Smart Home Load Management Using Dynamic Programming

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Introduction

What is Dynamic Programming?

- A type of machine learning.
- Needs defined state features, certainty in state transition, and all parameters before a run begins.
- Run time greatly increases with more parameters.
- Will always find the optimal case.

This project consists of a smart home system connected to the grid with a PV system as a supportive power source. The system will decide whether to use power from the grid or the solar battery depending on price, demand, and irradiance throughout a given period of time, or episode. This type of programming requires all parameters for the episode before it begins a run, so an experiential type of machine learning would be more beneficial for real-life applications. However, Dynamic Programming reduces cost by 26% when compared to experiential machine learning.

Goal of Program

- Search all possible paths for a 24-hour period to find the minimum cost to the consumer while always meeting demand.
- Use results to compare how experiential types of machine learning perform when searching for the optimal solution.

Design

Data Collection

- Real-time data for irradiance, demand, and price throughout the day.
- Collected from various online databases that post hourly data.
- Irradiance and demand were normalized so each value was between 0 and 1 and multiplied by an average value for each category to create an accurate set of data in terms of household units.

Program Design

- State features are hour and battery charge (i.e hour 13 and 55% charge).
- Two action spaces: two actions or four actions – Both have the option to take power from the grid or solar battery to cover demand with the added choice to charge the battery from the grid when price is low.
- Explores every choice at every state to find the best path of choices while always meeting demand.
- Reward is loss or profit for the hour times demand.

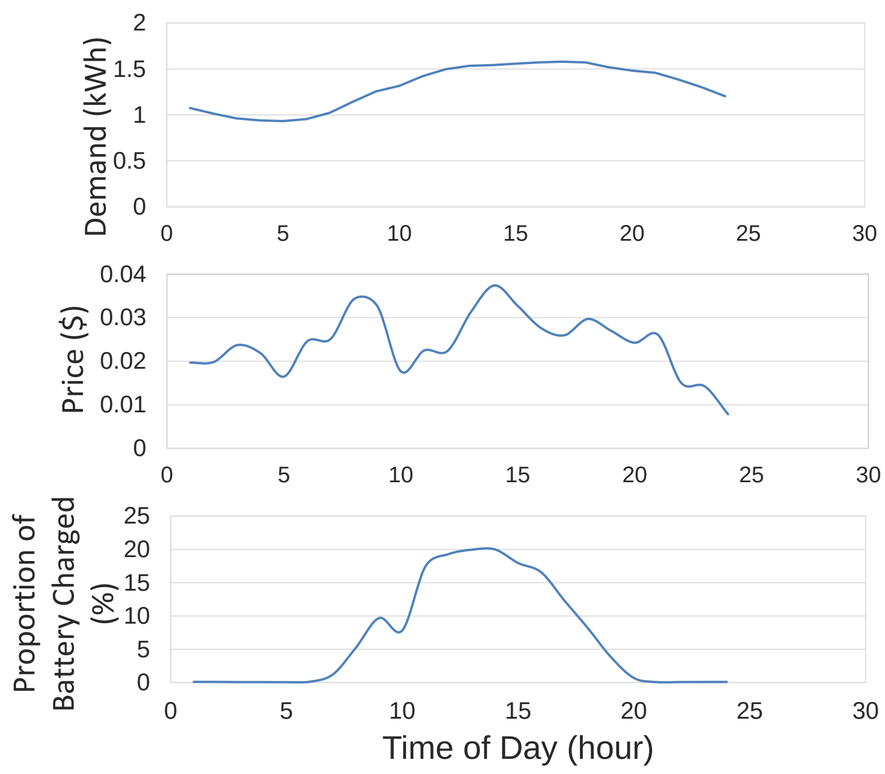

Figure 1. Graphs of price, demand, and how much the PV panel charges the battery each hour (based on irradiance).

