Annual Report

Topic: Vetting the Energy and Security of Smart Buildings with Data Science

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1. Introduction

Cyber Physical Systems have numerous applications in civil, energy, transportation, and manufacturing fields. Meanwhile, critical infrastructures are increasingly interwoven with cyber components such as sensing, computing, and control devices [1][2]. An ad hoc issue in Cyber-Physical Infrastructures (CPIs) is the security of the system, namely, how to protect it from cyber and physical attacks. The research into strategies to vet a CPI and minimize the influence of attacks is urgent.

With the rapid development of sensing technologies, i.e. Internet of Things (IoT), modern buildings are becoming more intelligent and automotive [3]. Considering the gap between the area of cybersecurity and physical protection, and the area of novel smart and connected sensors, it is necessary to learn information from the data in intelligent buildings to maintain them in a secure environment. This project aims to use a smart building as a platform to develop data mining technologies in intelligent buildings and to apply them to common Cyber Physical Infrastructures, which will have significant influence on system security.

2. Activities completed

Our initial approach in this project was to identify and clean the data set needed for us to analyze and make predictions. We collected the data from the ReNEWW House at Purdue. We categorized the data into two sections: daily energy and water consumption/production and living conditions (temperature and humidity).

Since the data was collected with respect to time, we addressed the problem with time series analysis. In our analysis, we observed some anomalies in the energy and water consumption data. We proceeded to investigate the anomalies using anomaly detection methods used in data science (figure 1) [4], which used clustering based anomaly detection with K-means algorithms. Detected "anomalies" were plotted in the time series plot to identify the actual occurrences. Additionally, we worked on data mining techniques to monitor energy consumption of the building [5].

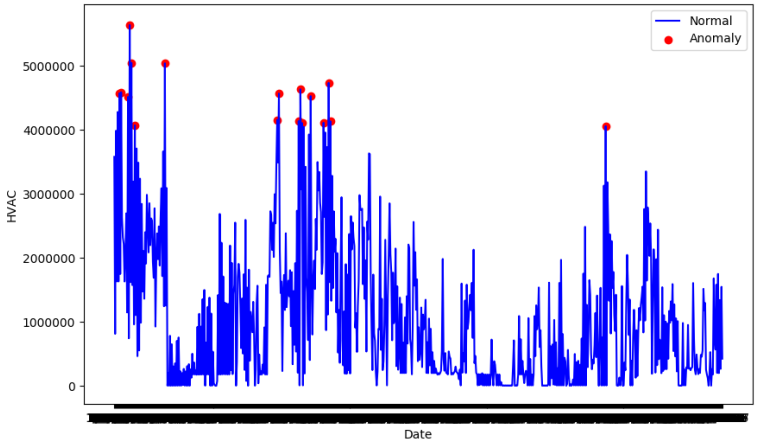

Figure 1: Anomaly in HVAC Energy Consumption

We observed that the HVAC usage data has significantly different distributions in warm and cold climates. The months from November to March were considered cold months and April to October were considered cold months. These two clusters were further divided into smaller clusters by K-means algorithm and then used to detect anomalies.

