Estimating Human Interactions with Electrical Appliances for Activity-based Energy Savings Recommendations

Motivation

Household Focus

- Smart Home:
  - Spread of communicating smart devices in the home
  - Future availability of appliance-level consumption data
- Household-level optimization for load shifting, peak shaving:
  - Accounting for the residents' lifestyle characteristics
- Ambient Intelligence System:
  - Combination of real-time grid status/prices, in-home states, etc.
  - Local (in-home) optimization → no privacy concerns

Activity-based Recommendations

- About 12% energy savings if personalized real-time feedback is employed [Carrie Armel et. all, *Energy Policy*, 2013]
- Relationship between human activities and succession of powered-on appliances
- Higher abstraction level for residents: activity vs. appliance-level feedback

Methodology

Appliances States

- User interaction incurs changes from *idle* state (stand-by/off) to *active* state (powered on/in use)
- Single appliance-level data:
  - Different operation modes (e.g. washing machine: soaking, spinning, etc.)
- Circuit-level data:
  - Power strip, room-level, etc.
- Challenges:
  - Different appliance types/models → different thresholds for *idle/active*
  - Unsupervised threshold detection

GMM

- Power measurements distribution shifted towards lower values
- Readings resampling:

$$C * \log(n_i + 1)$$

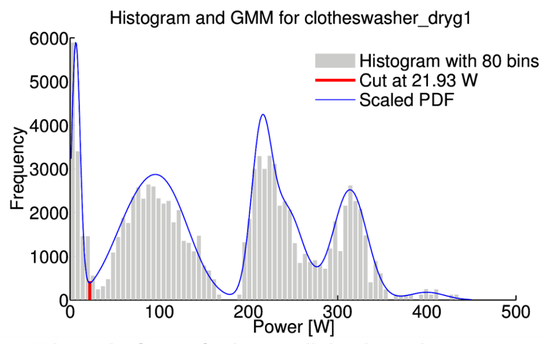
- States: differently shaped peaks in the distribution
- Best configuration (no. Gaussians): lowest Bayesian Information Criterion (BIC) value
- *Idle*/*active* threshold: the first valley in the distribution

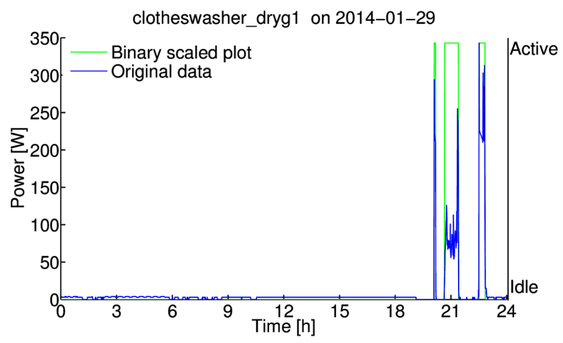
Experiment

- PecanStreet dataset
  - 239 households with 1-minute power measurements
  - January – May 2014
  - 73 categories of readings collected
  - At most 22 appliances/circuits per households
- No ground truth
- Ignore:
  - Always-on devices (fridges)
  - Devices consuming less than 0.5 Wh per week

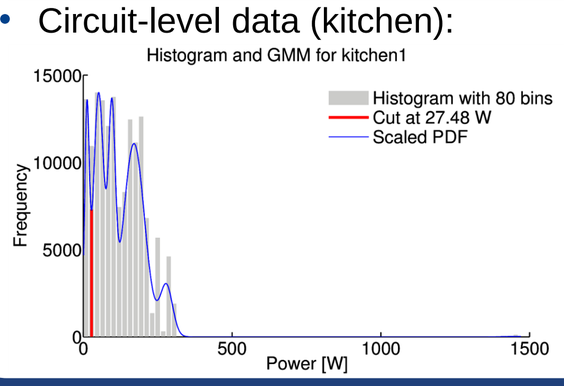
Results

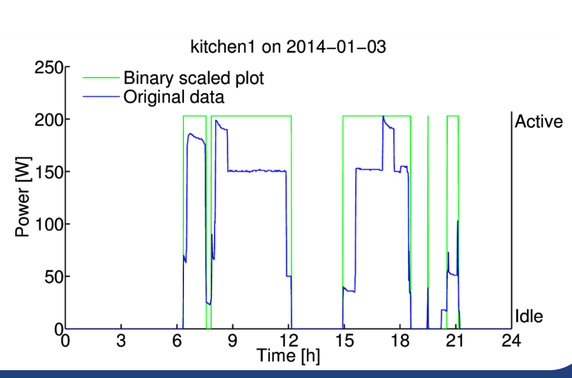
- Single appliance-level data (clotheswasher):





- Circuit-level data (kitchen):





Outlook

- Summary:
  - Modeling of appliance functioning through states
  - States detections via re-sampled power readings distribution modeling with GMM
  - Distinction between *idle/active* states based on the first valley between the first two Gaussians
- Future work:
  - Thresholding Evaluation
  - Ground truth acquisition
  - Activities detection:
    - Recurrent patterns of appliances usage
    - Temporal rules

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