Demo Abstract: TOSS: Thermal Occupancy Sensing System

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ABSTRACT

We propose a system that can accurately determine the occupancy of zones within a building. As an easily deployable sensor system, TOSS provides detailed information about a zone's occupancy to a building's energy management system in order to control the Heating, Ventilation, Air Conditioning, (HVAC) and lighting behavior for specific zones within the building. This incurs a significant benefit, as building zones that are not fully occupied do not require 100% use of the HVAC or lighting systems.

Categories and Subject Descriptors

J.7 [**Computers In Other Systems**]: Command & control; C.3 [**Special-Purpose and Application-Based Application Systems**]: Real-time and embedded systems

General Terms

Experimentation, Measurement, Performance

Keywords

Occupancy sensing, Occupancy-based HVAC

1. INTRODUCTION

To increase energy efficiency in buildings, many advancements have been made. The invention and production of building materials harnessing passive solar technologies along with increasingly efficient HVAC systems have minimized thermal leakage and improved indoor comfort. However, these improvements ignore another large problem; energy that is needlessly consumed within the buildings themselves.

In most buildings, HVAC and lighting systems condition large zones as one unit. Lacking real time occupancy data, zones are conditioned assuming maximum rather than actual occupancy. As HVAC and lighting systems are responsible for up to 60% of all energy consumption in large buildings [1], there is much incentive to reduce this unnecessary energy usage.

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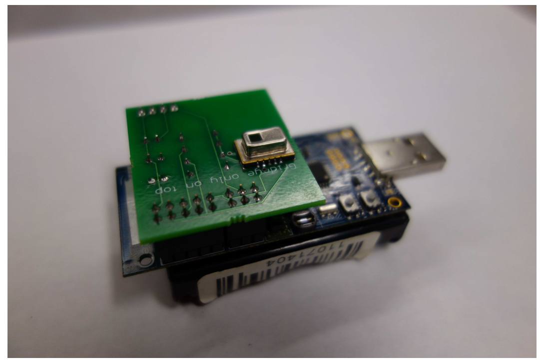

Figure 1: Tmote sky with GridEye

Several technologies have been exploited to detect zone occupancy. These include passive infrared sensors (PIR) [4] [8], carbon dioxide detection [2], and optical camera systems [5]. However, each have shortcomings that prevent them from reliably detecting human occupancy.

This has motivated the creation of TOSS, a distributed wireless sensor system that can provide an accurate quantification of human occupancy within a designated zone. TOSS allows the optimization of energy usage on a per-zone level. By increasing the knowledge of zone energy requirements based on occupancy data, the quality of building control and efficiency as a whole is increased.

2. TOSS

TOSS is a distributed system of independently operating nodes placed throughout a building to provide occupancy coverage. One or more units monitor zones with location-specific HVAC and lighting controls, which can be remotely adjusted. Based on current detected occupancy, TOSS is able to control HVAC and lighting actuators for the zone.

2.1 Node Characteristics

Each node in the TOSS system is built on the tmote sky, a low-power, low-cost module used as the backbone of many wireless sensor networks. With its sensor interface and 2.4GHz wireless transceiver, the mote allows TOSS to quickly perform data transfers across the network. TOSS has integrated two additional sensors to the tmote sky's base platform to determine occupancy. First and most critical is the GridEye (Figure 1), an array of thermal sensors oriented in an 8x8 grid. These modules scan their sensing area and collect data later used to detect any measurable changes in temperature from a dynamic "background" temperature.

The secondary sensor used is a Passive Infrared (PIR) sensor. Although PIR has shown some usefulness in determining occupancy, it has proven to be limited in its capabilities. For one, it can only produce a binary indication to a room's occupancy, rather than a true occupancy "count". This severely impacts its ability to be used in building control. However, its low power consumption and binary occupancy indication make the PIR sensor useful for activating the GridEye from a standby state to take an occupancy count when movement is detected.

2.2 System Operation

A number of steps are taken to detect occupancy from GridEye readings. To initialize, each node constantly takes "background" readings and noise measurements during long periods of inactivity. Subsequent grid readings are compared to the background using background subtraction. Constituent values exceeding three standard deviations from average causes the corresponding component to be marked as "active". The connected components [6] is run over the active component matrix. A feature vector is then created using the total number of active quadrants, total number of connected components, and the largest component. Lastly, this feature vector is analysed against existing training data using K-Nearest Neighbors, resulting in occupancy count within the zone.

3. DEMONSTRATION

The operational capabilities of TOSS will be demonstrated by providing a sample environment for spectators to occupy. This occupancy will be presented to viewers using a user interface displayed on a screen as well as through a simplified representation of a building's HVAC and lighting systems. Users will be able to access this data with mobile applications running on phones (iOS and Android).

The sample environment will take the form of a simple structure shaped and sized similarly to a typical office/cubicle space. Overhead will be one TOSS unit monitoring the area below. Each quadrant of the enclosed space will have a light, which will be toggled based on measured quadrant occupancy. The demo space will also feature a screen displaying real-time occupancy information, as well as an example HVAC system actuated based on occupancy.

The user interface displayed on the screen will show attendees a visualization of the thermal sensor readings retrieved by the overhead unit in the form of a heatmap. To make the thermal map human-readable, an image obtained by a normal optical camera from the same perspective of the TOSS module will be overlaid onto the heatmap. In addition, the interface will display critical information such as the current occupancy count and PIR readings within the zone.

The demonstrated HVAC devices will be manipulated using an Automated Logic Corporation (ALC) router and WebCtrl [7], a combination that can be found in many modern commercial buildings. To provide a realistic demonstration, these services will be controlling a commercial-grade actuator, typically used in HVAC control, to operate a fan damper assembly. In addition to showing TOSS's ability to condition based on thermal comfort, the demonstration will also emphasize ability to regulate ventilation in accordance to ASHRAE standards [3]. Overhead lighting will also be actuated by WebCtrl based on the zone's detected occupancy.

All actuation is performed in the same manner as in a commercial building. In principle, it will provide a representative demonstration of TOSS's ability to accurately control HVAC and lighting usage based on human occupancy.

Figure 2: View depicted in demonstration interface

4. CONCLUSIONS

While there are many different methods of measuring occupancy, each sensing technology has drawbacks. Ultrasonic and PIR sensors are only useful for binary indication of occupancy and cannot determine how many people occupy an area. CO_2 sensors can be used to estimate occupancy but are slow to respond and require regular calibration. Cameras can be used to measure actual occupant counts in near real-time but are prone to errors caused by lighting and shadow issues, are more energy intensive and costly to deploy. In this demonstration, we show TOSS is a low-cost, low-energy solution for measuring occupancy in near real-time and demonstrate its use for HVAC and lighting control.

5. REFERENCES

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