CEILING SENSOR NETWORK FOR SOFT AUTHENTICATION AND PERSON TRACKING USING EQUILIBRIUM LINE

Hidetoshi Nonaka, Shuai Tao, Jun Toyama and Mineichi Kudo

Graduate School of Information Science and Technology, Hokkaido University, Sapporo, Japan

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Abstract: In the previous stage of our research, we have developed a soft authentication system using a ceiling sensor network. Our aim has been to exclude psychological and physical load caused by using strict biometrics, video camera, and so on. We introduced a notion of distributed personality for authentication and tracking of several persons. Through experimental results, we confirmed that the system could keep track of up to 5 persons. However, it has been found the performance is not enough for practical use, and then we have reconstructed and improved the system. In this position paper, we present the design policy, overview of the network system, and the obtained performance.

1 INTRODUCTION

Soft authentication is one of the important elements of pervasive computing. Identifying and tracking of the user are indispensable for appropriate context-aware services. In general, there is a trade-off between the accuracy (and security) and the comfort in the user's authentication. In the case of context-aware services, the latter is more important, considering the user's privacy and psychological load.

In our project, we have developed a soft authentication and tracking system using ceiling sensor network (Hosokawa, 2009). Our aim has been to exclude psychological and physical load caused by using strict biometrics, video camera, and so on. Through experimental results, we confirmed that the system could keep track of up to 5 users with a high probability of correct identification. Now we are examining the combination of various techniques, such as individual ambient temperature (Kanda, 2009), and chairs with pressure sensor array (Yamada, 2009). Complementary integration of weak evidences is suitable for our purpose (Koumoto, 2009).

In the previous ceiling sensor network (Hosokawa, 2009), the sampling rate for 50 sensors has been relatively slow for effective tracking and practical use. We decided to reconstruct and improve the system, especially the network protocol.

In this position paper, we present the design policy, overview of the network system, and the obtained performance.

2 SOFT AUTHENTICATION

Recently, various authentication systems have come into practical use. The authentication factors are classified into three types: the ownership factors, the knowledge factors, and the inference factors. The ownership ones include ID card, cell phone with RF-ID, USB token, etc. The knowledge ones include password, pass phrase, PIN number, birthday, etc. The inference ones are mainly based on biometrics such as fingerprint, DNA, retinal pattern, iris, face, finger vein, speech, and so on. Such systems are effective for maintaining a high level of security and accuracy. On the other hand, for context-aware services in daily life at home or at the office, such a high level of security is not needed. The important feature required for such purpose is that there is no mental pressure, physical load, or invasions of privacy.

We call the traditional authentication for security "hard authentication," and we call the authentication for personalized services "soft authentication." The differences between them are summarized in Table 1.

Table 1: Difference between "soft authentication" and "hard authentication" (Hosokawa, 2009).

Item	Soft authentication	Hard authentication
Goal	Personalized service	Security
Process/Device	Unnoticeable	Noticeable
Population size	Small (2-20)	Large (10-100,000)
Place to use	Home or office, anywhere in a room	Building or security-controlled room, fixed place
Level of accuracy	Low	(Very) High
Strength of evidence	Weak (behavioural evidence, gait, etc.)	Strong (iris, DNA, finger vein, etc.)
User's cooperation	Unnecessary	Necessary
Psychological barrier	Weak/None	String
Sensors	Infrared, pressure, etc.	Camera, special devices
Necessary environment	No special condition, day and night, movable obstacles	Controlled condition, no obstacles
Establishment cost	Low and flexible	High and fixed
Stolen damage	Low	Crucial

In order to combine authentication and person tracking, video camera has been used in many studies. It is used for abnormality detection of single residents (Aviv, 1997), (Sawai, 2004). Multiple cameras and multiple omnidirectional cameras are also utilized for authentication and person tracking systems (Sogo, 2004), (Zhao, 2004), (Hightower, 2001), (Khan, 2001), (Yam, 2003). However, using a camera causes psychological load and invasion of privacy.

Pressure sensors have been used for the same purpose (Murakita, 2004), or auxiliary data for other methods (Ito, 2004), (Want, 1992), (Okuda, 2005). However, in general, large number of sensors is necessary for person tracking (more than 25 sensors per 1 m^2).

Pyroelectric infrared sensors have been also adopted for soft authentication and person tracking. In some of them, wireless ID badges are used for the person identification (Want, 1992), (Schulz, 2003), but some people would hesitate to wear such sensing devices in a room. Others are the systems for single person (Okuda, 2005). There is a series of studies using pyroelectric infrared sensors and Fresnel lens array (Hao, 2006), (Fang, 2006), (Fang, 2007), (Shanker, 2006), but they are the tracking systems for single person, and the resolution is not sufficient to specify the person's position in a room.

