Energy Disaggregation Using Convolutional Sparse Coding

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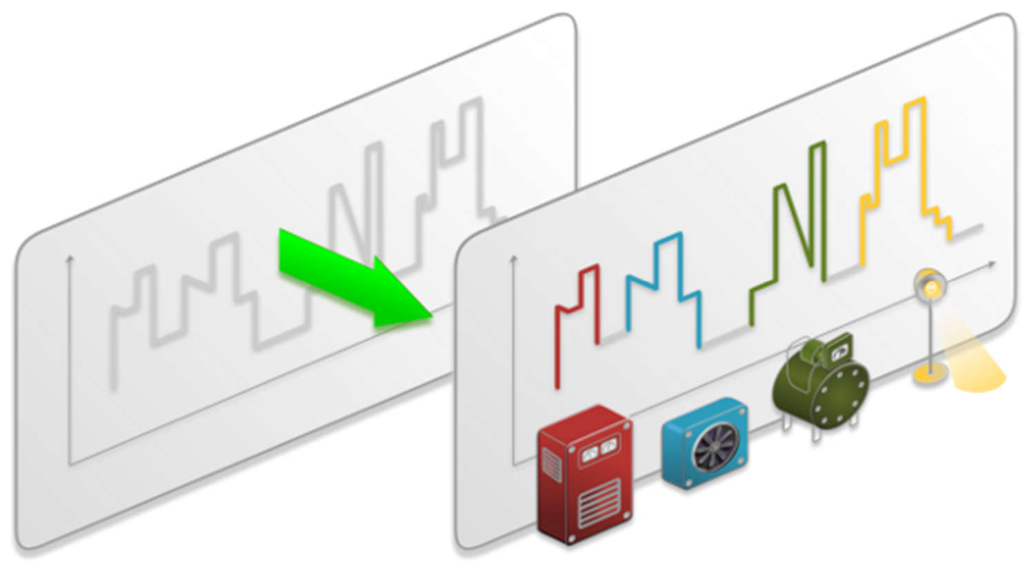
Abstract

Energy Disaggregation or Non-Intrusive Load Monitoring (NILM) is the process of analyzing aggregated power usage of a system to determine information about its components. This allows one sensor to acquire information about many devices. It is most commonly applied to residential or commercial buildings to acquire the usage profile of individual appliances.



The energy usage of a home is separated into the energy usage of individual devices.

An example of a Smart Meter

Motivation

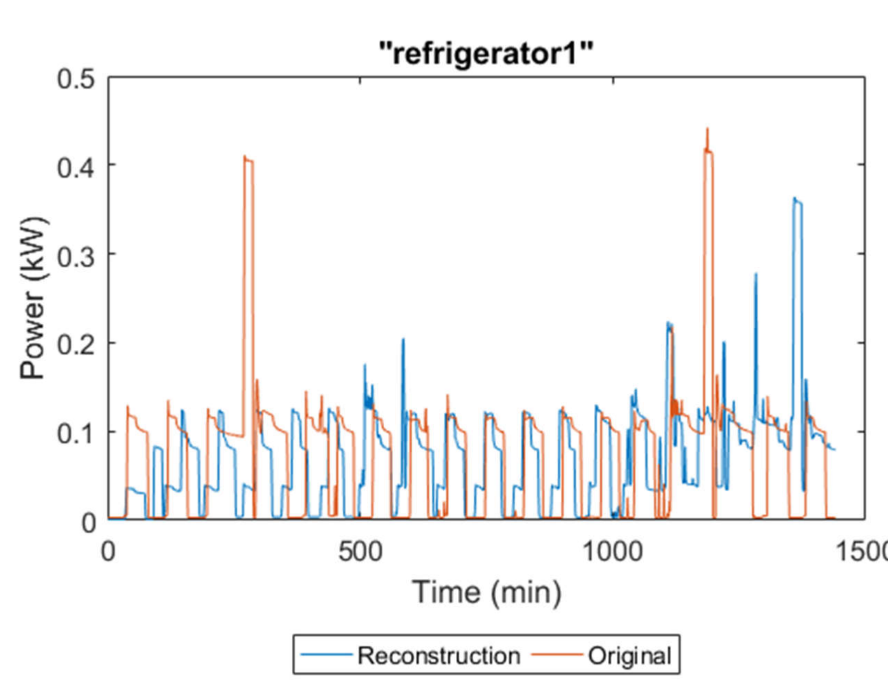
- Consumers with itemized power reports can reduce usage by up to 12% compared to those only receiving whole home power consumption reports.
- NILM has uses in fault detection and designing energy incentives.
- Installing device level sensors for each device is too costly and intrusive.
- Aggregated data is becoming available as smart meters become more ubiquitous.

