Deep Learning to estimate building energy demands in the smart grid context

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Deep Learning to estimate building energy demands in the smart grid context

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Department of Electrical Engineering

Problem and Motivation

- Occupancy information can improve building energy management systems
- Large meteorological variations yield intense power fluctuations
- Quantification of uncertainty introduced with the advent of new renewable energy sources

Energy prediction

**Prediction method:** Conditional Restricted Boltzmann Machine

![Diagram of Neural Networks: ANN, CRBM, HMM](image)

**Total energy function**

\[ E(v, h, u, W) = -v^T W^v h - v^T b^v - u^T W^u v - u^T W^u h - h^T b^h \]

**Learning for CRBM using Contrastive Divergence**

\[ C_{D_{KL}(p(x)||p_\lambda(x))} = D_{KL}(p_\lambda(x)||p(x)) \]

<table>
<thead>
<tr>
<th>Method</th>
<th>Lighting consumption</th>
<th>Total energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANN</td>
<td>2.24</td>
<td>0.93</td>
</tr>
<tr>
<td>ANN(ARI)</td>
<td>1.22</td>
<td>0.98</td>
</tr>
<tr>
<td>HMM</td>
<td>1.11</td>
<td>0.96</td>
</tr>
<tr>
<td>CRBM</td>
<td>1.11</td>
<td>0.96</td>
</tr>
</tbody>
</table>

People Detection and Localization

**Approach:** Inexpensive user tracking using Boltzmann Machine

**Classification method:** Extended Factored Conditional Restricted Boltzmann Machine

![Diagram of Classification Flowchart](image)

**Localization - 16 classes (8 moving, 8 sitting positions)**

<table>
<thead>
<tr>
<th>Method</th>
<th>SVM</th>
<th>NB</th>
<th>AB</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANN</td>
<td>53.40%</td>
<td>54.46%</td>
<td>50.78%</td>
<td>57.78%</td>
</tr>
<tr>
<td>ANN(ARI)</td>
<td>55.46%</td>
<td>54.66%</td>
<td>58.76%</td>
<td>57.78%</td>
</tr>
<tr>
<td>HMM</td>
<td>55.46%</td>
<td>54.46%</td>
<td>54.46%</td>
<td>54.46%</td>
</tr>
<tr>
<td>CRBM</td>
<td>55.46%</td>
<td>54.46%</td>
<td>54.46%</td>
<td>54.46%</td>
</tr>
</tbody>
</table>

**Localization - 17 classes (Empty room, 8 moving, 8 sitting positions)**

<table>
<thead>
<tr>
<th>Method</th>
<th>SVM</th>
<th>NB</th>
<th>AB</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
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<td>41.29%</td>
<td>24.70%</td>
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<tr>
<td>ANN(ARI)</td>
<td>39.90%</td>
<td>18.57%</td>
<td>20.43%</td>
<td>42.39%</td>
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<tr>
<td>HMM</td>
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<td>22.29%</td>
<td>31.10%</td>
<td>58.92%</td>
</tr>
<tr>
<td>CRBM</td>
<td>59.42%</td>
<td>84.40%</td>
<td>76.40%</td>
<td>87.60%</td>
</tr>
</tbody>
</table>

**Total energy function**

\[ E_n(a_n|p_{\lambda}(x)) = \frac{1}{n} \sum_{i=1}^{n} E(x_i) = \frac{1}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}^v y_{ij} + b_{ij}^v + \alpha (\text{data}_i - \text{rec}_i) + \beta (\text{data}_i - \text{rec}_i) \]

**Experiment & Results**

- Artificial data
