A person recognition system by tracking the behavior using Pyroelectric sensors

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Abstract

Having information about a person’s location is essential for the ubiquitous network environments of the future. It can be monitored using RFID and GPS, but these devices have to be carried. On the other hand, using monitoring cameras as image recognition devices is disagreeable to many people.

We propose a person recognition system by tracking the behavior using pyroelectric sensors. This sensor is inexpensive, but a single device can not identify a specific individual. However, when such devices are connected to a network and to an authentication system, we can trace a person’s activities using the collected sensor data. Then we can identify the person by utilizing authenticated information. The operation of the proposed system has been investigated by making a prototype. A person’s direction of movement and speed are analyzed by the network sensor signal. The system can then analyze the behavior of the person and display it on a monitor in real time.
1. Introduction

Having information about a person’s location is essential for the ubiquitous network environments of the future[1~4]. It can be monitored using RFID (Radio Frequency Identification) and GPS (Global Positioning System), but these devices have to be carried. For instance, when a RFID tag is attached to a person, that person’s position can be established from the response to the RFID transceiver signal. A mobile phone equipped with GPS can identify a person’s location remotely. On the other hand, while monitoring cameras do not have to be carried, they are disagreeable to many people.

Pyroelectric sensors[5], which are widely used in applications such as automatically turning on entrance lights and opening doors, can detect the presence of people by monitoring the thermal change of the environment. Thus, they aren’t disagreeable and do not have to be carried. However, this sensor used alone can detect only the presence of a person. However, when several of these devices are connected in a network, we can monitor human behavior. Moreover, if we obtain authenticated information, we can use these devices to recognize specific individuals.

We propose a person recognition system by tracking the behavior using pyroelectric sensors. This system can monitor human activity using the data obtained from many pyroelectric sensors and, if it is connected to authentication system, it can be used to identify a person.

First, we want to show an overview of our system. Next, we describe person recognition system architecture. The operation of the proposed system has been investigated by making a prototype. A person’s direction of movement and speed are analyzed by the network sensor signal.
2. Sensor network

This figure shows our proposed sensor network. We want to employ our system in an office or a house. The sensor network consists of sensors, sensor nodes and a server. Sensor nodes manage various kinds of sensors and convert the sensors’ signals to simplified data. This data is then sent to the server via a LAN. The server analyzes the sensor signal, recognizes the person’s behavior and predicts the person’s next action. Based on this prediction, it controls electrical appliances, such as lights, air conditioners, cameras and so on. For example, if the person wants to move to another room in the office, this system is aware of the person’s behavior and turns on the light in that room.

Unlike RFID, our system does not have a sensing device that has to be carried, neither does it use cameras. Instead, pyroelectric sensors and photoelectric sensors are used. A Pyroelectric sensor detects the thermal change produced by a person passing through the detection area. A photoelectric sensor detects when a laser beam is blocked by an object. These sensors can not identify a specific person using only one sensor. However, these devices can be connected in a network. The system analyzes the sensor’s signal and monitors human behavior. If this system is connected to an authentication device, it can identify the person. Our university has a fingerprint authentication device at the entrance to each laboratory. By connecting these devices, we can identify the specific person through their behavior. We use Ethernet for the sensor signal transmission network because we can easily connect sensors to the network everywhere and its construction is flexible. We could also use wireless networks such as Bluetooth, Zigbee.
3. Person Recognition System Architecture

This slide and the following slide show the architecture of our person recognition system. The system consists of a management section and sensor node section. This slide shows the management section. The following slide shows the sensor node section. The two sections communicate with each other via a LAN. As we intend to employ this system in an office or a house, the sensors are distributed over a wide area. However, LAN is available everywhere and is straightforward to rearrange. The management section is divided into three layers, namely, the node connection and management layer, the sensor-type management layer, and the human behavior management layer.

3.1 Node Connection & Management Layer

The main function of this layer is to establish a connection with the sensor nodes, to manage the nodes, and to synchronize the clocks. The node management function manages the connected sensor nodes. An Ethernet or wireless network connects the server and each sensor node with the TCP. If the network is congested, the data packets from the sensor nodes will be delayed. Therefore, the sensor node must have the correct time and the designated sampled time of the data packet. The clock synchronization function supplies the correct time to every sensor node.

3.2 Sensor Type Management Layer

This layer processes the sensor data received from the NIC (Network Interface Card) to the detected data. The data received from the sensor node will depend on the sensor type, since pyroelectric sensors and photoelectric sensors have different output waveforms. Therefore, this layer has to convert the received data into the detection data which indicates whether a person is present or not in the detection area. Moreover, this layer checks whether the signal is normal or abnormal. For instance, the detection speed of Pyroelectric sensors is limited. If the sensor sends data at an abnormal speed, this layer ignores that data. For the purpose of this calculation, this layer has sensor specific data such as the sensor type, the detection region, the detection speed, and so on.
3.3 Human behavior management

This layer identifies a person’s behavior using the signals from the sensor nodes and analyzes a person’s behavior in order to identify the person. The direction and speed of the person’s movement are calculated from the processed sensor data using the sensor location data. The calculated results are shown on the display. Utilizing other authenticated data, this system can identify a person. This layer contains data such as the sensors’ locations, office building map and so on.

