UNIVERSITI PUTRA MALAYSIA

APPLIANCE LEVEL STAND-BY BURST FORECAST MODELLING USING MACHINE LEARNING TECHNIQUES

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By

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Electric power is an expensive and scarce resource and the concept of modern life is not possible without the continuous uninterrupted supply of it. Therefore, a lot of efforts have been made in past to conserve and optimize the use of electric power so that it could be efficiently distributed to all consumers. The efforts to conserve the energy include government and other organizations' sponsored awareness campaign for public to encourage them to use the best practices while the efforts for optimizing its use are led by the researchers and industries. The electrical appliances and equipment are developed in a way that optimize the use of energy. In this direction, one of the important inventions was the use of standby mode for the electrical appliances which is employed when the appliance is plugged-in but not in active use. The standby mode helps optimize electric power use yet it causes some power leakage. This study strives to forecast the appliances' state (standby or running) in next minutes to prevent the power leakage during the standby mode: by accurately forecasting the standby burst the appliance could be put in off state during the forecasted burst duration. This work proposes a technique to model power consumption data and presents a comparative study of five different machine learning algorithms to study their suitability to forecast an appliance's state and standby burst. The proposed approach achieved around 90 percent accuracy and very good indications over precision, recall and F1-Score for models built using Decision Tree, Logistic Regression, Support Vector Machine (SVM), K- Nearest Neighbor (KNN), and Multilayer Perceptron (MLP).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PEMODELAN TAHAP PENGUASAAN STAND-BY BURST MENGGUNAKAN TEKNIK PEMBELAJARAN MESIN

Oleh

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Pengerusi : Profesor Madya. Ir. Mohammad Lutfi bin Othman, PhD
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Tenaga elektrik adalah sumber yang mahal dan langka dan konsep kehidupan moden tidak mungkin berlaku tanpa bekalan berterusan tanpa gangguan. Oleh itu, banyak usaha telah dilakukan di masa lalu untuk menjimatkan dan mengoptimumkan penggunaan tenaga elektrik sehingga dapat diedarkan secara efisien kepada semua pengguna. Usaha untuk menjimatkan tenaga termasuk kempen kesedaran yang ditaja oleh kerajaan dan organisasi lain untuk orang ramai untuk mendorong mereka menggunakan amalan terbaik sementara usaha untuk mengoptimumkan penggunaannya dipimpin oleh para penyelidik dan industri. Peralatan dan peralatan elektrik dikembangkan dengan cara yang mengoptimumkan penggunaan tenaga. Ke arah ini, salah satu penemuan penting adalah penggunaan mod siaga untuk peralatan elektrik yang digunakan semasa alat dipasang tetapi tidak digunakan secara aktif. Mod siap sedia membantu mengoptimumkan penggunaan kuasa elektrik namun ia menyebabkan kebocoran kuasa. Dalam kajian ini, kami berusaha untuk meramalkan keadaan perkakas (siaga atau berjalan) dalam beberapa minit berikutnya untuk mengelakkan kebocoran daya semasa mod siap sedia: dengan meramalkan secara tepat letusan siap sedia, kita dapat meletakkan alat dalam keadaan mati selama jangka waktu letupan yang diramalkan. Karya ini mencadangkan teknik untuk memodelkan data penggunaan tenaga dan menyajikan kajian perbandingan lima algoritma pembelajaran mesin yang berbeza untuk mengkaji kesesuaian mereka untuk meramalkan keadaan dan letupan siap sedia alat. Pendekatan yang dicadangkan kami mencapai sekitar 90 peratus ketepatan dan petunjuk yang sangat baik mengenai ketepatan, penarikan balik dan Skor F1 untuk model yang dibina menggunakan

Keputusan Pohon, Regresi Logistik, Mesin Vektor Sokongan (SVM), K Nearest Neighbor (KNN), dan Multilayer Perceptron (MLP).

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

MLA	Machine learning algorithm
DT	Decision tree
KNN	K- Nearest neighbor
SVM	Support vector machine
MLP	Multilayer perceptron
IEA	International energy agency
PV	Photovoltaic
SEMS	Smart energy management system
EMS	Energy management system
HEMS	Home energy management system
DR	Demand response
PAR	Peak to average
MILP	mixed-integer linear programming
DG	Distributed generation
ESS	Energy storage systems
HVAC	Heating, ventilation and air conditioning
GA	Generic algorithms
GDP	Gross domestic products
IT	Information technology
CFL	Compact fluorescent lamp
LED	Light emitting diode

AC	Air condition
TV	Television
ERM	Energy resource management
SRAM	Static Random access memory
DRV	Data retention voltage
SB	Static blockade
ARIMA	Auto-regressive integrated moving average
DLB	Dynamic Load Balancing
CMOS	Complementary metal–oxide–semiconductor
LP	Linear programming
MLP	Mixed linear programming
BMS	Battery management system
FES	Fuzzy expert system
WSN	Wireless sensor network
ANN	Artificial neural network
UK	united Kingdom
CSV	comma separated value

CHAPTER 1

INTRODUCTION

1.1 Background

Energy is one of the most scarce and expensive resource. The cheapest and cleanest energy is that which is not used. Using energy efficiently, conserving energy and materials will reduce energy usage, greenhouse gas emissions and is the focus of Energy Management (Susanne & Hiroshi, 2007).