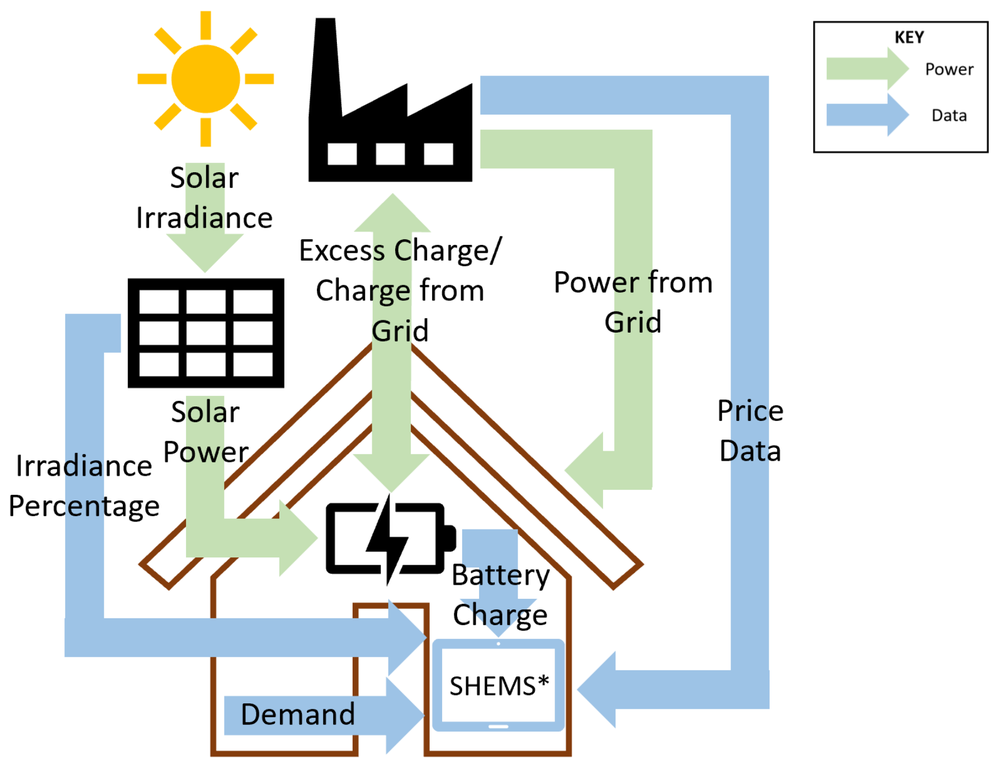

Figure 2. Program Flow Model (*Smart Home Energy Management System (SHEMS) is where the data is fed into the program to be analyzed for the next action).

Results and Conclusion

KEY

PV: percent charge the PV system can provide for each hour.

Action: list of the choices for the optimal path. The numbers represent the following:

- **0**: use power from grid
- **1**: use power from battery
- **2**: use power and charge battery from grid
- **3**: use power from battery and charge battery from grid

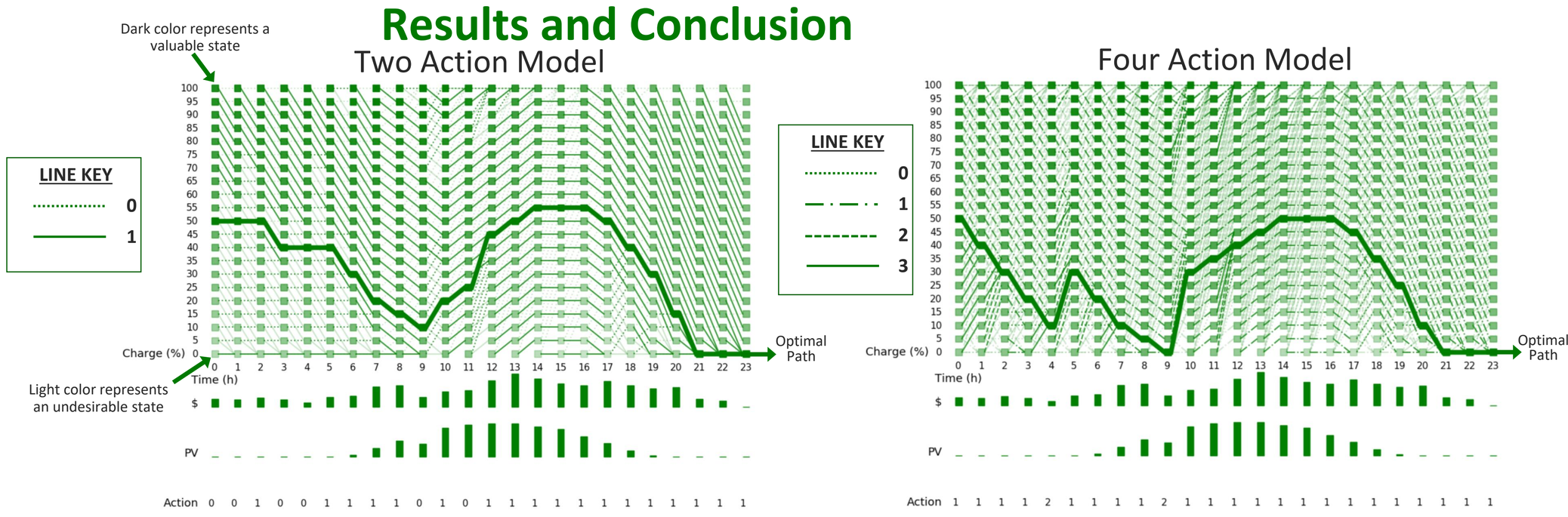

Figure 3. Tables of all states and their values after 50 episodes with optimal path.

The program makes the figures above as it steps through the 24-hour episode 50 times, assigning a value to each state and action base on the reward it receives. The darker colors represent higher values and more desirable states and actions. The amount spent for the day with two actions (left table) was $1.75 and $1.57 with four actions (right table). Compared to Q-Learning, an experiential type of Reinforcement Learning which had a bill of $2.11 for the day, Dynamic Programming had a lower bill. However, Q-Learning only took 4.17 seconds to run 1000 episodes, while Dynamic Programming took about 49 times longer. Q-Learning can be used in real-life systems since it learns as it experiences the states it comes across, but it probably won't find the most efficient path every time. Both Q-Learning and Dynamic Programming are improvements from manually choosing an action each hour which produced a bill of $2.62 for the 24-hour period.

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