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An Unsolicited Heart Stroke Alert System for Humans

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Abstract: - **Health care for the elderly is one of the promising application fields of IoT. Among them, detecting and preventing indoor heatstroke conditions is a crucial issue. We propose a method for monitoring indoor environment, detecting any risky conditions, and then effectively warning them to the elderly. Since elderly people have different physical weaknesses such as low vision and poor hearing, we designed and developed a system for alerting the elderly through multi-sensory information presentation. It can convey risky situations to the elderly via visual, auditory, and tactile stimuli.**

I. INTRODUCTION

In recent years, the number of heat stroke patients over 65 years old has been increasing and about half of all the patients are occupied by that age. Additionally, half of elderly patients are affected indoors. Because aging petrifies the sensitivity of temperature, the consciousness level for heat stroke of the elderly drops significantly [1]. Implementing a system for monitoring and detecting any risky states of heat stroke and effectively warning the elderly can improve the situation. There are some precedent research activities. Hamatani et al. proposed a system for measuring body temperature using a wearable sensor device [2]. Constantly wearing the sensor, however, forces a psychological burden on the elderly. Imran et al. proposed a system for monitoring temperature and humidity in a car and notifying dangerous situations to its owner via Wi-Fi network [3]. This is a trial targeted at avoiding life-threatening situations for children and pets left in a car due to heat stroke. In this paper, we propose a method for monitoring indoor environment of the elderly in real time by the installed device and promptly notify them when it detects any dangerous states of heat stroke. An essential requirement for conveying such critical information to the elderly is to make the system easily be individualized according to each user's physical weakness. Therefore, we devised a new multi-sensory alert notification method for efficiently presenting the dangerous states to the elderly by combining visual, auditory and tactile information. We designed and implemented the system based on portable IoT devices with high scalability, enabling persistent danger notification to the elderly for reliably avoiding the crisis.

II. SYSTEM IMPLEMENTATION

Figure 1 shows the proposed system organization. It consists of the system controller running on a Raspberry Pi board, a mobile weather station [4], and a set of multi-sensory output devices such as LED lights for vision, a speaker for auditory, and a vibrator for tactile sensation. The weather station

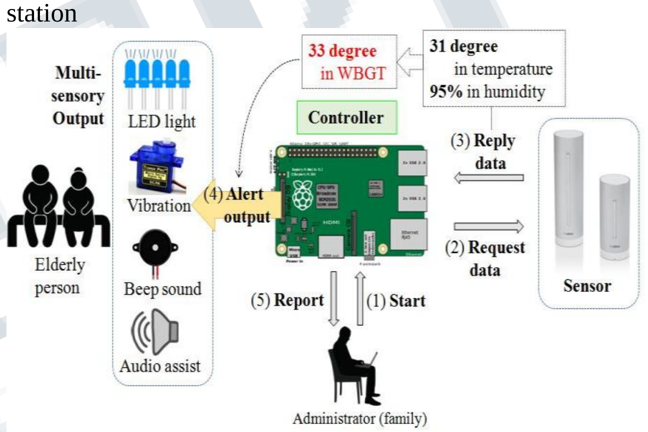
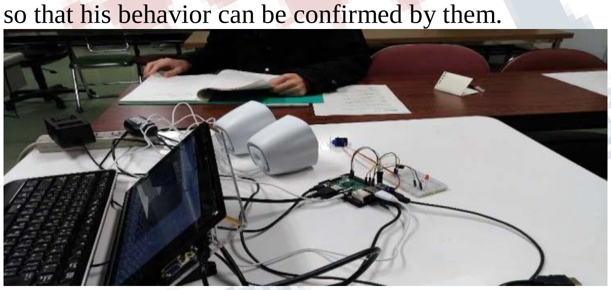


