ETH zürich

Seminar Thesis - An Example in the Smart Grid Domain

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Smart Grids

Next generation of power systems enabled by cutting-edge information and communication technologies.

Capabilities:

- Prevent and mitigate black-out in real-time.
- Utilization of renewable energy resources in large-scale.
- Micro-generation.
- Electrical vehicles.
- Demand-side energy management.

E. Pournaras, M. Vasirani, R. Kooij, and K. Aberer. *Decentralized planning of energy demand for the management of robustness and discomfort.* Industrial Informatics, IEEE Transactions on, 10(4):2280âĂŞ2289, Nov 2014.

A Semester Thesis Guideline

... for a successful project!

1. Define the challenge
2. Define the outcome and its significance
3. Reason about a data-science approach
4. Select the data sources
5. Define evaluation metrics and measurements
6. Build the data analytics pipeline
7. Perform validation and evaluation
8. Draw conclusions and future work

1. Define the challenge I

Motivation:

- Robustness of power grids can be improved by planning energy demand of consumers.
  - load-shifting
  - load-adjustment
  - software agents & smart sensors
- Planning may cause changes in usual consumption behavior.
  - Turning on devices at different time points, e.g. making a warm shower or activating laundry machine earlier/later in time.
  - Changing the thermostat set-point of the air-conditioner, feeling warmer or colder.

1. Define the challenge II

- Such changes may be perceived as "discomfort" that can make consumers unhappy.
  - shifting-discomfort
  - adjustment-discomfort

Research Question

How can we measure & manage trade-offs between system robustness & consumer discomfort under demand planning?

2. Define the outcome of your project

- **Metrics** to measure robustness and discomfort.
- A (decentralized) **mechanism** to control robustness and discomfort.
- A **decision-making tool** for managing quality of service in Smart Grids (robustness vs. discomfort).

3. Reason about a data science approach

- **Main intuition**: Reasoning about changes in electricity usage based on historic demand data!
- **Local** demand data model consumer behavior (discomfort experienced).
- **Global** demand data model system behavior (robustness trajectories).
- **Measuring trade-offs** also generates data that can be used to reason about quality of service in Smart Grids.
- **Limitations**: generalization in different demand datasets.
- Consumer behavior is governed by **different factors**: time, location, demographic characteristics, culture, policies, etc.

4. Select the data sources I

Requirement (1)

Historic time series demand data for each household.

Requirement (2)

Comfort preferences of consumers

4. Select the data sources II

- **The Electricity Customer Behavior Trial Project**
  `http://www.ucd.ie/issda/data/commissionforenergyregulationcer/`
  - Time: 2009-2010, Space: Ireland, Scale: 5000 residential & business consumers
- **The Olympic Peninsula Smart Grid Demonstration Project**
  `http://svn.pnl.gov/olypen/`
  - Time: 2006-2007, Space: Olympic Peninsula, the USA, Scale: 112 residential consumers
- Électriciteé de France
  `https://archive.ics.uci.edu/ml/datasets/Individual+household+electric+power+consumption`
  - Time: 2006-2010, Space: France, Scale: 1 residential consumer

4. Select the data sources III

Human perception of discomfort:

1. Survey questions:

- Question
  My household may decide to make minor changes to the way we use electricity.
- Question
  My household may decide to make major changes to the way we use electricity.

2. Selections of thermostat setpoints

5. Define evaluation metrics and measurements I

Robustness:

$$R = \frac{1}{T}\sum_{t=1}^{T}\rho^t, \tag{1}$$

where:

$$\rho^t = \begin{cases} (\hat{g}^t - \hat{d}^t)^2 & \text{if } \hat{g}^t \geq \hat{d}^t \\ -(\hat{g}^t - \hat{d}^t)^2 & \text{if } \hat{g}^t < \hat{d}^t \end{cases}, \tag{2}$$

and:

$$\hat{g}^t = 1 - \frac{|g^t - avg(\overrightarrow{g})|}{avg(\overrightarrow{g})} \text{ and } \hat{d}^t = 1 - \frac{|d^t - avg(\overrightarrow{d})|}{avg(\overrightarrow{d})} \tag{3}$$

