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ScienceDirect

Energy Procedia 116 (2017) 407–415

Energy Procedia

www.elsevier.com/locate/procedia

The 15th International Symposium on District Heating and Cooling

Trend Analysis to Automatically Identify Heat Program Changes

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Abstract

The aim of this study is to improve the monitoring and controlling of heating systems located at customer buildings through the use of a decision support system. To achieve this, the proposed system applies a two-step classifier to detect manual changes of the temperature of the heating system. We apply data from the Swedish company NODA, active in energy optimization and services for energy efficiency, to train and test the suggested system. The decision support system is evaluated through an experiment and the results are validated by experts at NODA. The results show that the decision support system can detect changes within three days after their occurrence and only by considering daily average measurements.

Peer-review under responsibility of the Scientific Committee of The 15th International Symposium on District Heating and Cooling.

Keywords: District heating; Trend analysis; Change detection; Smart automated system

1. Introduction

In the district heating (DH) domain, operators address several conflicting goals, such as satisfying demands of customers while minimizing production and distribution costs. To achieve this, one solution is to equip each customer building with a smart system. Such a system should continuously monitor heat usage, predict future demand, exchange information with operators, and perform demand-side management. Moreover, the system needs to automatically learn the energy usage of the building and adopt its behavior accordingly.

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1876-6102
Peer-review under responsibility of the Scientific Committee of The 15th International Symposium on District Heating and Cooling.
10.1016/j.egypro.2017.05.088

NODA Intelligent Systems AB[1], an active company in the DH domain, is developing and providing retrofit smart systems to maximize energy efficiency in buildings. These systems consist of controlling hardware together with a range of sensors, which are added on top of the existing control system.

Self-learning and adaptation are two important features of any smart system. However, these two features make the system sensitive to manual changes in the heating system, forcing the system to re-learn its characteristics. Most commonly, this relates to applying changes in the temperature program of the controller e.g. by the owner's building. These changes can lead to use more energy and to add extra charges in the case of increasing the temperature of the system.

Although retrofit solutions such as NODA's smart system can decrease the cost of replacement of the existing control system, their functionality can be affected by the limitation of these existing controllers. Due to this reason, NODA's smart system is unable to detect manual changes online. Hence, NODA's operators need to spend significant efforts to detect the manual changes by analyzing the received information from each building controller. To make this process more efficient, a decision support (DS) system can be used to assist operators. DS systems are computer-based information systems, which aim to facilitate and support the decision-making processes [1]. The major components of DS systems are: 1) the user-interface, 2) the models and main logic, 3) the database, and 4) the DS functionalities and architecture. DS systems are categorized based on their functionalities into: data-driven, knowledge-driven, model-driven, document-driven and communication-driven DS systems [1]. Among these different types, data-driven systems can provide an online support for decision making through applying machine learning (ML) and statistical techniques to analyze large collections of data.

Machine learning is a branch of artificial intelligence, which includes the study of algorithms that can learn and improve their knowledge by building models from input data to perform specific tasks. Most common tasks in ML, such as classification and regression modeling, are solved with supervised learning methods. Supervised learning uses labeled data to train models [2]. Suppose we are given data in the form of $(\vec{x}_1, y_1)$, $(\vec{x}_2, y_2)$, …, $(\vec{x}_N, y_N)$. In each pair or instance $\vec{x}_i\ (input)$ denotes a vector, which consists of feature values such as indoor and outdoor temperature, and $y_i(output)$ indicates a label or outcome of the target attribute. The aim is to train a model to predict the label of the target attribute (y_i) of each new instance, e.g. predicting the secondary supply temperature based on the indoor and outdoor temperature. The target attribute in regression modeling is numeric and in classification modeling it is categorical.

In this paper, we propose a data-driven decision support system that uses ML techniques to detect manual changes by predicting the secondary supply temperature based on the outdoor temperature and analyzing the energy consumption of each building. The aim of such a system is to provide complementary decision support for NODA's operators to detect manual changes easily and efficiently. The proposed DS system uses a two-step classifier, a combination of k-means and support vector regression (SVR), to detect manual changes within three days after their occurrence by considering daily average measurements.

2. Background and related work

A district heating system (DHS) is a centralized system that produces space heating and hot tap water for consumers based on their demand at a limited geographic area. A DHS consists of three main parts: production units, distribution network, and consumers. The heated water supplied in a production unit circulates through the distribution network and will be available to consumers.

The main aim of a DHS is to minimize the cost and pollution by considering demands of consumers and producing just the necessary amount of heat. Hence, being able to predict the heat demand can assist production units to plan better. However, modeling the heat demand forecasting is a challenging task, since water does not move fast. In some situations, the distribution of heated water can take several hours. Moreover, there are a number of factors that affect the forecast accuracy and need to be considered before any plan for production units can be constructed. Some of these factors include [3,4]:

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[1] www.noda.se/en/main