Non-Intrusive Appliance Load Identification with the Ensemble of Classifiers

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System architecture (NIALM)

- Single DAQ node outside of the apartment
- Software responsible for the event detection and appliance identification
Current waveform for selected appliances

- Multiple devices working simultaneously!
The proposed ensemble approach

ensemble

IF $U_1 > 1.23V$ AND $U_3 < 4.56V$ THEN $FS=21$

... 

IF $U_2 > 5.32V$ AND $U_3 > 1.17V$ THEN $FS=32$

decision
Current changes detection method

- Find the changes in the current level regarding the previous vector and wait for the steady state
Rule-based approaches for appliances identification

If (conditions met) then (appliance identified)
Rules induction

- Traditional expert system method, used mainly discrete versions of algorithms (AQ, CN2, etc.)
- High off-line computational cost (generation of rules)
- Knowledge easily interpretable by the human operator
- Premises=complexes
Complexes and selectors

- **Inequality:**

  \[ f_1 f_2 \ldots \]

- **Interval:**

  \[ \phi_1 \rightarrow \phi_2 \]

**Complex specialization:**

\[ \phi_{\text{new}} \rightarrow \phi_{\text{old}} \]

\[ \phi_{\text{old}} \rightarrow \phi_{\text{new}} \]

\[ \phi_{\text{new}} \rightarrow \phi_{\text{old}} \]
Decision trees

- Memory-efficient classifier
- Inherent machine-learning
- Problem of selecting one feature for the test when multiple are equally good!
Decision tree variants

a) the largest distance from the neighbouring values
b) the smallest distance from the neighbouring values
c) the most frequent occurrence
d) the least frequent occurrence
e) random selection
Random forest – ensemble of decision trees
Design problems

- Number of trees
- Number of candidates for the node test
- How to vote?
Experimental setup

- 6 different appliances of the binary state (on/off) considered
- 69 features extracted from the current and voltage patterns
- 2 kHz sampling
# Results (pt. 1)

<table>
<thead>
<tr>
<th>No</th>
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<th>$d_{DT}$</th>
<th>$d_{RI}$</th>
<th>$d_{RF}$</th>
<th>$d$</th>
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</table>

0 – no change (false alarm)  2 – dryer  4 – mixer  5 – blender
1 – bulb  3 – vacuum cleaner  6 – kettle
## Results (pt. 2)

<table>
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<th>Algorithm</th>
<th>DT</th>
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<tbody>
<tr>
<td>Overall accuracy</td>
<td>82.81</td>
<td>64.06</td>
<td>85.93</td>
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<td>False alarm accuracy</td>
<td>97.82</td>
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<td>94.56</td>
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<tr>
<td>Appliance identification accuracy</td>
<td>55.55</td>
<td>58.33</td>
<td>83.33</td>
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</table>
Conclusions

• The proposed method is able to detect turning on and off of most appliances
• The application of ensemble with the proper strategy allows for maximizing the identification accuracy
• Each classifier has distinct advantages, making it useful in different situations
• The system detects multiple false alarms, but these errors are corrected by the ensemble
Thank You for Your Attention