5. Define evaluation metrics and measurements II

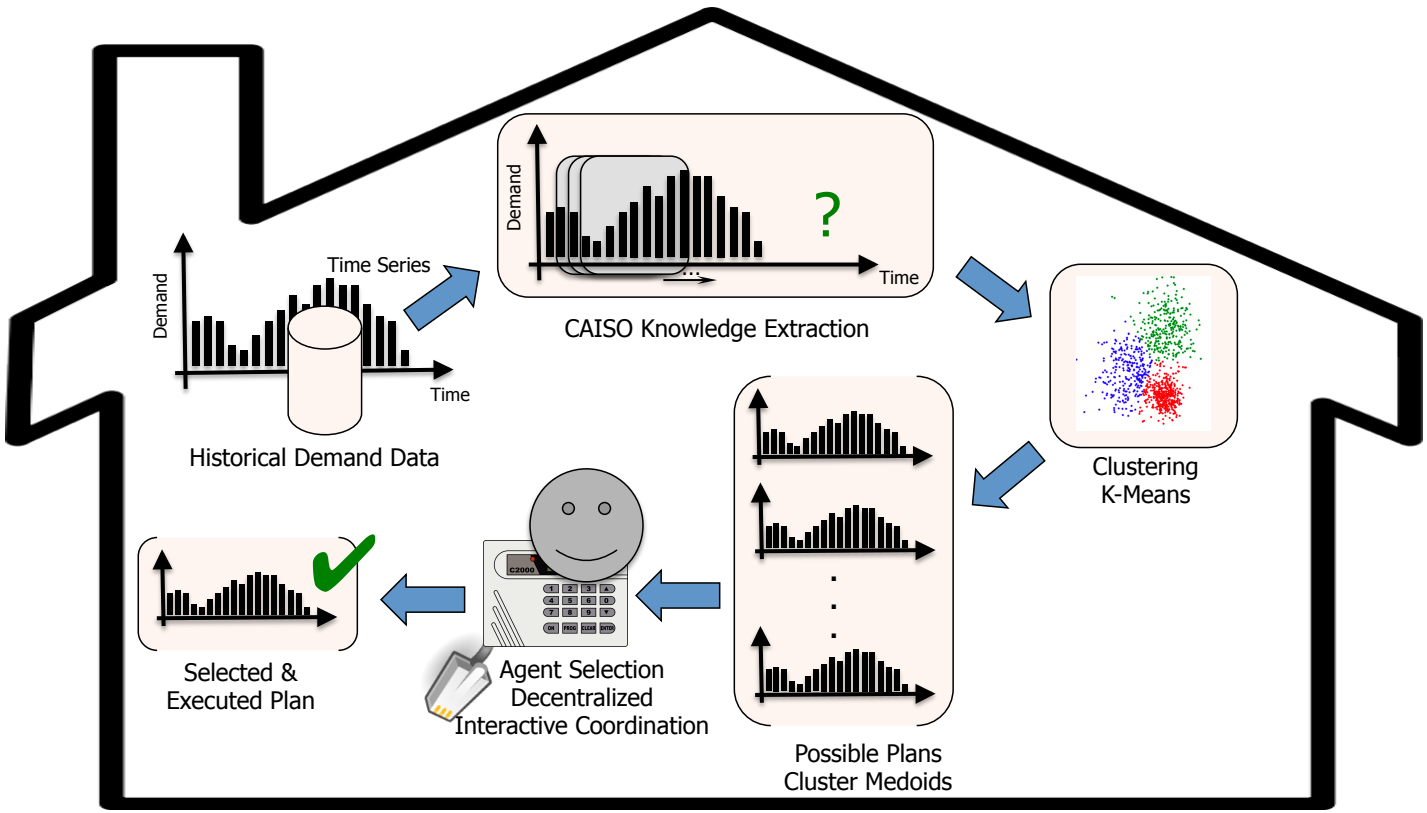
Shifting discomfort:

$$D_s = \sum_{i=1}^{n} \left\{ w_i^s \sqrt{\frac{1}{T} \sum_{t=1}^{T} (s_i^t - d_i^t)^2} \right\} \tag{4}$$