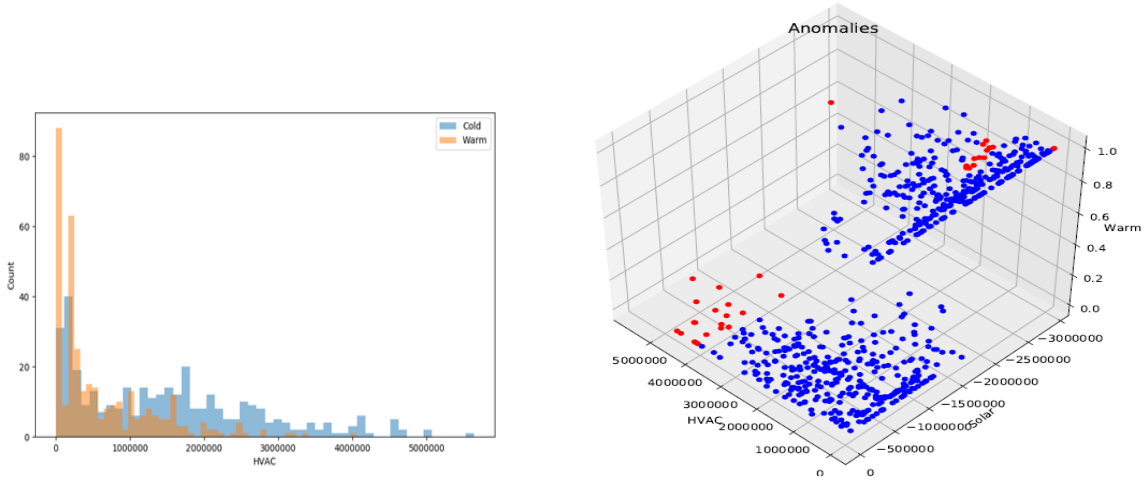

Figure 2: HVAC Usage in Warm and Cold weather (left)

K-cluster to distinguish the abnormal data(right)

For the temporal data, we used Autoregressive Integrated Moving Average (ARIMA) [6] analysis. We found a review article that addresses energy management using data science which gives us insight into methods for our project.

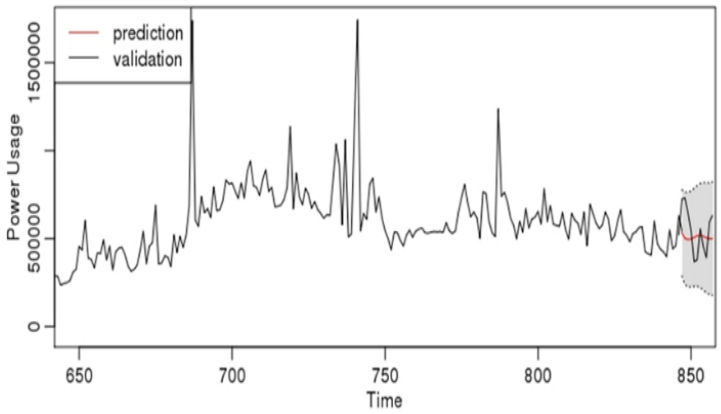

Figure 3: Prediction of Power Usage

3. Future Work

The team has accomplished to detect the abnormal data point and to predict the data trend. Due to the limited data we can access, the current study is terminated with the ReNEWW House energy system. The future work will be focused on validating the model and methods applying to different buildings or systems. In addition, more varied data from all systems in smart houses, like data from security cameras and smart thermostats can be used to explore the connections within different systems.

4. Supplements

a) Meetings

We usually use GroupMe and Email to communicate.

Date	Location	Members
2/28/2019	Skype	Zhen, Dinuka, MyVan
7/29/2019	Denver	Zhen, Dinuka

b) Conferences

Poster Presentation: 2019 Joint Statistical Meetings at Denver Colorado

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Abstract:

Cyber Physical system has various applications in civil, transportation and energy infrastructure. With the development of sensor technology and communication, all of the above infrastructures become more intelligent and self-sustained. Meanwhile those facilities have also become vulnerable to cyber attacks due to the gaps in the cyber security and physical protection. Our goal is to use a smart building as a platform to develop data mining technologies in intelligent buildings and to apply the technologies to common Cyber Physical Infrastructures (CPIs), which will have significant influence on the system security. The chosen residence for the case study is a research level residence at Purdue University. The installed sensor network provides continuous data regarding the utility consumption like water and energy in real or near-real time. With the accumulated data over a period of two years, the researchers used time dependent data mining techniques to figure out the relationships between and within different aspects of building performances.

c) Funding

Attending the JSM conference: $3434.53

The remaining balance is $ 2565.47. We are considering taking a building related conference or seminar to get more feedbacks from experts and audients.

References

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[4] Zucker, G., Habib, U., Blöchle, M., Wendt, A., Schaat, S. and Siafara, L.C., 2015, September. Building energy management and data analytics. In 2015 international symposium on smart electric distribution systems and technologies (EDST) (pp. 462-467). IEEE.

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[6] Molina-Solana, M., Ros, M., Ruiz, M.D., Gómez-Romero, J. and Martín-Bautista, M.J., 2017. Data science for building energy management: A review. Renewable and Sustainable Energy Reviews, 70, pp.598-609.

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