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DATE: 3/10/19
Homework: 05
STAT/CS 387

# 1 Final Project Proposal

The goal of this project will be to research, design, and implement a strategy for on-line energy storage control based on real-time prices. In order to do this, I will need to pull historical data for real-time prices from the internet. Then, I will compare reinforcement learning algorithms to determine the actions of the energy storage device. Finally, I can use a test set of data to assess the algorithms' performance compared to an optimized control or baseline.

The project is a good match for what we have covered in class because it uses some of the concepts we have covered such as reinforcement learning and using data for predictions. We covered multi-armed bandits which are one example of a reinforcement learning problem and the algorithms we studied such as greedy and epsilon-greedy could be adapted for this problem. Other reinforcement learning algorithms such as Q-learning could also be used. In addition, there will be some data analysis components as I will need to incorporate historical real-time prices in order to train and test the algorithms.

Energy storage is becoming an important aspect of the electrical grid as prices of lithium-ion batteries and other technologies begin to decrease. With the increased adoption of renewable energy, there is an increase in the demand for flexible resources that can temporarily "move" the electricity by storing or controlling them. Since most renewable energy, such as solar and wind, are nondispatchable and intermittent, energy storage is one solution that can fill these holes in electricity production when the wind stops blowing or the sun stops shining. One method for tracking how available electricity production is versus electricity demand is having pricing signals. Electric pricing signals can come in the form of real-time prices at the wholesale level or time of use pricing at the consumer level which blocks out times where electricity is cheap or expensive.

Energy storage has many possible services it can provide such as backup power but a major revenue source is using energy storage for real-time temporal arbitrage. This basically means that the energy storage device will charge at low prices and discharge at high prices. While this is easy to do when the prices are known ahead of time, deciding when to charge and discharge becomes more difficult when there is some uncertainty such as the real-time electricity prices.

The main ideas of this project have been looked at in *Energy Storage Arbitrage in Real-Time Markets via Reinforcement Learning* [1]. The authors implement a Q-learning algorithm and use a $\epsilon$-greedy method to solve an online version of an energy storage arbitrage maximization problem. A similar problem was also solved in *Online Modified Greedy Algorithm for Storage Control Under Uncertainty* [2]. In *Reinforcement Learning-Based Control of Residential Energy Storage Systems for Electric Bill Minimization* [3], a TD($\lambda$)-learning

algorithm is used to control energy storage and compares it to an on-peak, off-peak baseline strategy. I will attempt to simulate some challenges that these papers do not cover and tackle the problem with new algorithms.

The scientific knowledge that will hopefully be gained from this project will be three-fold. First, it will assess if a reinforcement learning algorithm can be used to effectively control an energy storage device under uncertainty of real-time prices. Then, it will be used to assess the benefits and downfalls of certain algorithms for this implementation. By defining performance metrics such as the expected regret, we can compare which algorithms performed the best. Finally, there will be opportunities to determine what future work could be done in this area.

From this project, I hope to personally expand my data science repertoire. By testing reinforcement learning algorithms on a real problem, I will learn about actual implementation strategies and potential downsides of each. In addition, by using actual data I will have to deal with practical data problems such as missing data or outliers. All the while I will continue to flex my python chops and expand my knowledge of useful packages and commands.

For implementation, I plan to use PyCharm to interact with python code. To support the tool, I will likely use python packages such as numpy and pandas to handle the data analysis and matplotlib to do the visualizations. In addition, I might utilize a more build out and dedicated reinforcement python learning package such as pyqlearning. Using these tools I can create functions for different reinforcement learning algorithms and then run the algorithms on different datasets.

# References


[1] Hao Wang and Baosen Zhang. Energy storage arbitrage in real-time markets via reinforcement learning. *CoRR*, abs/1711.03127, 2017.

[2] J. Qin, Y. Chow, J. Yang, and R. Rajagopal. Online modified greedy algorithm for storage control under uncertainty. *IEEE Transactions on Power Systems*, 31(3):1729–1743, May 2016.

[3] and Y. Wang, , S. Nazarian, and M. Pedram. Reinforcement learning-based control of residential energy storage systems for electric bill minimization. In *2015 12th Annual IEEE Consumer Communications and Networking Conference (CCNC)*, pages 637–642, Jan 2015.