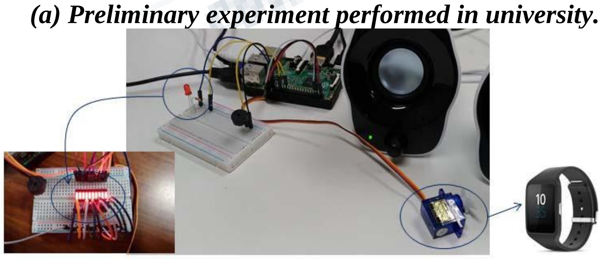
Figure 1. System organization.

continuously measures some indoor environment data such as temperature, humidity, CO_2 concentration, and noise level. After the system started, it periodically requests the measured data to the station via a Wi-Fi connection and uses the temperature and humidity values to detect any risky conditions. The system uses an indoor heat index called Wet Bulb Globe Temperature (WBGT) as a threshold value to detect the dangerous states of heat stroke. The WBGT index value can be calculated by temperature and humidity and its related site provides a guideline for judging the conditions with the derived values. As exemplified in Figure 1, when the temperature is 31 degrees and the humidity is 95%, the WBGT value becomes 33 degrees. If the WBGT value is equal or larger than 31 degrees, there is a danger of heat stroke. Then, the system tries to notify the risk as alert signs to the elderly through the multi-sensory output devices.

Firstly, the system turns on LEDs with beeps for notifying the occurrence of the risky condition. The beep sound is given for making the elderly awake the LEDs are on, and he can easily perceive that a problem occurs by looking at the red flashing LEDs. Additionally, the system presents a woman voice message and vibrations for emphatically convey the danger state. Because elderly people have various information receiving abilities such as weak eyesight or hearing loss, the system attempts to convey the condition through the multimodal information presentation. The user can also personalize the system on site by adding more appropriate devices through the controller's USB and GPIO (General Purpose Input/Output) ports. It is important to confirm that the elderly took some actions against the warning. Therefore, the system reports his family members and/or carers about the event occurrence via SNS messages so that his behavior can be confirmed by them.



(a) Preliminary experiment performed in university.



Change a single LED light to an array of LED lights

Change the vibrator from stationary- to bracelet-type

(b) Functional enhancements made after preliminary experiment.

(c) Main experiment conducted at the elderly's residence. Figure 2. Experiments for the system evaluation.

III. EXPERIMENTS

We conducted experiments for verifying the effectiveness of the proposed system. As a preliminary test, we employed six university students (all of them are in their early 20s) and one sexagenarian as subjects and checked the validity of the multi-sensory alert notification function. Then, we conducted another experiment for one subject in her 80s after improving the problems found in the preliminary experiment. In the preliminary test, we set the system close to the subjects as shown in Figure 2(a). Then, we asked them for doing normal things in daily life such as reading, smartphone operations, and watching TV. After that, we requested them to indicate their awareness whenever the system suddenly activated the multisensory alert function without notice. An alerting event occurred in a preset order such as LED, beep, vibration, and voice guidance, with fixed time intervals from 5 to 10 sec. After the alerting event, we asked them for evaluating each device from the viewpoint of easiness to aware in five ranks (5 is "good" and 1 is "bad"). Table 1 shows an evaluation result. The subjects A to F are university students, and G is a subject in her 60's. The subject G did not notice the beep sound, so the rate is nothing. Most subjects have difficulties for noticing the LED because the system originally used a single LED light. We changed it to an array of LEDs and implemented three scale gradation display function according to the WBGT value as shown in Figure 2(b). Although the other three devices got relatively good rates above four, the vibration was a lowest among them. Some subjects indicated that the vibration should be more effective if it directly stimulates the user's skin. Then, we also changed it from the stationary-type to the bracelet-type vibrator as shown in Figure 2(b).

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Then, we brought the system to the 80's subject's residence and conducted the main test as shown in Figure 2(c). We requested the subject to use the system with and without improvements in the same manner as the preliminary test and checked to see the improvements are adequate. The result using the pre-improvement system got the similar scores in the preliminary test (LED and vibration were relatively low rates). In the test with the post-improvement system, the subject gave the highest score (5) in all devices. While we acquired positive messages from the subject, she also mentioned the difficulty to judge true usefulness of the system. We, therefore, need further experiments for the elderly with different physical conditions to enhance the customization function.

