Ambient Monitoring System for Urination

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***Abstract*—Urination is one of vital quotidian activities that is closely involved in maintaining the healthy life of the elderly. The number of times and the time of day that an elderly person urinates are important data to detect a latent, dangerous situation that may require medical treatment. In this paper, we propose a sensor system for monitoring urination at home. Since the bathroom of a house is shared by elderly persons and their family members, the monitoring system has to detect urination but also identify a person who uses the bathroom. Urination is usually accompanied by the use of tap water from a toilet's flush tank. Urination can be made recognizable by monitoring the flow of water in the toilet bowl. The monitoring system uses the water flow sensor that is attached to the toilet. Active Radio Frequency IDentification (RFID) tags are used for identification of persons. The subject of the monitoring wears an active RFID tag when he/she uses the bathroom. The ID code of the tag is read by the tag reader contactlessly without any actions, when a person carrying a tag gets closer to the tag reader. Our system reports his/her records of urination to a local nursing center without explicit user interaction. The proposed sensor system is available at a reasonable cost and can be installed easily in any type of housing. No interaction by the user is required. The monitoring system has been installed in a volunteer's housing and some results from this experimental trial will be presented.**

Keywords–Urination; The elderly; Water flow sensor; Active RFID tag; Vibration sensor.

I. INTRODUCTION

We are confronted with an increasing population of the elderly, many of whom are apt to suffer from latent dangerous situations that may require medical attention. However, the number of home-care nurses available for regular home visits is limited to check their health status. Thus, new care services, such as those that use monitoring systems [1][2], are needed to cut costs in health care while still providing adequate medical treatment for the elderly.

Since urination is one of vital quotidian activities that is closely involved in maintaining a healthy lifestyle, we focus on urination as a sign of latent dangerous situations. As you know, it is not uncommon to pass urine more frequently in the senior years. This is partly due to age-related changes in the bladder muscle. However, sometimes, frequent urination is a sign of some underlying disease. Humans urinate an average of four to eight times a day; thus, if an individual makes much less or much more frequent use of the toilet, then some illness or problem can be suspected [3]. If one wakes two or more times before dawn to urinate, this can also be a sign of a poor health state [4]. Common causes of such symptoms are a urinary tract infection, diabetes, stroke or other neurological diseases, chronic kidney disease, dehydration, and so on. Therefore, some of these causes of frequent urination or nocturia can be serious and an early diagnosis can play a significant role in treating the condition.

The number of times and the time of day that the elderly urinate are important data to investigate and treat them accordingly, and could help the doctor to make a correct diagnosis for them. However, it is very boring and troublesome to record the frequency of urination with time stamps. We can not expect the elderly themselves or their family members to record them correctly. Some systems for monitoring urination have been proposed [5] but they are supposed to be used in the process of taking care of patients with bladder dysfunction or in critical care. The assistance of medical professions is needed to operate such a system. In this paper, we propose a simple, easy monitoring system for urination at home. Our system records the number of times and the time of day that an individual urinates, and reports his/her records to a local nursing center without explicit user interaction. The proposed sensor system is available at a reasonable cost and can be installed easily in any type of housing. No interaction by the user is required. No personal data, such as photographs or video recording are saved in the system or transmitted.

This paper is organized as follows. In Section 2, we give a brief outline of the proposed monitoring system. Section 3 describes the technical aspect of the monitoring system. Section 4 describes the implementation of the monitoring system and experimental results. Concluding remarks are given in Section 5.

II. OVERVIEW OF THE PROPOSED MONITORING SYSTEM

Our monitoring system is supposed to be set up in the bathroom of a house, which is shared by an elderly couple or an elderly person and his / her family members. The monitoring system has to detect urination but also identify a person who uses the bathroom. An Active Radio Frequency IDentification (RFID) tag is used for identification of persons. The subject of the monitoring wears an active RFID tag when he/she uses the bathroom. RFID tags emit Radio Frequency (RF) signals periodically with an unique ID code. The ID code can be read by the tag reader contactlessly without any actions, when a person carrying a tag gets closer to the tag reader. Urination is usually accompanied by the use of tap water from a toilet's flush tank. The proposed monitoring system uses a sensor which can detect the flow of water in the toilet. The sensor was originally developed in the previous work[2] but some parts of the sensor are redesigned to connect the tag reader.

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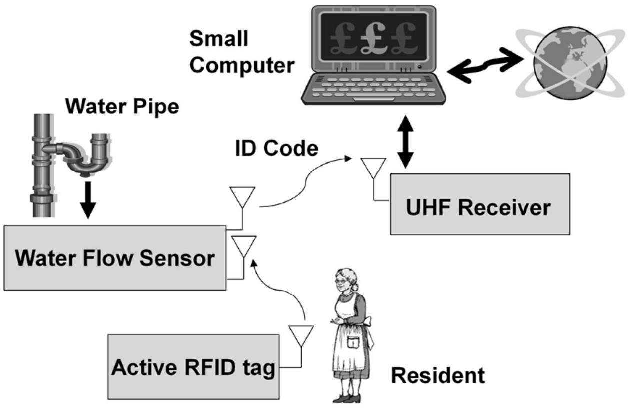

Figure 1. Functional deployment of the monitoring system.

