Optimal IoT control in Smart Homes

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Introduction and Motivation

Goal

- To design an intuitive dishwasher that can be activated at an optimal time during the day via voice command through Amazon Echo Dot.

Negative Prices

- Happens when electricity supply is greater than the demand.
- Customers are actually being paid to use electricity during negative priced hours.

Some Notations

- $P$: Retrospective averages for any usage in time interval $[t-60, t]$ $P = \frac{1}{t-60} \sum_{t-60}^{t} P_{t-60}$
- $T_{\text{cycle time}}$: Cycle running time for the appliance
- $\delta$: 5 minutes
- $\Delta$: 24 (a day’s worth of time)
- $T_{\text{MAX}}$: $T_{\text{MIN}} = 5$ (Activate time between 11 PM and 5 AM)
- $N = (T_{\text{MIN}}, T_{\text{MAX}} + 1..T_{\text{MAX}})$
- $D$: No. of days in the past to train policies

Mean price is low around Setup Components

- Electricity during negative priced hours

Happens when electricity supply is greater than the demand.

Customers are actually being paid to use electricity during negative priced hours.

Setup Components

- Smart Home architecture
- Negative Prices observed May 14, 2017

System Components and Implementation

Decision Logic for Alexa and Cloud Watch

- Alexa, Cloud Watch Server architectures resp.

Price Modeling

Trade off

Mean price is low around 4 AM, but the variance is also large at that time.

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Optimal Stopping Policy

- Constructed: Forward Direction
- Evaluated: Backward Direction.

The Exercise price ($P_{t}^{\text{opt}}$) of consuming energy is computed at each of the future nodes.
- Continuation value ($V_{t} = \infty$) at end node.
- Continuation value $V_{t} = E[P_{t+1}^{\text{opt}} + V_{t+1}]$ for $n = T_{\text{MAX}}$
- Optimal Time: Exercise Price < Continuation Price: $t^{*} = \min \{ n : P_{t}^{\text{opt}} < V_{t} \}$ where $V = E[P_{t}^{\text{opt}}]$

Economic Impact

- WiFi accessible with inexpensive and fast installation
- Can be extended to any electrical appliance with a switch leading to energy savings
- Can establish a “Smart Grid” preventing overloading and power outages.
- Particle Photon: $\$19$, Relay Shield: $\$19$, Lifetime Electricity Savings
- Results when back tested on a year’s data:

<table>
<thead>
<tr>
<th></th>
<th>Mean (average prices)</th>
<th>Mean (policy prices)</th>
<th>Average savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argmin Policy</td>
<td>2.34/13</td>
<td>1.86/45</td>
<td>9.4 %</td>
</tr>
<tr>
<td>Optimal Policy</td>
<td>2.34/13</td>
<td>1.83/44</td>
<td>10.5 %</td>
</tr>
</tbody>
</table>

Table 1: Savings from the Argmin and Optimal Stopping policies in a single cycle

Future Research

- Implementation and comparison of Machine Learning models predicting price patterns
- Inclusion of consumer demand and weather conditions as well for the forecast

Acknowledgements

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