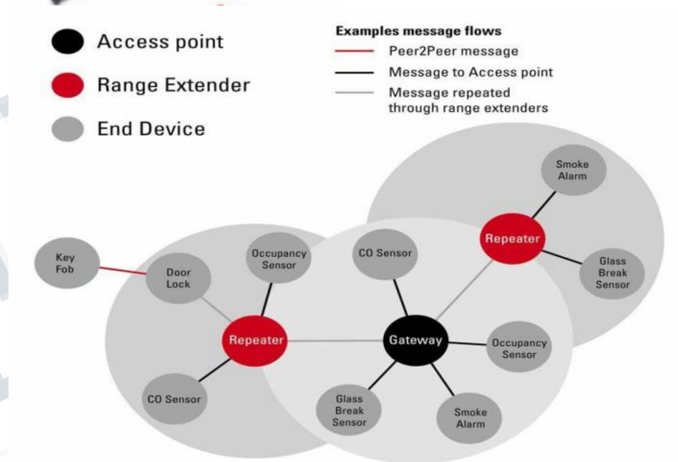
Table 1. Easiness to aware for output devices in the preliminary test.

	A	B	C	D	E	F	G	Ave
LED	1	1	1	1	1	1	1	1
Beep sound	3	5	4	5	5	5	-	4.5
Vibration	3	4	3	5	3	5	5	4.0
Voice	4	4	5	5	5	5	5	4.7

A-G: subject IDs, Ave: average value

Easiness in five ranks (5: good - 3: neutral - 1: bad)

The WBAN is built by using custom developed and available commercially devices for the acquisition of biomedical signals and a wireless development kit (evaluation module eZ430-RF2500 from Texas Instruments) for wireless communication. The eZ430-RF2500 kit uses the low power MSP430F2274 16bit microcontroller (from Texas Instruments), that provides all necessary parts (HW and SW) for the 16-bit MSP430F2274 microcontroller and CC2500 radio transceiver (from Chipcon). The transceiver operates on the 2.4 GHz and provides the support for wireless data transmission with low-power energy. It also provides the support for power supply management, is interfaced to the microcontroller by using the high speed serial interface, and has 25/100m range indoor/outdoor (Fig. 2) Based on the system architecture illustrated in Fig. 1 we have developed a prototype of a WBAN of devices for physiological parameters measurement. For SpO2 and HR measurements we used a commercially available AFE44x0SPO2EVM (from Texas Instruments – Fig. 3). The device is intended for evaluating AFE4400 chip, designed to be used in the development of medical devices for the acquisition and processing of the photoplethysmographic signals.



Respiratory rhythm measurement has been performed by using a commercially available piezoelectric respiratory transducer, PNEUMOTRACE (from UFI), attached around the patient's thorax. It generates an electrical signal in response to the modification in thoracic circumference due to patient respiration (Fig. 4). More details about the wireless device can be found in [7]. For body temperature measurements, we used a specialized temperature sensor (TMP275 from Texas Instruments) directly connected to the eZ430-RF2500 development kit by using the serial interface (Fig. 5). The TMP275 is a 12-bit 220ms temperature sensor capable to measure with 0.5°C accuracy, with a resolution of 0.0625°C. The accuracy of the TMP275 temperature sensor for the range between 35-45°C is below ±0.2°C, making it suitable for medical temperature measurements. More details about the body temperature device can be found in [12].

As wireless network protocol, SimpliciTI supports End Devices in a peer-to-peer network topology, an Access Point as a network coordinator to store and forward the measured temperature to the PC, and Range Extenders used to extend the range of the wireless network.

IV. CONCLUSIONS

We proposed a method for monitoring and detecting risky conditions of heat stroke and effectively warning the occurrences to the elderly through multi-sensory information notification. We implemented the system based on the proposed method and observed some effects in experiments. We would like to further evaluate the system by employing larger number of subjects with various conditions and requirements in the near future.

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