmed that the TVOS best represented the health condition of the subject [15]. Stroetmann *et al.* [16] performed a survey of 9661 interviews of elderly people in Europe related to e-health and telemedicine issues. They reported that 98% of all respondents had access to a TV set, with virtually the entire general population of developed countries experiencing TV availability. A survey of approximately 4800 German TV households in 1996 reported that Germans aged 50 years and above watched on average 233 min of TV per day [17]. Another survey regarding TV use and favorite TV categories in Baltimore, USA, reported that elderly female subjects (n=289) watched an average of 4 hours each day of TV, and watching news was the most popularly endorsed category [18]. According to the literature, TV is the most widely used electric appliance and people in developed countries use it every day. In the present study, Subject A watched on average 6 hours per day and watched a few programs including news programs regularly as shown in Fig. 4 and 5. This result corresponds to those of the above reports regarding developed countries [16-18]. If deviation from the consistency of the rhythms of TVOS appears, the family can detect a significant disruption of daily habit from a remote place.

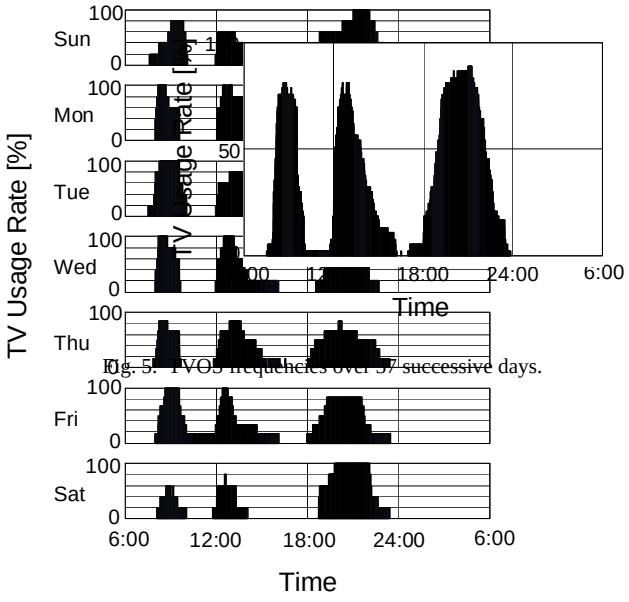

Fig.4. TVOS frequencies.

Some telemedical and telecare systems have been developed which are already in clinical use [19, 20]. Commercial emergency call services are currently available in Japan, but these services are not widely used at this time, due probably to their costs. These companies must prepare a customer service center and provide emergency call services which are available 24 hours a day, 365 days a year. The costs for operators and medical experts in such a center are relatively high, so that this cost is clearly reflected in the price of the service. Heinzelmann *et al.* [20] reported that most health systems in the world are supported through public funding. Nobody will buy this kind of service if the elderly people in question do not have a clear need for it. However, elderly people living alone and their families may nevertheless have concerns regarding an appropriately rapid response to injury or illness. Elderly individuals and their families may communicate using inexpensive devices such as the telephone, fax, or e-mail, but frequent communication may increase emotional stress on one side or the other, or on both. Ideally, it would be possible to put in place a system that can help to recognize the health condition of an elderly parent which does not entail any emotional stress and allows the elderly family member to be monitored unobtrusively. Although our system required original sensors costing about $30 and about $4 of electricity per month, no extra fee was needed in this study because we used the Internet facilities that had already been put in place by the users. Moreover, the system worked well without any maintenance in the trial and did not disturb Subject A. As expressed in our interview after the trial, she was conscious of the system's existence at the beginning of the trial, but hardly noticed its presence after a few days.

The number of Internet users at the end of 2004 in Japan was estimated to be 79.48 million, with a penetration rate of 62.3 % [21]. In particular, the rate of Internet use by the generation 13-39 years old was over 90%. Although Internet use among people 60 years old or older was 26.0%,

it has increased by 2.43 times in last 4 years, a faster rate of growth than that in other age groups [22]. Internet facilities will come into wide use by the aged generation in the near future. In fact, Subject A uses a PC with an Internet connection, and she checks her e-mail twice a day.

In conclusion, we have developed a low-cost Internet-based system that allows the family to monitor the TVOS at the home of an elderly person living alone. The family itself monitors the data coming from the computer at the EPE without any help from operators and medical experts. Thus, the present system can be implemented at a low cost and is highly cost-effective. Using this inexpensive telemonitoring system, a family should be able to monitor the daily life of an elderly people living alone without disrupting that person's daily life or unduly invading his or her privacy. The regular rhythms of the TVOS were obtained during a trial period. The present system does not specifically describe the health condition of an elderly person living alone, but if that individual's family is familiar with his or her viewing habits, they would be able to identify any change that might indicate a need for assistance.

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