Forecasting building occupancy: A comparative study of approaches

James Howard
Colorado School of Mines
1500 Illinois St.
Golden, CO 80401
jahoward@mines.edu

William Hoff
Colorado School of Mines
1500 Illinois St.
Golden, CO 80401
whoff@mines.edu

ABSTRACT

This paper provides a sample of a LaTeX document which conforms to the formatting guidelines for ACM SIG Proceedings. It complements the document *Author's Guide to Preparing ACM SIG Proceedings Using LaTeX2$_\epsilon$ and BibTeX*. This source file has been written with the intention of being compiled under LaTeX2$_\epsilon$ and BibTeX.

The developers have tried to include every imaginable sort of "bells and whistles", such as a subtitle, footnotes on title, subtitle and authors, as well as in the text, and every optional component (e.g. Acknowledgments, Additional Authors, Appendices), not to mention examples of equations, theorems, tables and figures.

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1. INTRODUCTION

According to the U.S. Department of Energy energy for heating and cooling accounts for approximately 35 - 45% [2] of the total expenditure within a building. With such a large investment of energy being used to regulate the temperature of a building, any possible areas of improvement in this area are heavily sought after. Knowledge of occupancy of people within a building are an important component to intelligent heating and air condition systems. True levels of occupancy are rarely known and as a results most buildings instead rely on existing systems such as carbon dioxide sensors or motion activated lights.

A number of other researchers have created local wireless network occupancy sensing devices using a combination of sensors. In this paper we explore the forecasting accuracy of multiple common time series forecasting models using a number of forecasting measurement metrics. Or occupancy is derived from infrared sensors densely placed around a building. The data is collected from two different types of buildings, one is an office building, the other a classroom and research building with different schedules of levels occupancy. We believe that this work will lead researchers to have a better idea of what forecasting algorithms will perform best under the specific conditions of our buildings.

The remainder of the paper is laid out as follows: Section 2 discusses the other work in this area including research from vehicle traffic systems. Section 3 discusses our forecasting models. In section 4 we introduce the datasets and give a brief description of the data collection method and the types of buildings from which the data was generated. Section 5 show the results of our forecasts and the paper concludes with a discussion of our conclusions and future work in section 6.

2. RELATED WORK

There has been considerable work in generating simulated models of occupancy [7, 3]. These simulations often involve agent based models where the concern is more with the accuracy of the models occupancy at any given time instead of the model's forecasting abilities. Agent based models also tend not to scale well to large buildings where the where large numbers of agents, rooms and interactions lead to non-trivial solutions.

Researchers have also created systems to attempt direct occupancy estimation using a combination of simple sensors and wireless motes. Agarwal, et. al [1] has created motes using a combination of an IR sensors reed switch place on a door to determine the likelihood that a room is occupied. This work is excellent for occupancy data acquisition, but little work was done on occupancy forecasting. Mamidi [6] and the University of Southern California have developed a building-level energy management system using a combination of motion detectors and environmental sensors. They compared their readings against a ground truth recorded by occupants using specifically monitored rooms. They used a variety of standard learning algorithms, including ensemble methods to accurately estimate the occupancy of a room. Work from both those these groups however seems to be more focused on occupancy estimation instead of forecasting.

Outside the world of building occupancy forecasting, there has been considerable work with counting vehicles on road ways. Forecasting for traffic roadways present many of the same challenges that buildings present. The data has clear daily trends and is subject to large shifts in those trends based on environmental factors such as accidents or weather. Thus it seems pertinent to discuss any promising forecasting techniques used in the traffic domain along with the building domain.

The classic time series Auto Regressive Moving Average Model (ARMA) or derivations on its form (ARIMA, SARIMA, VARMA, etc) have been used in numerous papers on forecasting. The results on this class of models seem mixed. William's [8] showed promising short term forecasting results using Seasonal ARIMA models on traffic sets from London and Atlanta. Hong [4] , while again demonstrating the feasibility of Seasonal ARIMA models to traffic forecasting, achieved better results combining genetic algorithms and simulated annealing.

Zheng [9] used a bayesian combination of time delayed neural networks to achieve better forecasting accuracy than each neural network alone. This demonstrates the feasibility of both a bayesian combined approach and the use of time delayed neural networks for traffic forecasting. The problem with these forecasting approaches is that they focus only on short term forecasts, typically one time step into the future (often 15 minutes). While this forecast horizon may be applicable to traffic forecasting, pre-heating and cooling systems can utilized occupancy forecast up to 24 hours into the future [5].

3. OCCUPANCY DATA

SHOW IMAGES AND WRITE ABOUT OUR DATASETS HERE

4. FORECASTING MODELS

SHOW MODEL MATH HERE

5. RESULTS

SHOW RESULTS HERE

6. CONCLUSION

7. REFERENCES

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