Convolutional Sparse Coding

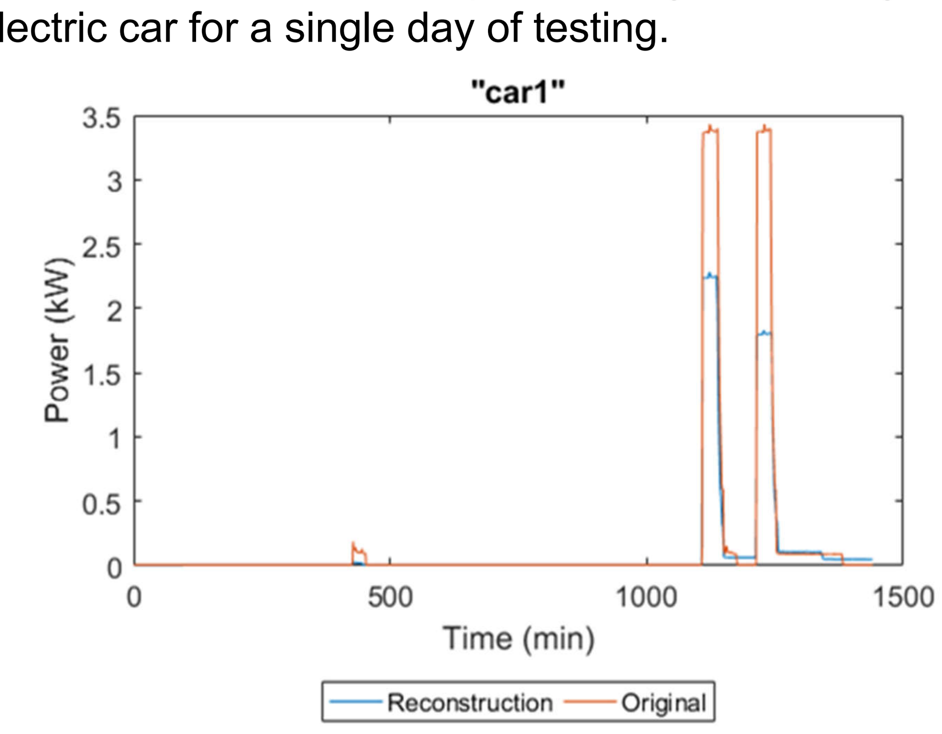
- We propose a supervised method for energy disaggregation utilizing convolutional sparse coding.
- The aggregate power signal is represented as a linear combination of learned signals and their time shifts.
- Convex Quadratic constraints are imposed to improve accuracy.
  - Sparsity
  - Total Energy
  - Non-Negativity
  - Time Sparsity
- An active set method was employed to solve the optimization problem.

$$\hat{A} = \underset{A}{\operatorname{argmin}} \left\| \bar{X} - \sum_{i=1}^{N} B_i * A_i \right\|_2^2 + \sum_{j=1}^{k} C_j (A)$$

where $\hat{A}$ are the optimal activation coefficients
$\bar{X}$ is the aggregate power usage signal
B_i are matrices containing data for each device
C_j are constraint functions of A



Reconstructed and Actual power usage of a refrigerator and electric car for a single day of testing.



Results And Future Work

- The algorithm was tested using a publicly available, real data set from Dataport Pecan Street.
  - Realistic sample rate of once per minute.
- 70 days of data were used to train the algorithm.
- 30 days of data were analyzed during testing.
- Two measures of error were defined for evaluation:
  - Root Mean Squared
  - Disaggregation Error

$$\sqrt{\frac{\sum_{t=1}^{M} \|X - \hat{X}\|_2^2}{T \cdot 1^{\intercal} X}} \qquad \frac{\sum_{i=1}^{N} \sum_{t=1}^{T} |X_{i,t} - \hat{X}_{i,t}|}{1^{\intercal} \bar{X}}$$

Root Mean Squared Error	0.1613
Disaggregation Error	1.163