In the early stage of our study, we constructed a ceiling sensor network using pyroelectric infrared sensors (Hosokawa, 2005). We tried to use a Bayesian network for prediction of the user's current position. However, we noticed that it was difficult to embed into the algorithm several kinds of knowledge about the difference in trajectories and the difference in layout of obstacles. To learn the probability of possible movements depending on the locations, many training data are necessary.

Therefore we decided to use a simpler method (Hosokawa, 2009).

We introduced a notion of distributed personality (Hosokawa, 2009). In principle, two persons cannot be distinguished when they meet at one place. When this situation occurs, we divide their personalities. For example, when persons A and B get together at the same place, we replace them with two virtual persons who have multiple personalities consisting of a half of A and a half of B. By this division of personality, the total number of persons is kept as two. In this way, we have ambiguity but can keep tracking them. The probability of each personality is updated incrementally according to various weak evidences, such as walking speed, trajectory of movement, sitting down specific chair, and so on.

Through experimental results, we confirmed that the system could keep track of up to five persons with a high probability, however, precise identification was difficult and more than six persons could not be authenticated. We found the main defect of our system was the sampling rate from the sensor nodes, which was 2 Hz when all of the 50 sensors are activated. Therefore, we decided to reconstruct and improve the system, especially the network protocol.

3 REQUIREMENTS

In our system, up to 128 pyroelectric infrared sensors are attached on the ceiling. They are interconnected by a sensor network. By gathering the data from sensors, authentication and tracking of users are achieved. The scope of our system extends to not only home, office, laboratory, but also nursing home, elder-care facility, assisted-living condominium, welfare hospital, and child-care

institution. Consequently, following conditions are required:

1. *Low noise*. Medical electronic instruments such as artificial pacemakers might be used in the room. Influence of EMI (electromagnetic interference) should be avoided. Wireless network is not preferable, and the wire should be shielded-cable or at least balanced-line.

2. *Simple and easy installation and wiring*. The positions of sensor units should be changed along with the rearrangement of the furniture. Light-weight wire is preferable.

According to the requirements mentioned above, we adopted a wired network with balanced equilibrium line (ANSI EIA-422).

4 SPECIFICATIONS

4.1 Sensor Network Topology

Figure 1 shows the physical topology of the sensor network. There are 8 segments, and each segment composes a bus network. In the figure, "T" stands for the terminator, which can be set by jumper plug. The bus line can be branched as is shown in the figure (the lower left segment). The number of sensor nodes is up to 16 for each segment, and then the total number of sensor nodes is 128.

Figure 2 illustrates the logical topology of each segment. Sensor nodes and the controller node are interconnected with balanced equilibrium line (EIA-422). The controller node plays the role of bus master, because only one node is permitted to transmit packets at each moment.
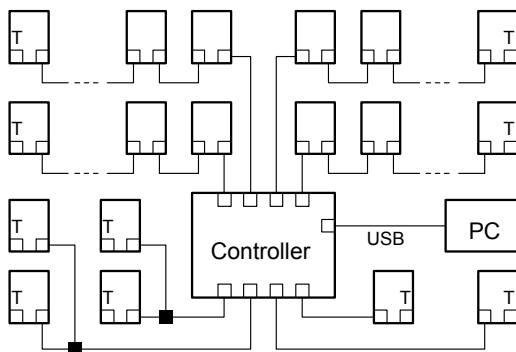

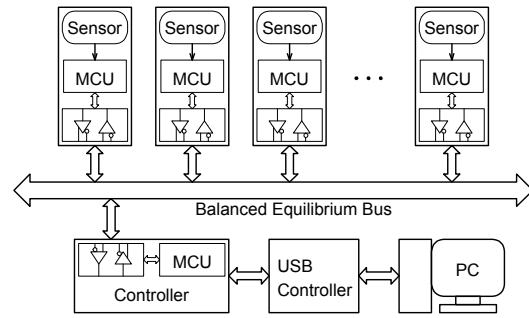Figure 1: Physical topology of the sensor network.

Figure 2: Logical topology of the sensor network of each segment.

4.2 Sensor Node

Passive infrared sensor is also called "pyroelectric infrared sensor" or "infrared motion sensor". It detects change in the motion of a person or an object with a different temperature from the ambient temperature. It has been used for many applications, such as automatic security lights, burglar alarms, visitor acknowledgement, light switch control and door opener.

