Real-Time Recognition and Profiling of Appliances through a Single Electricity Sensor

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Overview

- Real-Time Recognition and Profiling of Appliances through a Single Electricity Sensor
  - IEEE Secon 2010

- Goal : Real-time Electrical Appliance Recognition (RECAP)

- Origin : NALM (Nonintrusive Appliance Load Monitoring)
- **NALM** (Nonintrusive Appliance Load Monitoring)
  - Real power (active power) edge
    - Insufficient computing power
Evolution of NALM

- Sufficient computing power
  - Instantaneous current & voltage
  - Complex computation such as FFT, Wavelet transformation
- Various features can be extract
  - Instantaneous power
  - Reactive power
  - Apparent power
  - Current
Instantaneous power

Real

Reactive

Apparent Power

Last Week
• **Instantaneous Power**: product of the voltage and current at a given time

• **Real Power**: net transfer of energy in one direction
  – the average of the instantaneous power

• **Reactive Power**: measure of the power going back from the load to the supply

• **Apparent Power**: product of the Root-Mean-Squared (RMS) of the Voltage and the RMS of the Current

• **Power Factor**: \( \cos(\theta) \)
• **Instantaneous Power**
  – \( \text{inst\_power} = \text{inst\_voltage} \times \text{inst\_current} \)

• **Real Power**
  – \( \frac{\text{sum\_instantaneous\_power}}{\text{number\_of\_samples}} \)

• **Apparent Power**
  – \( \text{apparent\_power} = \text{root\_mean\_square\_voltage} \times \text{root\_mean\_square\_current} \)

• **Power Factor**
  – \( \text{power\_factor} = \frac{\text{real\_power}}{\text{apparent\_power}} \)
• Challenges
  – Appliances with similar current draw
  – Appliances with multiple settings
  – Parallel appliances activity
  – Load variation
  – Long appliance cycles
**RECAP**

- **Features**
  - real power
  - power factor
  - peak current
  - RMS current
  - peak voltage
  - RMS voltage

- **Normalize**
  - signature length
  - sampling frequency

<table>
<thead>
<tr>
<th>Captured Parameters</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature ID (SID)</td>
<td>SID</td>
</tr>
<tr>
<td>Real Power</td>
<td>Device Location</td>
</tr>
<tr>
<td>Power Factor</td>
<td>Temperature</td>
</tr>
<tr>
<td>RMS Current</td>
<td>Humidity</td>
</tr>
<tr>
<td>RMS Voltage</td>
<td></td>
</tr>
<tr>
<td>Peak Current</td>
<td></td>
</tr>
<tr>
<td>Peak Voltage</td>
<td></td>
</tr>
<tr>
<td>Sampling Rate</td>
<td></td>
</tr>
<tr>
<td>Timestamp</td>
<td></td>
</tr>
<tr>
<td>State: [startup, steady, shutdown, off]</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical</th>
<th>Contributor</th>
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</thead>
<tbody>
<tr>
<td>Appliance ID (AID)</td>
<td>User ID (UID)</td>
</tr>
<tr>
<td>Type</td>
<td>Name</td>
</tr>
<tr>
<td>Model</td>
<td>Confidence Rate</td>
</tr>
<tr>
<td>Make</td>
<td>Association</td>
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<table>
<thead>
<tr>
<th>Energy Meter</th>
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<tbody>
<tr>
<td>Meter ID (MID)</td>
<td></td>
</tr>
<tr>
<td>Device Type</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Signature Property</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SID (Primary key)</td>
<td></td>
</tr>
<tr>
<td>AID</td>
<td></td>
</tr>
<tr>
<td>MID</td>
<td></td>
</tr>
<tr>
<td>UID</td>
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</table>
RECAP

- Markov Chain
RECAP

• **Markov Chain Classifier**
  – Although MC can be a suitable solution for monitoring a limited number of appliances, the system may not scale well to handle appliances in the order of tens via a single energy meter

• **Multistate Markov chains**
  – Complexity
  – Flexibility
RECAP

• Bayesian classifier
  – Can’t handle with vibration of parameter

• Artificial Neural Network
  – handle any type of data
  – unnecessary prior understanding
  – easy extensibility
  – learning process can be automated
  – error feedback
  – multiple simultaneous appliance states
• 3-Layer ANN
• Training
• Recognition
Experiment

(a)

(b) Kettle, Heater, Microwave, Fridge

(c)