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Data Mining Approach for Energy Management based on Internet of Things (IoT) Paradigm

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Abstract

With the rapid growth of population and the evolution of new technologies, energy demand is increasing expeditiously in the residential sector. Energy management solutions should be provided to save environmental resources and guarantee the efficient use of energy.

The Internet of Things (IoT) plays a crucial role in promoting the smart city development. Smart grid environment has been introduced with the advent of the IoT. The smart grid has enabled the transmission of electricity in a bidirectional way between dwellings and utilities since that dwellings can generate electricity by integrating with renewable energy sources such as solar panels and windmills.

Smart meters are considered the main component of the smart grid environment. Smart meters measure the consumed power frequently based on a specified time interval for each dwelling at appliance level. Infinite stream of consumption data is being generated from smart meters. Precious information can be obtained by analyzing these data.

Data mining techniques are extensively used for extracting valuable information from smart meters data. However, mining smart meter data is a challenging task with the infinite stream being generated with its granularity level.

Energy management solutions can be developed with the availability of smart meters data. Demand Response (DR) programs are developed for guiding home residents to save energy. The key success of DR programs is to respect home residents preferences and their usage behavior. Thus, Designing DR programs that are tailored based on their preferences to motivate them to respond to DR programs.

The proposed approach presented in this work extracts interesting usage patterns from smart meters data to help home residents understand their consumption usage. The First contribution of this work is to extract temporal associations of energy consumption at appliance level. The second contribution of this work is to extract association between appliances usage through mining temporal association rules. Moreover, applying temporal clustering technique for grouping appliances with similar usage time.

In this work, an incremental approach has been developed to process data generated from smart meters. Thereby, new associations are discovered without mining the whole data in addition to maintaining the old ones since that residents behavior is changing continuously with time.

The proposed approach extends the Utility-oriented Temporal Association Rules Mining (UTARM) algorithm to discover appliances usage preference at a time. The basic idea for extending the UTARM algorithm is that it merges two data mining tasks together: temporal association mining and utility oriented mining.

The proposed approach is applied on a real-world time series dataset to evaluate its results. The UK Domestic Appliance-Level Electricity (UK-DALE) dataset has been used in this work. The dataset holds consumption logs for five dwellings with different durations starting from November 2012 to April 2017 with time resolution of 6 seconds.

The results achieved succeeded to extract interesting usage patterns with respect to the 24-hours of the day. Appliance-time associations are extracted considering appliances usage priority as a utility factor and the hour as a temporal partitioning factor. In addition to, discovering appliance-appliance associations having similar usage pattern with respect to the 24-hours of the day.

List of Publications

[1] S. Osama, M. Alfonse and A. M. Salem, "Intelligent Techniques for Smart Home Energy Management Based on Internet of Things (IoT) Paradigm," *Egyptian Computer Science Journal,* vol. 41, no. 3, pp. 33-43, 2017.

[2] S. Osama, M. Alfonse and A. M. Salem, "A Study on Pattern Discovery of Smart Meter Data for Energy Efficiency," *International Journal Information Models and Analyses",* vol. 7, no. 2, pp. 14-24, 2018.

[3] S. Osama, M. Alfonse and A. M. Salem, " Mining Temporal Patterns to Discover Inter-Appliance Associations using Smart Meter Data," *Big Data and Cognitive Computing",* MDPI, vol. 3, no. 2, 2019.

[4] S. Osama, M. Alfonse and A. M. Salem, " An Efficient Algorithm for Extracting Appliance-Time Association using Smart Meter Data," *heliyon",* ELSEVIER. (accepted)

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List of Abbreviations

ARMADA	Algorithm for Discovering Richer Relative Temporal Association Rules
CoPMiner	Correlation Pattern Mining
DCMiner	Dynamic Correlation Miner
DR	Demand Response
EU	External Utility
FP-tree	Frequent Pattern tree
FTU	Frequent Temporal Utility
FU	Frequency
HEMS	Home Energy Management System
IoT	Internet of Things
IU	Internal Utility
Kulc	Kulczynski Measure
LDA	Latent Dirichlet Allocation
M2M	Machine-to-Machine
PBuilder	Pattern Builder
SGSC	Smart Grid Smart City
SOM	Self Organising Maps
SPADE	Sequential PAttern Discovery using Equivalence classes
StrPMiner	Streaming Pattern Miner
TPUP	Time-slot Probability Usage Pattern
TWU	Transaction Weighted Utility
U	Utility
UK-DALE	UK Domestic Appliance-Level Electricity
UTARM	Utility-oriented Temporal Association Rules Mining

Chapter 1

Introduction

Chapter 1. **Introduction**

With the rapid growth of population, there is an expeditious rise in energy demand all over the globe [1]. Energy management solutions are needed to guarantee the efficiency of energy use, thereby maximizing productivity, minimizing energy costs, reducing environmental effects such as the emissions of carbon dioxide CO2. Thereby, providing a cleaner environment and preserving natural resources.

Energy is consumed by mainly four sectors: residential, commercial, transportation and industrial. The proposed work focuses on energy management solutions in the residential sector.

Energy consumed in residential sector is related to the activities of home residents and their behavior of using their home appliances. The daily life of home residents follows some routines habit to some extent that makes it possible to study and understand their preferences. For example, microwave and coffee machine are used during breakfast activity while oven and kitchen lights are used during dinner activity. Understanding the behavior of home residents and respecting their preferences are essential factors for developing energy management solutions.

Extracting useful patterns from consumption data has a great benefit for both consumers and producers. For consumers by lowering their electricity bills and for producers by preventing system stress and supply shortage.

1.1 Motivation

In regard of the evolution of new technologies, energy demand is increasing expeditiously. Thus, increasing the pressure on power plants, utilities and natural resources. Moreover, traditional electric power systems are facing several challenges such as system stress conditions in peak hours causing supply limit and blackouts in large areas [1].

The residential sector is one of the main contributors in power consumption. The power consumed in residential sector has an increase around 300% in the United States from 1949 to 2011. The power consumed in 1949 was around 5,599 Quadrillion Btu of power energy and then in 2011 the consumption has been increased to be 21,619 Quadrillion Btu [2].

With the inflation rates of electricity prices, home residents begin to pay much attention to their energy consumption. However, they failed to save energy in their daily activities due to the lack of knowledge of their appliances usage consumption. Since the only measure they have is their electricity bills which do not help them to understand what behavior that they are doing to make it high or low.

1.2 Objectives

Recognizing and understanding home residents behavior and provisioning a continuous feedback about their consumption usage is one of the effective ways to save energy in the residential sector.