Adjustment discomfort:

$$D_a = \sum_{i=1}^{n} w_i^a \sum_{t=1}^{T} (s_i^t - d_i^t) \tag{5}$$

6. Build the data analytics pipeline

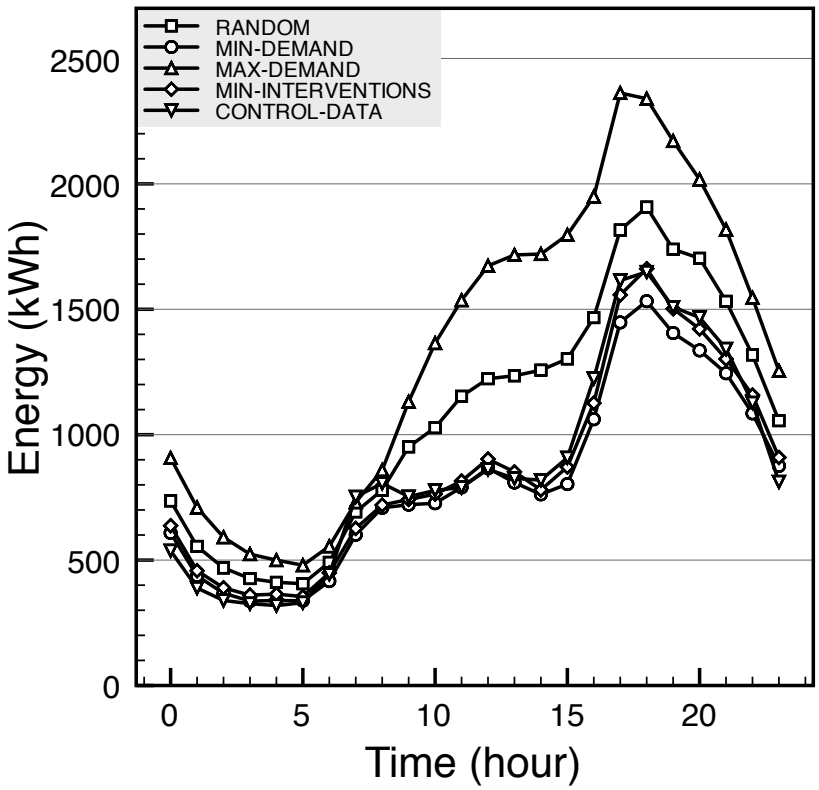


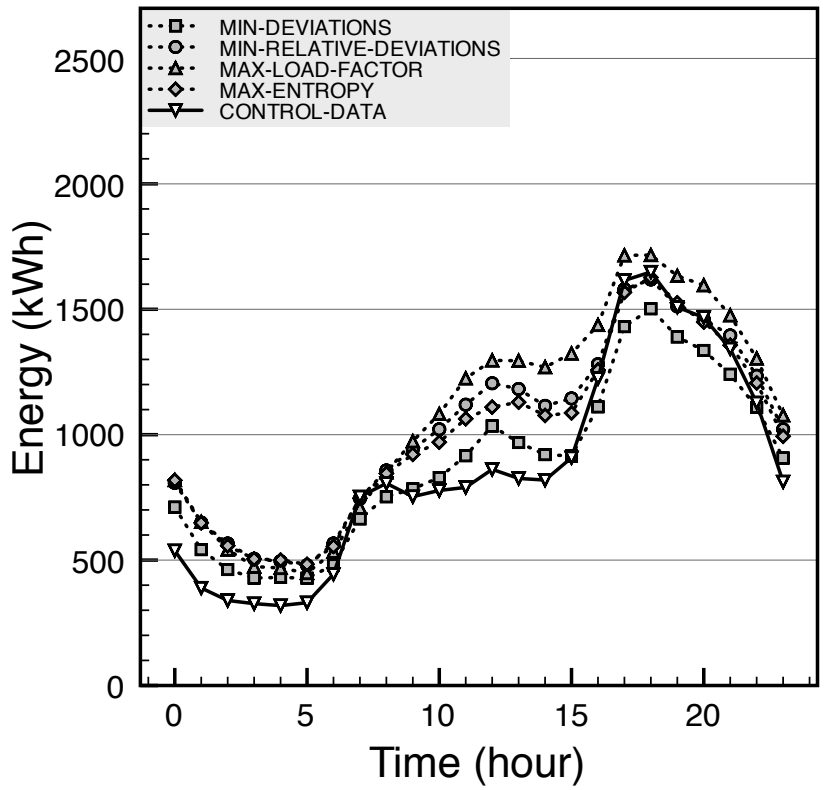
7. Perform validation and evaluation I

- Comparison of *agent selections* vs. *actual selections* (control data)
- Agent selections: **8 different strategies**
- **Comparison of agent strategies**: measurements of robustness, shifting/adjustment discomfort

7. Perform validation and evaluation II

Demand curves

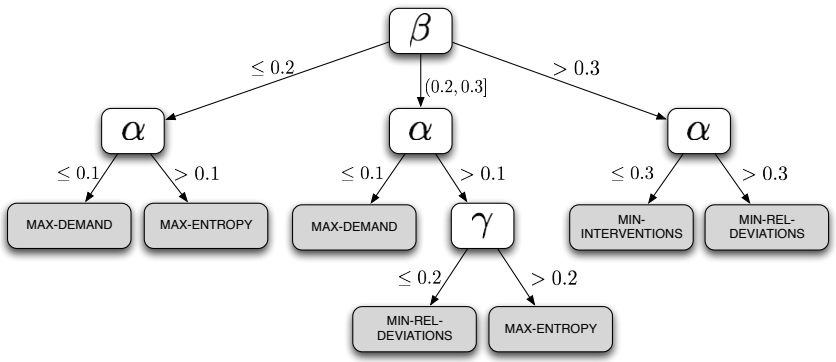


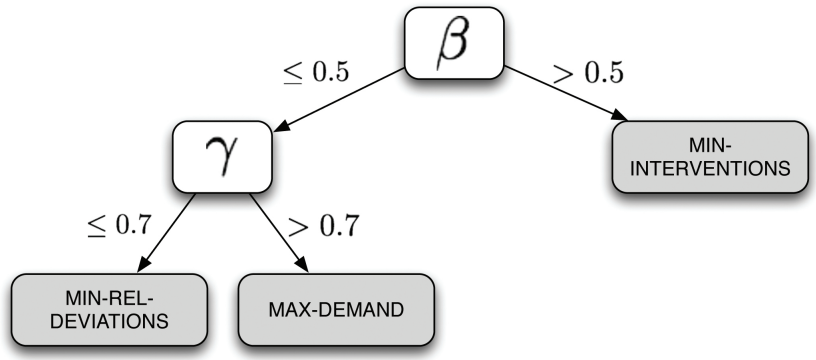


7. Perform validation and evaluation III

Regulating quality of service with decision trees - **C4.5 algorithm**

$$\arg\max_{o \in \overrightarrow{F}} = \alpha r_o^r + \beta r_o^s + \gamma r_o^a, \quad (6)$$





8. Draw conclusions and future work I

- "*... tradeoff between robustness and discomfort in demand-side energy self-management is quantifiable, manageable, and can provide different quality of service levels.*" [1].
- "*...experimental validation with real data from two operational smart grid projects confirms the load-shifting and load-adjustment potential of various selection functions, but also their discomfort impact on consumers.*" [1].

8. Draw conclusions and future work II

A direction for future work:

Research Question

How is discomfort distributed among consumers as a measure of fairness? [2]

References

E. Pournaras, M. Vasirani, R. Kooij, and K. Aberer.
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Industrial Informatics, IEEE Transactions on, 10(4):2280–2289, Nov 2014.

E. Pournaras, M. Vasirani, R. Kooij, and K. Aberer.
Measuring and controlling unfairness in decentralized planning of energy demand.
In *Energy Conference (ENERGYCON), 2014 IEEE International*, pages 1255–1262, May 2014.

What is next?

- Data science fundamentals
- Applications