A WEARABLE PIR SENSOR SYSTEM FOR THERMAL SITUATION PERCEPTION

Qi Hao, Rui Ma, and Zhigang Zhu
The University of Alabama; The City College of New York
qh@eng.ua.edu; rma3@crimson.ua.edu; zhu@cs.ccny.cuny.edu

1. INTRODUCTION

This project aims to develop a low-cost wearable sensor system that can help visually challenged people to perceive the surrounding situation consisting of human and non-human thermal sources. Video camera or laser scanner based technologies have been proposed and developed to help visually impaired people understand their environments as well as avoid obstacle. However, these devices usually are limited by (1) illumination conditions, (2) hardware cost, (3) large data throughput, (4) high computational complexity, and (5) high power consumption. On the other hand, low-data-through sensors such as thermal, acoustic, ultrasound sensors have their unique strengths in acquiring environmental/situational information. Ideally, an integrated multi-modality sensor system can meet the various conflicting requirements for practical applications. In many cases, the information about the surrounding human subjects can help the visually impaired people to adapt themselves well to the situation.

In this paper, we propose a wearable PIR thermal sensor system that can help users to perceive the surrounding environment from a thermal perspective. Today, PIR sensors have been widely installed in many buildings for human motion detection. The advantages of using PIR sensors include (1) low hardware cost, (2) low power consumption, (3) low data throughput, and (4) protection of privacy. In our previous work, we have developed a wireless PIR sensor network technology that can track and recognize multiple moving human subjects, as well as understand their activities. However, the PIR sensor is a kind of motion sensor: it can detect moving thermal targets only. Therefore, a wearable PIR sensor system is capable of detecting/identifying static thermal sources by utilizing the random movements of PIR sensors worn on users' arms. Each sensing unit contains two PIR sensors. The sensory signal is a two-bit data stream. The signal features are chosen from an orthogonal 3-D parameter space. The initial experiment results show (1) different scenarios of static multi-human subjects can be identified; and (2) human/non-human thermal sources can be distinguished.

2. METHODOLOGY

2.1. Sampling Scheme Design

The sensor node's sampling scheme design is based on binary geometric sensing principles. When the sensory signals are converted into binary forms, only two types of target information are preserved: geometry and motion. Each sensor node contains two PIR sensors, modulated by two Fresnel lens array. The resultant sampling structure consists of two sets of non-overlapped radial lines.

2.2. Feature Selection

For a 2-bit PIR sensory data stream, three orthogonal statistical parameters can be chosen: spatial correlation θ_{12}, temporal correlation θ, and marginal density η. Given a joint distribution of a 2-D binary sequence, $[P_{00}, P_{01}, P_{10}, P_{11}]$, its orthogonal coordinates are the marginal densities, $P_{01}+P_{11}$ and $P_{10}+P_{11}$, and the correlation $\log(P_{00}P_{11}/P_{01}P_{10})$. Marginal densities can be derived from the intersection probabilities between static thermal sources and moving sampling structures. The correlation can be either spatial or temporal: between two sensors' measurements or among the same sensor's sequential measurements. The temporal correlation is partly related to the moving trajectories of sampling structures; the spatial correlation is related to the spatial distribution of thermal source; the marginal density is related to the size of thermal sources. As the moving trajectories of users' arms are unknown, multiple random movements have to be used to average this unknown factor out.

2.3. Classification

A Gaussian mixture model (GMM) is used to classify the different types of features. The dataset is divided into two parts: training and testing. The training dataset is used to train the GMM; the testing dataset is labeled after likelihood estimation.

3. EXPERIMENTS

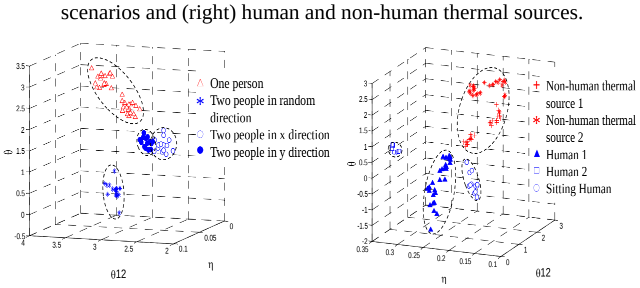
3.1. Dataset

We tested the wearable PIR sensor system with three different indoor scenarios of static multiple humans: (1) one person, (2) two persons standing randomly, and (3) two people blocking each other within one sensor FOV. We also tested the sensor system with standing/sitting human subjects and non-human thermal sources, e.g., computers and large screen LCD display.

3.2. Results

Fig. 1(a) shows the classification results of three indoor scenarios using a wearable PIR sensor node. **Fig. 1**(b) shows the classification results of human and non-human thermal sources.

Figure 1. Feature distributions of (left) different static multi-human scenarios and (right) human and non-human thermal sources.



It can be seen that through moving the wearable PIR sensor system, (1) different multi-human scenarios can be identified and (2) human and non-human thermal sources can be distinguished. More experiments will be performed to further verify the performance of the wearable PIR sensor system.

4. CONCLUSION

The proposed wearable PIR sensor system can identify different scenarios of static multi-human subjects and distinguish between human and non-human thermal sources, which would assist visually challenged users to understand their situations from a thermal perspective and hence to adjust their behavior accordingly.

This work is partly supported by NSF CNS #1059212.