Figure 1 provides the functional deployment of the monitoring system. The monitoring system consists of three main components: a water flow sensor equipped with an UHF (2.4GHz) transmitter and a tag reader, an active RFID tag, and a small computer with an UHF receiver and WiFi. When a resident uses the bathroom, the water flow sensor transmits UHF signals to the receiver connected to the computer at one-second intervals while water is flowing into the flush tank. If the resident is carrying a tag, the water flow sensor transmits the ID code emitted by the tag. If not, the default ID code is sent.

The computer records the receipt time of the ID code sent from the water flow sensor. The program installed in the computer derives the time of tap water use from the time stamps of the received ID codes. The data is collected and compiled, day by day or week by week. The computer sends a report to a local nursing center via the Internet. If there is something wrong with the urination record, then, a caregiver will visit the resident to verify his/her condition. If a reasoning program is installed in the computer, the program could report signs of declining health to a local nursing center, when there are major variations between the patterns of the normal and actual urination [6].

III. Equipments for the Monitoring System

This section describes the technical aspect of the functional blocks shown in Figure 1. Our system adopts a RFID system to see if a person in the bathroom is the subject being monitored or not. There are two types of RFID systems: passive RFID system and active RFID system. Passive RFID systems use tags with no internal power source and instead are powered by the electromagnetic energy transmitted from a RFID tag reader. The tags are very light and small but the reader becomes relatively large because a big antenna is necessary for transmitting the electricity to tags. Active RFID systems use battery-powered tags that continuously broadcast their own signal like radio beacons. The tag readers become the small size, such as a USB memory stick. Although active RFID systems are compact and fairly uncomplicated, many of the ready-made tag readers are supposed to be connected to computers through standard I/O ports, such as Bluetooth. It is very difficult to embed such tag readers into sensor systems without a microprocessor from a technical view point. Therefore, we designed an active tag system which suits the monitoring system. The tag reader is easy to integrate other electric circuits in the water flow sensor. In our system, we simply need to confirm the presence of a tagged person in a small area like a bathroom. Since the tag system plays the role of a non-contact proximity sensor, the read range of the tag must be shorter than a few meters. Therefore, the active tag is set to a lower transmit power not to exceed the read range. The number of a family member is usually two or three people. The ID code of 2-bit length is sufficient to recognize one of the family members.

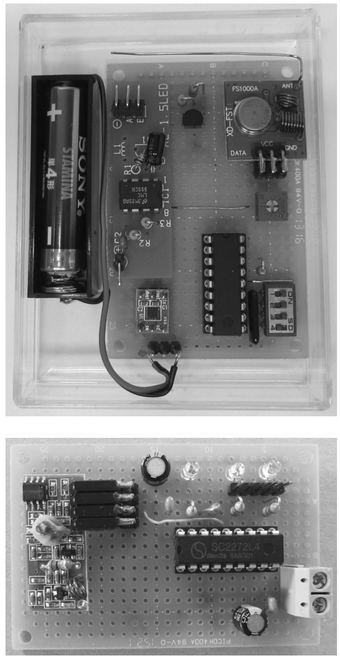

Figure 2. Active RFID tag (the upper image) and the tag reader (the lower image).

Figure 2 illustrates a prototype of the active RFID tag and tag reader. The tag consists of an UHF (433MHz) transmitter module, an IC chip for encoder, and a timer which switch on the transmitter at one or two second interval. The tag reader module is comprised of an UHF receiver module and an IC chip for decoder. The tag emits a weak RF signal periodically with a 2-bit code. If the tag is adjacent to the tag reader within a few meters, the reader outputs the parallel data of 2 bits.