This figure also shows an example of the management system display. Eight sensors are positioned in a T intersection, and are denoted by A~H. The dashed-line circles represent the sensor detection areas. The foot mark icon represents someone moving in this area.

4. Sensor node section

The sensor node section manages the sensors. The sensor node converts the analogue signal of the sensor to a digital signal. The digital signals are converted to Ethernet frame format when we use an Ethernet. Moreover, this section has a clock synchronization function. The clock synchronization function gives the correct time received from the management section.

The sensor node has an Ethernet interface and a PIC (Peripheral Interface Controller) for processing the sensor data.

4.1 Connection establishment

The connection establishment procedure is as follows. First, the management section starts establishes a connection with the registered sensor nodes. Next, the management section sends a clock synchronization packet to every sensor node. After this procedure, the sensor nodes commence to transfer the sensor data. It is sufficient to synchronize the clocks once a day.
5. Sensor node and Processing

The figure on the left shows the pyroelectric sensor[5] detection area and the output waveform. The output of this sensor is digitized and produces several pulses when one person passes through the sensor detection area. This device has a turn-on delay and turn-off delay of several hundred milliseconds.

We decided to use a LAN, such as Ethernet, Bluetooth, Zigbee and so on, as the sensor signal transmission network. When we use a wireless system, we have to decrease the transmitted data capacity because we want to power the sensor node using a battery. Moreover, the processing capacity of the sensor node is limited. Thus, the transmitted data has to be reduced using a simple method. The sensor node extracts the changing point from the time of the sensor data to decrease the data capacity. The sensor node sends this data to the management section. The data is in ON/OFF states, ON/OFF time. Then the management section reconstructs the signal using only this data.

5.1 Packet Format

The transmitted data packet consists of the sensor number, ON/OFF state, ON/OFF time and line feed code. The sensor number is a unique sensor number and is assigned 1 byte. The ON/OFF state is the extracted signal state and is assigned 1 byte. The ON/OFF time is the sensor state changing time and is assigned 4 bytes. The linefeed code is assigned 1 byte. The total packet length is 7 bytes. This data is sent to the management section by the Ethernet frame in the case of an Ethernet.

6. Human tracking

6.1 Pyroelectric Sensor Characteristics

We have investigated the characteristics of pyroelectric sensors. The following slide shows an example of pyroelectric sensors installed in a house and the output waveforms. The sensors are located on the ceiling and arranged along the walking area. The detection area is a conical shape with the apex on the ceiling. The space between sensors is an important factor for the accuracy of the position determination.
6.2 Moving speed calculation algorithm

The person’s location is calculated from their moving speed. The first pulse from a sensor indicates that someone has entered the detection area. We can trace this pulse from sensor to sensor. If we receive first pulse from another sensor, we can calculate the person’s speed from the time difference between the two pulses and the distance between the two sensors. If the calculated speed lies within the detectable speed of the sensor used, we conclude that the human has moved from the detection area of the first sensor to that of the second sensor. If the calculated speed does not lie within the detectable speed of the sensor, we conclude that the person is still within the area of the first sensor. However, if the detection area of the two areas overlap, this algorithm often miscalculates the person’s behavior.

6.3 Experimental results

The walking speeds of a person were measured using pyroelectric sensors. The person walks through the walking area at a constant speed. The calculated result from the sensor data is shown in the graph on the right. The data fits to the actual walking speed well with the exception of a few abnormal data points.

The following results were found about the space between sensors. It is difficult to identify a person’s movement in real time when the sensors are installed in a narrow space which necessitates overlapping of the sensor detection areas. This is because the pyroelectric sensor used has a long turn-on and turn-off delay. However, it is straightforward to measure a persons movement when the detection areas of the sensors are not overlapped. Therefore, we install the sensors so that their detection areas do not overlap.

The human behavior tracking results are displayed on a monitor as shown in the inset of the person recognition system architecture figure.
Summary

- Installed a sensor network in our laboratory.
- Created a prototype person recognition system.
- Displayed a visual person moving on a monitor.

Current difficulty
- Detecting two & more people simultaneously is problematic.

Future plans
- Improving the human behavior algorithm
- Increase the detection accuracy by combining with another recognition system.
- Use other communication devices (e.g. Zigbee, Bluetooth, etc.)

7. Summary

We have demonstrated a prototype of a personal recognition system employing pyroelectric sensors. The system can analyze a person’s direction of movement and speed using data from many pyroelectric sensors. Then, it is able to detect the person’s behavior which is displayed on a monitor.

Our university employs a fingerprint authentication system which intend to use to combine human behavior data with authentication data to identify the person.

This human behavior algorithm has problems distinguishing when more than two people are within the sensor detection area. Therefore, to overcome this problem we intend to improve the algorithm or use another kind of sensor. We will also use a wireless network as the sensor data transmission network such as Zigbee or Bluetooth.

References
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