Chapter 11

Global and Local Clustering-Based Regression Models to Forecast Power Consumption in Buildings

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ABSTRACT

The study of energy efficiency in buildings is an active field of research. Modeling and predicting energy related magnitudes leads to analyze electric power consumption and can achieve economical benefits. In this study, classical time series analysis and machine learning techniques, introducing clustering in some models, are applied to predict active power in buildings. The real data acquired corresponds to time, environmental and electrical data of 30 buildings belonging to the University of León (Spain). Firstly, we segmented buildings in terms of their energy consumption using principal component analysis. Afterwards, we applied state of the art machine learning methods and compare between them. Finally, we predicted daily electric power consumption profiles and compare them with actual data for different buildings. Our analysis shows that multilayer perceptrons have the lowest error followed by support vector regression and clustered extreme learning machines. We also analyze daily load profiles on weekdays and weekends for different buildings.

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INTRODUCTION

Nowadays, building consumption is estimated to be about 40% from total energy consumed in developed countries (U.S. Department of Energy, 2010). The International Energy Agency (IEA) claims that building sector is one of the most interesting sectors to invest in energy efficiency. From the economical point of view, it is possible to reduce the energy consumption in 1509 Mtoe (1 toe = 1 tonne oil equivalent = 11.63 MWh) in year 2050. This fact also implies important environmental benefits: if the energy demand is reduced from buildings, the carbon dioxide (CO$_2$) emissions could be dramatically reduced too. It can be estimated that 12.6 Gt of CO$_2$ could not be emitted to the atmosphere in 2050 (I.E.A. International Energy Agency, 2013).

An important part of this consumption is due to the Heating, Ventilating and Air Conditioning (HVAC) systems. For instance, in the USA, HVAC systems are 50% in building consumption and 20% in total electric energy consumption (Pérez Lombard, Ortiz, & Pout, 2008).

European Commission has initiated actions to reach a 20% reduction in energy consumption until 2020. It would imply 30 billion Euros savings per year (European Commission, 2010). The prediction of energy demand in buildings is an important tool to obtain economical and environmental benefits, allowing to:

- Improve the knowledge of electric power demand.
- Optimize HVAC systems.
- Contract the optimal electric power requirements that fit buildings needs.

In the literature, there is a great variety of techniques that can be used in prediction of energy demanding tasks: Linear regression (LR) is applied to predict monthly electrical consumption in large public buildings (Ma, Yu, Yang, & Wang, 2010), autoregressive integrated moving average (ARIMA) models let failure detection in electronic equipment (Bian, Xu, Li, & Xu, 2007), also, the building occupancy is considered to improve predictions (Newsham & Birt, 2010). Artificial neural networks (ANN) have been widely applied to study energy consumption in buildings: minimization of the energy to air condition an office-type facility (Kusiak, Li, & Tang, 2010), energy of office buildings with day lighting (Wong, Wan, & Lam, 2010) and air condition heating dependence on electrical consumption (Ekici & Aksoy, 2009). Also, ANN are applied to analyze power consumption in subway station design in (Leung & Lee, 2013) and support vector regression (SVR) is utilized in (Zhao & Magoulès, 2010) to predict electrical consumption in large buildings using simulated dataset.

For this study we used real datasets from 30 different buildings of the University of León (Spain). Linear time series and machine learning techniques, as Multilayer Perceptrons (MLP), SVR and ELM were utilized to model and predict active power of each building. We observe that multivariate non-linear methods as MLP, SVR and ELM give better results than classical autoregressive (AR) or LR models.

ANALYZED DATASETS

From the technical code of Spanish buildings (Ministerio de Fomento, 2010), the city of León (Spain) is placed in E1 climate zone at 346 m above sea level. This zone has severe climate conditions in winter as well as in summer, hence the electrical consumption due to HVAC equipment is high. Table 1 shows some statistics of climate variables, the temperature goes from -3.69°C in winter to 38.95°C in summer.

The data was recorded simultaneously for 30 buildings placed at campus of the University of León from March 1, 2010 to March 31, 2011. The buildings purposes are of different nature: teaching, research and services as administration
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