We have used NaPiOn (AMN11111, Panasonic Denko Co. Ltd.) as the sensor module. It includes 16 lenses for gathering infrared radiation to 4 quadrants on the surface of the pyroelectric infrared detector. Then, 64 detection zones are formed in front of the sensor module. The detection area is up to 7.42 m × 5.66 m on a plane at a distance of 2.5 m from the sensor. In our system, the detection area of each sensor was narrowed by a hand-made cylindrical lens hood. Specifications of the sensor module are shown in Table 2.

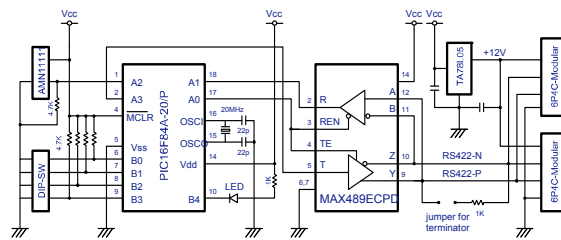Figure 3 shows the circuit diagram of sensor node attached on the ceiling.

Figure 3: Circuit diagram of sensor node.

Table 2: Detection performance of the sensor module.

Rated detection distance	5 m (max)
Horizontal detection range	100°
Vertical detection range	82°
Detection zone	64 zones
Movement speed	0.5 m/s (min) 1.5 m/s (max)
Object = human body	H 700 mm × W 250 mm

4.3   Controller Node

The controller consists of MCU (PIC16F873), USB controller (FT232BM), and eight RS-422 (EIA-422) transceivers (MAX489), which correspond to 8 segments. Some of these devices are slightly obsolete, but obtainable by low prices at such as junk shop. Figure 4 illustrates the circuit diagram of the controller node. In the diagram, only the signal lines are indicated.
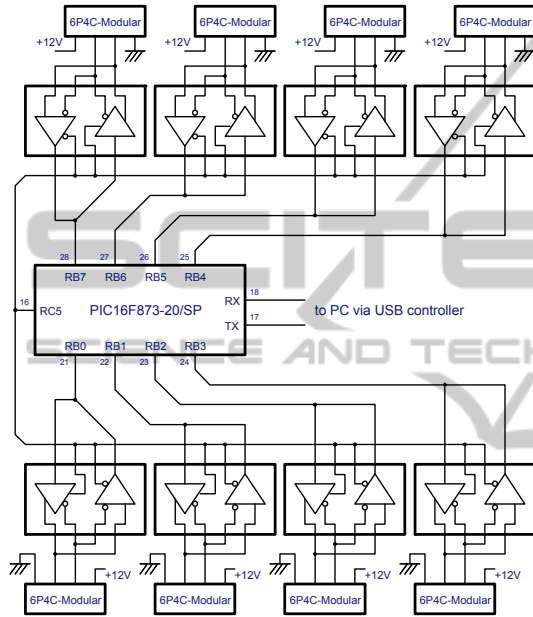

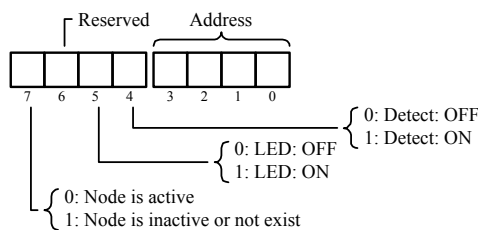Figure 4: Circuit diagram of controller node.

Figure 5: The format of packet framing.

Figure 6: Interconnection of sensor nodes with cables.

4.4   Cables for Equilibrium-lines

Figure 6 shows the physical connection of sensor nodes. We adopted general ready-made phone cable with modular connectors 6P4C (RJ14) without shield. The reason is easiness of installation and wiring. This type of cable is easily obtainable and light enough to wiring only by connecting to the plugs and leaving the cable drooping. It is expected that EMI noise is suppressed by using equilibrium-line, but further test is necessary.

4.5   Packet

The request from the controller node and the answer from the sensor nodes are transmitted by packets. The packet consists of only 8 bits (Figure 5). The least significant 4 bits contain the address of the sensor node, which is set using the dip switch beforehand. If a node detects human motion, Bit 4 is set when the node transmits the answer packet to the controller node. Bit 5 toggles the flag of LED on the sensor node, which blinks along with the human motion. Bit 7 is usually unset. If time-out occurs, the controller sets this bit internally.

4.6   Timing of Transmission

Data rate is suppressed to 250 kbps because of the EMI matter (Figure 7). It takes 36 us to transfer each packet with a start bit. In order to switch the tri-state buffer of the equilibrium line, additional 8 us is required. Consequently, time required to collect the sensor data is within 90 us per node. If the number of nodes is 128, the total time is about 12 ms, and the sampling rate is up to 80 Hz.