Figure 3 illustrates a prototype of the water flow sensor. A water flow sensor consists of a vibration sensor, a sound-activated switch, a tag reader, and an UHF (2.4GHz) transmitter. Mechanical vibration in the range of 0.5 to 10KHz occurs at the water pipe to the flash tank while tap water is running. The vibration sensor is attached to the water pipe to a flush tank to pick up the mechanical vibrations. A ready-made contact microphone based on piezoelectric effect can be applied to the vibration sensor. The contact microphone are originally used for tuning musical instruments, such as guitars, and available for less than 5 euros in the market. The microphone is clip-on and the point of the clip is machined to fit the shape of a water pipe. Since similar vibrations are observed on the surface of a toilet bowl while tap water is running, a metal disk with

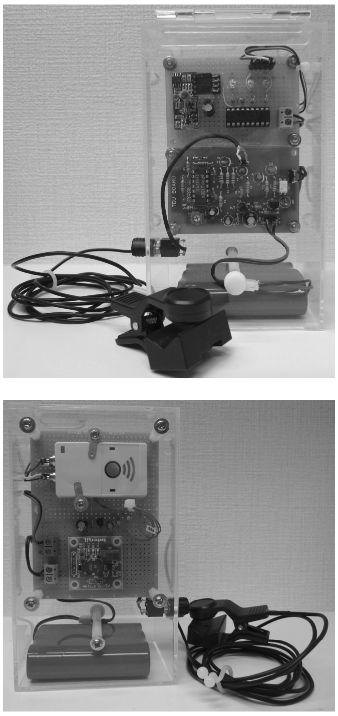

Figure 3. Prototype of the water flow sensor which consists of a vibration microphone, a sound-activated switch, the tag reader (the upper image), a UHF transmitter (the lower image), and a battery.

piezo material used for buzzers is stuck on the toilet bowl with adhesive tape, in the case of wall toilets where the tank and water pipe are conceal with a wall. Figure 4 shows examples of the vibration microphone clipped onto the water pipe to the flush tank of a toilet, and the metal disk stuck with adhesive tape on the surface of a toilet bowl.

When the sensor detects mechanical vibrations from the toilet, the sound-activated switch turns on the transmitter. Consequently, the transmitter sends a radio frequency signal (2.4GHz) with a 2-bit ID code from the tag. The code "00" is reserved as the default code. If the resident is not carrying a tag the default ID code is sent. The signal is transmitted at one-second intervals while the water continues to flow through the pipe. The transmitter can send signals indoors to a range of up to about 15 m, which is sufficient in a normal house. The sensors have a rechargeable lithium polymer (Li-Po) battery (6600 mAh) built-in and can keep functioning for about 12 months.

Figure 5 illustrates the small computer (Raspberry Pi B+) with a UHF receiver. The receiver receives UHF signals with the ID code from the water flow sensor, and the ID code is transferred to the computer through a USB port. Programs installed in the computer are written in C and run on the Pidora (a kind of the Linux for the Raspberry Pi). The number of times that the ID codes were transmitted from the sensor indicates the amount of time that there is running tap water, and this is proportional to the amount of water used because ID codes are transmitted steadily at one-second intervals while the water is running. The received ID codes are accumulated at half-hour intervals to obtain a distribution of the duration of tap water use.

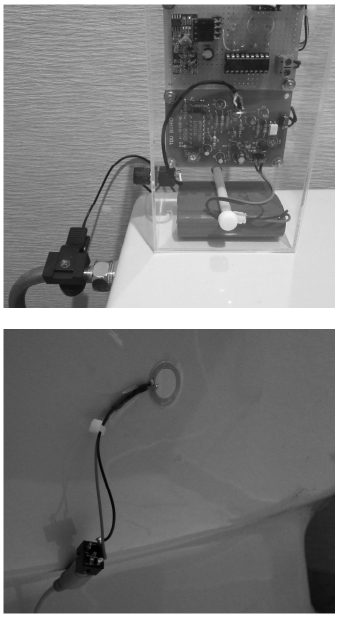

Figure 4. Contact microphone clipped onto the water pipe to the flush tank of a toilet (the upper image), and the metal stuck on the surface of a toilet bowl (the lower image).

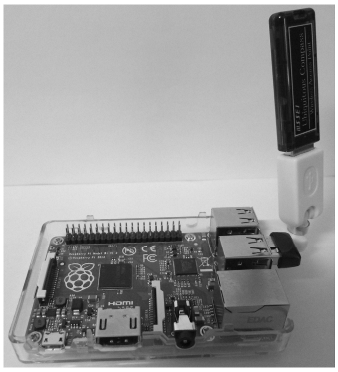

Figure 5. Small computer with a UHF receiver inserted in its USB port.

IV. Implementation and Experimental Results

A monitoring system was installed in a real housing environment and an experiment was conducted to see whether the sensor system can acquire the time and frequency of water use from the resident's quotidian activity. The house had a living area of 108 square meters (roughly 15 m by 8 m), and the water flow sensor was set on the water pipe connected to the toilet's flush tank in the bathroom. The distance between the sensor and the computer was 5 m. The residents were a 70-year-old man and 67-year-old woman. He filled the role of the subject being monitored and wore the RFID tag with an ID code of "01". When she or guests used the bathroom the default ID code "00" was assigned because they did not have any RFID tags. First, the sensitivity and reliability of the monitoring system were checked. The system could detect gently running water, such as would be poured into a glass.

