

Project 1 Proposal:

Detecting Occupancy Patterns of Smart Buildings for Efficient Energy Management

Team 10

Problem Statement

In 2011, the US building sector accounted for 41% of total energy consumed and outperforming the transportation (28%) and industrial sectors (31%) [EIA 2011]. In an effort to mediate this, designers and engineers model, simulate, and evaluate the potential energy consumption of buildings, leveraging inputs such as patterns of occupancy, which predicts how occupants intend to use the building, whether it be residential, commercial, or mixed. More heating and cooling ventilation is required for spaces with more tenants, however, currently there is no standard for determining a building's potential pattern of occupancy, nor how they might change over time.

Additionally, occupancy patterns are used in operating building control systems so that they respond proportionally to the number of occupants in buildings. Prior studies show that occupancy pattern detection can reduce the energy consumption of lighting by 50% [Harle and Hopper 2008] and air conditioning by 20% [Erickson and Cerpa 2010].

Related Work

Several studies have used occupancy patterns to improve the energy consumption of buildings, such as the ARIMAX model developed by the National Research Council in Canada to forecast the power demand of a building [Newsham and Birt 2010]. To increase the accuracy of the model, researchers used building occupancy as a significant independent variable. Moreover, researchers in the Lawrence Berkeley National Laboratory defined five occupancy patterns using measured light-switch data [Chang and Hong 2013]. They concluded that such detailed models can replace the fixed or predefined models in energy simulation software. Dong and Andrews [2009] developed an event-based pattern recognition algorithm to model and predict the behavior of occupants by incorporating temperature, relative humidity, acoustics, lighting, and CO₂ into their models.

Researchers have used various methods to model the occupancy pattern of buildings. Erickson et al. [2009] developed an agent-based model that simulated occupancies by modeling the behavior of individuals. They also proposed a multivariate Gaussian model that calculates the probability of a particular state at a given time. To model the temporal dynamics of occupancy, Erickson et al. [2011] used an inhomogeneous Markov Chain method, by which they could achieve 42% annual energy savings. Erickson et al. [2014] expanded their study by comparing the performance of three Markov Chain algorithms, Closest Distance Markov Chain, Moving Window Markov Chain, and Blended Markov Chain. The results show that the most elegant and the best performing model was the Blended Markov Chain.

Project Description

The aim of the project is to construct an AI-based model that would predict the end user's behavior and occupancy patterns in a smart building. We propose to analyze human motion data collected from Mitsubishi Electric Research Labs (MERL) over two years [Wren et al. 2007], using over 200 sensors that detected changes in the thermal background radiation over a small region, to successfully capture over 30 million (raw) motion data points from movement of people in and around the lobbies and hallways within the MERL Labs premises. This dataset is available to the public domain.

The objective of this study is to simplify existing models of determining the occupancy patterns of a commercial building through a more generalized data set. The goal is to output recurring patterns of usage that can be leveraged by either designers of commercial buildings or building control systems.

Methods of Evaluation

Currently, we have two years, or 104 weeks of data. We are going to construct our model using 30%, 40%, and 50% data as training data, and then evaluate the model's precision and recall using the rest of 70%, 60%, and 50% data.

Future Work

This project proposal was designed as the first part of a larger project. Potential avenues of research consist of extending this to the optimization of evacuation plans. Understanding and predicting the "escape behavior" of occupants has implications within firefighter mediation and building safety in the event of a catastrophe.

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