Table 3: Command set of the controller.

| Command	Function
0x01	The controller is reset and all the bits of 8 mask registers corresponding to the 8 segments are set. One byte is returned only as acknowledge whose value is 0x00.
0x02	The controller is reset and all the bits of 8 mask registers corresponding to the 8 segments are set. One byte is returned only as acknowledge whose value is 0x00.
0x03	The controller sends the "LED ON" commands to all the sensor nodes. One byte is returned only for acknowledge whose value is 0x00.
0x04	The controller sends the "LED OFF" commands to all the sensor nodes. One byte is returned only for acknowledge whose value is 0x00.
0x05	The controller scans the sensor nodes without acknowledge.
0x06	8 words (16 bytes) of mask registers are returned.
0x07	8 words (16 bytes) of sensor data are returned.
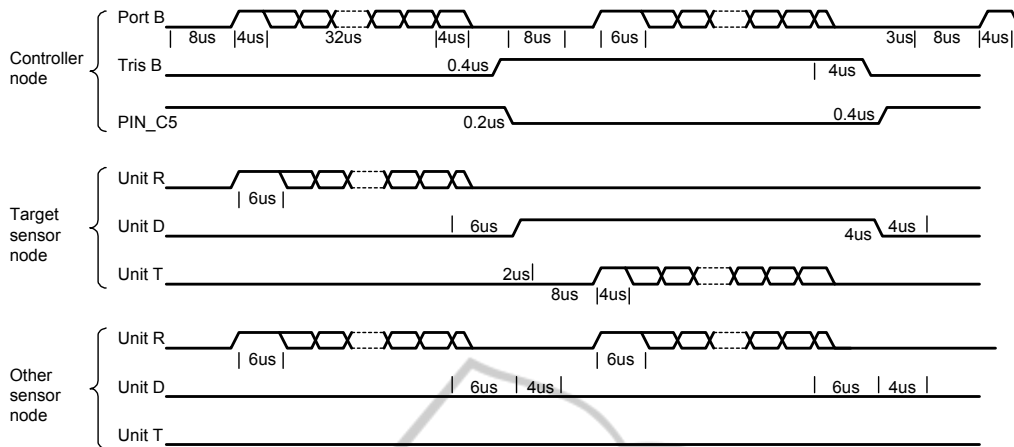
Figure 7: Waveforms of packet transmission.

4.7 Gathering the Sensor Data

All the data of 128 nodes in the network can be gathered within 12 ms, but all the addresses are not necessarily used. The number of nodes may be less than 128, and there are possibilities that some nodes get out of order or a node is detached while operating. We adopted a time-out checking. The time-out period is set to 50 us. When a time-out occurs, the corresponding bit of the 16 bit mask register for the specific segment is unset, and after that, the request to the node is skipped. On the other hand, each mask bit is set compulsorily once every 16 times. It allows the hot-plugging of sensor nodes without shutting down the network. A newly plugged node can be detected within 200 ms. Table 3 shows the command set of the controller node.

5 DISCUSSION

If electromagnetic interference can be disregarded, the wireless sensor network seems to be applicable. However, usually it is used for discrete data acquisition, for example in several samples per second with power saving mode, because of the limitation of power supply. There have been many researches, for example, (Bandyopadhyay, 2004), (Liu, 2006), (Jafari, 2009), and so on. To our purpose, much higher rate sampling of 80 Hz from up to 128 nodes are necessary. It means 80×128=10240 samples per second, thus it is difficult to make use of wireless network.

As is mentioned in the introduction, we are now examining the integration of various kinds of weak evidence of soft authentication and person tracking. Wireless sensor network will be effectively used for gathering and processing such heterogeneous sensor data. Also, it will be suitable for tracking inter-room or ambulant sensor nodes in nursing home, child-care institution, and so on.

There have been following items to be studied empirically in current solution of our system:

1. The performance of the authentication and the tracking increase with the data rate.
2. EMI increases with the data rate.
3. Using shielded cable reduces EMI.
4. Using shielded cable diminishes the easiness of wiring and installation.

It is necessary to examine above items experimentally and quantitatively as the near future work.

6 CONCLUSIONS

We have presented an improved ceiling sensor network for soft authentication and person tracking. Sampling rate of 80 Hz for up to 128 nodes using 250 kbps equilibrium line have been realized. The total sampling rate is up to 10k samples per sec. Now, the development and improvement of the soft authentication system using our network system is in progress. The experimental evaluation of the performance of tracking persons is also needed.

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