Figure 6(a) illustrates an example of the distribution of the duration of water flow during the day at the residence's

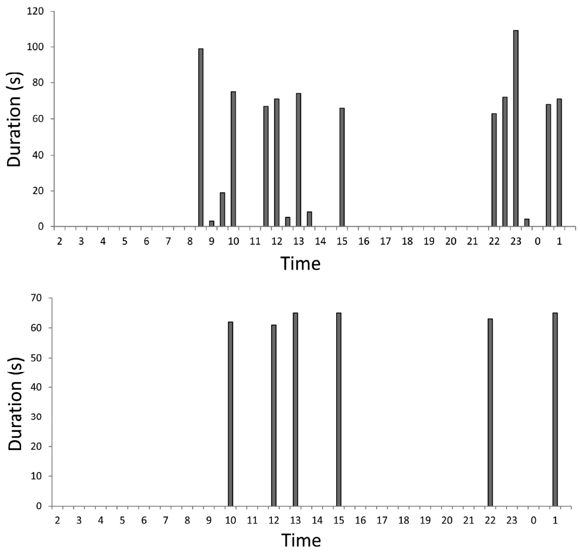

Figure 6. (a)Distribution of the duration of water flow into the toilet's flush tank (the upper image), and (b) the use record of the subject being monitored (the lower image).

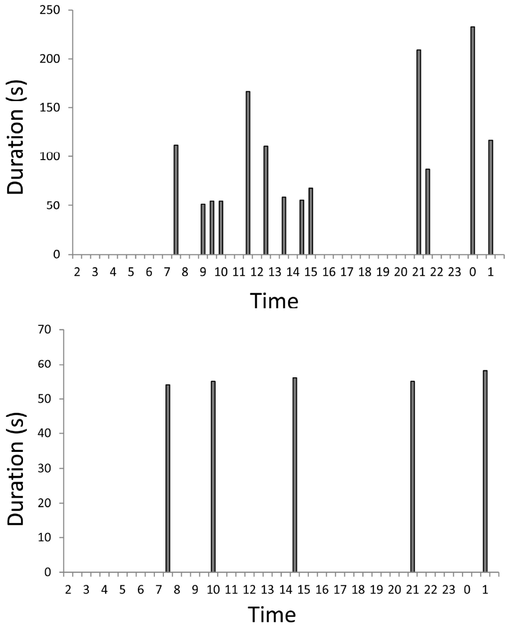

Figure 7. (a)Distribution of the duration of water flow into the toilet's flush tank (the upper image), and (b) the use record of the subject being monitored (the lower image).

toilet. In this case, the residents stayed in the house all day. The horizontal axis of the graph denotes the time at half-hour intervals starting at 2 a.m. The vertical axis indicates the duration of water use in seconds. The water flow sensor transmitted ID codes at one-second intervals while water was flowing into the flush tank. It depends on the water pressure, but it takes 60 seconds from 40 to fill the tank with water. Figure 6(a) expresses that the bathroom was used 13 times by the family members during the day. Figure 6(b) illustrates the distribution of the duration of water flow which was extracted from the distribution shown in figure 6(a), based on the ID code "01". The graph shows the use record of the bathroom by the subject being monitored, and expresses that the subject being monitored urinated 7 times during the day, at an average interval of 2.5 hours.

Another example of the distribution of the duration of water flow is illustrated in figure 7(a). In the case, their son's family with kids visited the home and stayed overnight, and the family member, including the subject being monitored went out from 3 to 9 p.m. for shopping or something. The figure expresses that the bathroom was used 22 times during the day. Figure 7(b) shows the use record of the bathroom by the subject being monitored. The graph expresses that the subject being monitored urinated 5 times or more during this day, at an average interval of 3.5 hours.

Each night at 2 a.m., the program sent out a daily report to the appointed addresses by e-mail, which denotes a time log of urination for the day. At the same time, all the data gathered to the monitoring system was saved to the ftp server on the Internet, and was deleted from the monitoring system.

V. Conclusion

Urination is one of vital quotidian activities that is closely involved in maintaining the healthy life of the elderly. The number of times and the time of day that an elderly person urinates are important data to detect a latent, dangerous situation that may require medical treatment. There is a demand for a reasonably priced, noncontact monitoring system that can directly recognize such quotidian activity. In addition, the monitoring system should be affordably installed into any type of housing. To meet these demands, we proposed the water flow sensor with a vibration microphone that can be easily clipped on to a water pipe leading to a flush tank of a toilet. Since the bathroom of a house is shared by elderly persons and their family members, the monitoring system has to detect urination but also identify a person who uses the bathroom. Active RFID tags were adopted for identification of the subject of the monitoring. We made a prototype of the monitoring system from electronic parts that are all available in the market. The prototype has been installed in a volunteer's housing and useful results were derived from the experimental trial.

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