

ABSTRACT

The modern urban life and increasing demands of energy are calling toward more energy conservation and energy efficient strategies. With increasing energy consumed by the households, energy savings and energy managements in the residential sectors are of great interests for obvious economic and environmental reasons. An efficient energy conservation and monitoring program requires some means of monitoring the power consumed by individual appliances within the households. The deployments of smart meters in smart grids in many countries have generated an increase in research interests in the areas of Non-Intrusive Load Monitoring (NILM) in recent years. NILM, or load disaggregation, are sets of techniques and methods that decompose the total aggregate consumptions, measured at a single point by the smart meter, into the respective appliance-specific consumptions in the household. Studies conducted have shown that information of the energy consumed by individual appliances in the homes can influence the behavior of the house occupants in a way that can achieve noticeable energy savings. There are several research challenges in the domain of unsupervised NILM approaches that do not require human intervention for learning and the set-up of additional measuring instruments for each appliance, apart from the smart meters, allowing a feasible economic adoption of the NILM method for energy disaggregation.

In this thesis, detailed literature reviews on methods and techniques applied to NILM and common challenges were presented. Enhanced approaches that tackle three essential challenges in the domain of NILM were proposed. Firstly, with the aim to achieve an improved disaggregation accuracy, an unsupervised approach for load disaggregation that embeds the mutual devices interactions information into the Factorial Hidden Markov Model (FHMM) representation of the total aggregate signal was introduced. The method was further extended with adaptive estimations of the devices main power consumptions effects and their two-way interactions. Secondly, the problem of devices with overlapping consumptions was addressed. A method to analyze the cohesion of devices' clusters to determine if a cluster should be split into two smaller clusters was proposed. The analysis of clusters cohesion is based on normality tests performed against two confidence levels. Thirdly, the modeling of continuously varying loads using a quantized continuous-state Hidden Markov Model (HMM) was proposed. A method to estimate the transition matrix that mitigates the two extreme cases of too frequent and never occurred transitions was introduced, and the Viterbi algorithm was used to estimate the power consumption profiles of the variable loads. Finally, the proposed model for continuously varying loads was integrated with the standard FHMM to produce a novel hybrid continuous/discrete state HMM, which is capable of modeling and disaggregating energy consumptions for a wider range of home appliances types.

The proposed approaches and techniques were applied and tested on data received on real houses from the Reference Energy Disaggregation Data Set (REDD). The proposed approaches, in general, enhanced the overall performance and accuracy of energy disaggregation. The work presented in this thesis represents an advancement in the state-of-art in the domain of NILM and contributes toward achieving energy savings in residential homes.