Recent environmental problems as a global issue has attracted great attention for energy saving. As a result efforts are being made for energy saving and governments are devising policies that encourage the distribution of energy saving systems, including individual households who voluntarily install energy saving systems to reduce electric power consumption (Jinsung et al., 2013). For the last few decades, various alternatives to conventional sources of energy like solar, wind, hydrokinetic and biomass energy have been explored. However, attention must also be given to the best utilization of energy, improvement in energy efficiency and optimum management of energy resources. In-fact, energy management deals with already existing sources and actual consumption. It includes planning and operation of energy related production and consumption units (M. Reyasudin et al., 2016). Energy management is the best solution for direct and immediate reduction of energy consumption.

An energy saving system refers to a system that saves energy consumed by cutting off wasted electric power such as standby power (Jinsoo et al., 2009). Factors that are involved in the wastage of energy include consumer carelessness, line and supply losses, distribution and standby mode loss.

1.2 Problem Statement

Many works have been carried out to forecast the power consumption in various settings, such as household, commercial building, city, etc., as well. However, to the best of our knowledge, no work has been carried out to forecast the standby mode switching time and burst at an appliance level with a fine temporal granularity such as minute. In this work, the problem to predict the state of an appliance and determine the suitability of various machine learning algorithms, namely Decision Tree, Logistic Regression, KNN classifier, MLP, and SVM, for predicting the state of an appliance at a given instance of time is addressed.

1.3 Objectives of the Study

This work aims to achieve the following objectives.

1. To propose an appliance state (standby or running) forecast model, and
2. Study the suitability of Decision Tree, Logistic Regression, KNN classifier, MLP, and SVM to predict the burst.

1.4 Hypothesis of the Research

Using machine learning algorithms (e.g. Decision Tree, Logistic Regression, KNN classifier, MLP, SVM, etc.), the standby mode switching time and the burst (interval an appliance would remain in this mode) could be forecasted and hence used in power conservation.

1.5 Scope of the Study

This research work is limited to study existing machine learning algorithms to effectively forecast the standby switching time and burst. The study uses published online datasets (https://www.refitsmarthomes.org/datasets/) of household power consumption, as detailed in Chapter 3, and does not use on purpose collected data. In this work, only cooling devices (fridge, refrigerator, freezer, fridge-freezer, etc.) are used as these are the ones which are continuously plugged in and need to be automatically switched on-off, rather than going to standby mode, after a certain period of time. This fact makes these devices an interesting case of study for stand-by burst forecast, unlike other electric/electronic devices such as computer, kettle, microwave, etc. which are switched on/off or put on stand-by mode as per the need of the user.

1.6 Research Contribution

This work comprises of all the steps as mentioned above, in Section 1.4. However, it's main contributions are:

i. Data preparation to remove the consistencies in the data sets such as, irregular peaks, null values, and missing data. The appliance profiling was also performed to categorize the power consumption is running and standby mode.

ii. The primary contribution of this work resides at the data modelling stage. It proposes to model the available time series data in a tabular form as past events representing the independent variables while the current event is the dependent variable. The problem is modeled as a classification problem and it is shown that such modeling technique gives very accurate results with accuracy of machine learning algorithms reaching close to 100 percent.

iii. This work uses the most suitable machine learning algorithms (Decision Tree, Logistic Regression, KNN classifier, MLP, and SVM) to build the forecast models and evaluated them using the most appropriate evaluation metrics (accuracy, precision, recall, F1 score). Findings of the chosen algorithms are documented that produce very promising results.

1.7 Thesis Layouts

Chapter 1 discusses the background and motivation for this study. This chapter also provides the hypothesis and formally state study problem. The objectives, scope and contributions of the study are also outlined here.

Chapter 2 analyzes the related work and discusses the state-of-the-art standby power consumption management.

Chapter 3 details the methodology and procedures of the study including the data sets and the analysis performed. Rationale to choose the selected machine learning methods is also detailed in the same chapter.

In Chapter 4, results obtained from the analysis are presented and it is discussed that how useful could they be in standby power management.

Chapter 5 summarizes the work and puts whole of this study into a nutshell. It also discusses the important future directions that can lead from this work.

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