Zone-based Temperature Control Using Sensor Nodes and Actuators

Ho-Kyeong Ra, Myunggyu Won, and Sang Hyuk Son*
Daegu Gyeongbuk Institute of Science and Technology

Abstract : Cyber-Physical Systems (CPS) are expected to play a major role in the design and deployment of future systems, allowing interconnectivity between multiple computing units to work together. By having multiple communication enabled sensor motes, future environment can be enriched with useful data to actuation units. Among CPS studies, HVAC is one domain that can be improved to support this connectivity as well as bring better usability, reliability, and functionality to the system itself. This enhancement is important especially because room temperature control can strongly affect quality of life in home, workplace, or any environment that have temperature requirements. The main goals of HVAC system is to maintain a comfortable temperature for occupants, healthy temperature for patients, and reliable temperature for substances in temperature crucial environments. However, areas near windows, doors, or electronic equipment tend to be cooler or warmer than other places in the room. This may result discomfort to the occupant and even affect safety issues in facilities that require strict restrictions on room temperature, such as healthcare facilities and food storage buildings. In this paper, we take this into account and introduce a way to map temperature in a 3D scale of a room, which is essential for providing a uniformed distribution of room temperature.

Keywords : room temperature control; HVAC; air conditioning

I. Introduction

Few of primary goals of HVAC system is to maintain a comfortable temperature for occupants, a healthy temperature for patients, and a reliable temperature in critical areas. For example, HVAC can control the temperature in a room for people who are sensitive to cold or hot temperature such as people with asthma. Too low or high temperature can aggravate asthma symptoms. Moreover, environments such as healthcare facilities and food storage buildings always need to maintain a set temperature for the health of patients or preservation of food.

To achieve these goals, having a uniformed distribution of the temperature is crucial for the temperature in all areas in a room to be equally satisfactory. However, having a uniformed distribution of the temperature over time is a challenging task especially when there are different actuation sources such as large sized window and existing electronic equipment within a room. In solving this issue, we need to consider how to deploy the sensors and divide zones, and where to locate sensors and direct wind blades. Most, importantly, we need to first develop a systematic thermal model to have a strong understanding of the temperature behavior of a

* Corresponding Author
Ho-Kyeong Ra, Myunggyu Won, and Sang Hyuk Son : DGIST
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room. With a goal of providing a uniformed distribution of the room temperature, in this work, we first survey few of recent studies that relate to our work and deploy sensors that can map temperature data in a 3D scale to observe temperature changes in different zones of a room.

Ⅱ. Related Works

In order to model room temperature in a 3D scale, collecting temperature itself is a huge challenge. Currently available tools recommend deploying multiple sensors or using thermal imaging to view the temperature over the wall. Of the few studies that concentrates on collecting room temperature, RACNet [1] gathers data through 52 Genomotes inside a data center facility. This study shows that wiring sensors all around the room is unpleasant due to the fact that the data center already lacks large space. Additionally, they state that wireless communication is unreliable due to tall metallic server racks. RACNet overcomes this issue by presenting Wireless Reliable Acquisition Protocol (WRAP), which is a protocol that adaptably distributes nodes among multiple channels to lower the data latency.

In addition to deploying sensor to measure temperature of a room in a 3D scale, researches have also successfully modeled rooms into a mathematic equations that considers thermal conductivity, heat capacity, and air density. Thermal modeling, which is a mathematical equation that describes how temperature is flowing around a room, has been computed by using Euler equations [2] in fluid dynamics. For the heat equation [3], which recommends the best location to place a temperature sensing unit, simulation is used to compute heat transfer in sub-volumes. Many of these studies show that using multiple sensors deployed to a wall of a single room can result varied physical temperature reading for each sub-volumes [4-6], which needs to be considering when using multiple sensors. actions, five supervised classifiers are used to recognize five common abusive actions: hitting, kicking, slapping.

Fig. 1. Sesnor deployed in open space

shaking, and pushing. Each of these are binary classifiers recognizing an action from a window of skeleton frames obtained from Kinect. Frames from Kinect are first converted into feature vectors which are invariant to relative position and orientation of the body, and speed of an action. The feature vectors are used to train support vector machine (SVM) classifiers.

Ⅲ. 3D Temperature Mapping

To map a 3D temperature of a room, we deployed multiple sensors in a room by using a total of 54 TelosB motes in the room that has a ceiling type heating and cooling unit. One of the 54 motes is connected to the Zotac PC, which acts as a base station for temperature collection. The TelosB motes are all equipped with TSR, PAR photodiodes, and SHT11 (humidity and temperature) sensors. For this study, we only utilize the SHT11, which has a temperature sensing range of -40 to 125 degress Celsius. Referred from RACNET, we need to consider data drops for a steady communication. With low data drop rate, 54 nodes are connected to the base station with one hop. For every 5 seconds, each sensing node reports back to the base station with information such as ID, temperature, and battery level. Battery power level is important because low battery level can result the SHT11 sensor samples to overflow. To enable decimal temperature reading, additional library is implemented to the TinyOS of the TelosB.

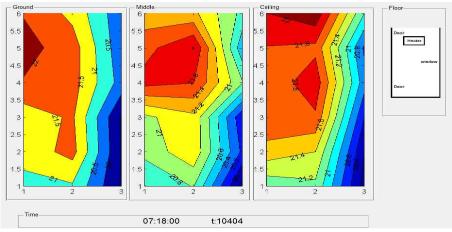

Fig. 2. Visual 3D room temperature with heating unit turned on

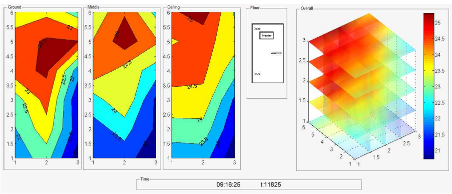

Fig. 3. Visual 3D room temperature with heating unit turned on

As shown in Fig. 1, 3 motes are place in each vertical zones, and a total of 18 motes are place in each horizontal locations that are 1 meter apart. Note that the sensor motes in the middle of the air are all hanged by wire. The sensor drift phenomenon is avoided due to the weak output from the ac unit. The GUI is implemented using Matlab to view the temperature over several hours in a 3D scale. Collected samples are in a single array that 3D mapping is necessary. The 3D mapping of the temperature is displayed on a GUI, as shown on Fig. 2. The map shows that the temperature near the window is colder than the center or near the door of the room. According to the building operator, the desired room temperature is set to 24 degrees Celsius. However, temperature difference from cold to warm place varies by 4.5 degrees Celsius. As shown in Fig. 3, when the heating and cooling is not operating, the room temperature is about even with temperature variance of 2 degrees Celsius.

IV. Conclusion

This is work, we aim on providing uniformly distributed room temperature, which is essential to have a satisfactory temperature dispersed all around a room, not only in a particular location. Having an uneven temperature will not only produce discomfort to the occupant due to not feeling as warm or cool as a person intend to be, but also affect safety issues in facilities that require strict restrictions on room temperature. As a first step in accomplishing the goal of providing a uniformed distribution of the room temperature, in this work, we survey few of recent studies that relate to our work and deploy sensors that can map temperature data in a 3D scale to observe temperature changes in different zones of a room. As of future work, with the map of a room temperature that we gathered through this work, we want to model the temperature to find out how to divide zones and where to locate sensors and direct wind blades to ultimately provide a uniformly distributed room temperature.

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