KnE Engineering

SEC 2019
III Annual International Conference "System Engineering"
Volume 2020

Knowledge E
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Conference Paper

Smart Thermostats in Building Automation Systems and Smart Homes

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Abstract

This article surveys the current achievements concerning smart thermostats for smart homes and smart buildings and observes the level of smartness of the microclimate control systems for buildings and rooms. The article shows the results of analyzes the advantages and disadvantages of the marketed solutions and sets requirements for smart thermostat as a component of building automation system. All solutions were classified at three "smartness levels", from zero to second, where zero level means simple manually adjusted temperature regulator, first level assumes working according the programmable schedule. The second level smart thermostat automatically generates and dynamically changes its schedule basing on the users' activity and presence, as well as on user-defined priorities. The article sets goals for further research in the field of self-learning algorithms for smart thermostat, because it seems actual to develop a self-learning smart thermostat capable of supporting a large buildings; it should analyze user behavior and effect control both at the level of a whole building and at the level of single rooms.

Keywords: smart thermostat, smart home, building automation, energy saving, control systems, controller, regulator, algorithm

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Received: 5 March 2020
Accepted: 18 March 2020
Published: 8 April 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the SEC 2019 Conference Committee.

1. Introduction

One of the most interesting cyber physical systems, *Internet of Things* stands for the conception of a network of physical objects (things) equipped with embedded technologies for interaction with ambient environment and with each other [1]. In categorizing IoT market, authors distinguish: a production component always existing in various industries; a regulatory component built by federal authorities adopting acts for better government and public safety; a consumer component encompassing solutions for a wide range of end users and matters of handling smart homes [2].

Smart home is a system for automation of the building's technical systems. It can be used to control heating, ventilation and conditioning systems (HVAC), turn on/off and tune lighting, contribute to security (as a trespass- or water/gas-leak alarm system) [3, 8]. Energy saving is a wide-spread function of the smart homes [4–7]. Spreading these functions through the whole building, one can speak of *smart building*, a building automation system.

We will take a closer look at the cyber physical system designed to maintain the indoor microclimate parameters. Modern buildings are equipped with various system for heating, ventilation and conditioning. Each of such systems usually has its own control system. In most cases, a room is equipped with water heating radiators, electric underfloor heating and a conditioning system. The radiators are manually controlled with a mechanic temperature regulator maintaining a selected temperature. The underfloor heating is also user-configurable and designed to keep a selected temperature. The ventilation system has either constant or variable capacity. The conditioning system has its own temperature regulator with its own user-defined temperature. All the above system installed in the room are not connected; they are controlled independently.

Improper control of the above systems operating together may make them work against each other, thus wasting electric energy.

Another point to consider is that different systems for heating or cooling may have different capacities and thermal energy cost factors which depend on external reasons. For example, at certain correlations between the indoor and outdoor temperatures, ventilation is more energy efficient than conditioning [9]. It is also important to plan operation modes and to analyze the actual need for microclimate which depends on whether there are people in the room.

Summarizing the above, optimal indoor temperature control requires an optimal regulator to provide a required regulation quality at minimal power consumption or minimal total cost of consumed power [9].

2. Results and Discussions

Here, we will observe the basic requirements for self-learning systems of temperature control (smart thermostats).

1. Power saving in natural and money form. Classic thermostats can set temperature to one value which has to be changed manually. Not an effective way to use power, we will call it "smartness level 0". Programmable classic models can plan indoor temperature

at certain hours of the day; so, the temperature can be decreased when there are no people inside which saves electric power greatly (“smartness level 1”).

Smart thermostat automatically generates and dynamically changes its schedule basing on the users’ activity and presence, as well as on user-defined priorities. This approach allows the best economy (“smartness level 2”). Some thermostat models analyze human’s preferences over time and build their schedule accordingly. Instead of predicting user’s schedule according to user’s previous behavior, other thermostats automatically react to user’s actions. Auto scheduled models rely on user’s habits, local weather or user’s answers to a few simple questions.

2. Integrability of thermostat in smart building. Some models allow home automation for a thermostat to connect to other devices of the smart home environment. For example, a thermostat can be coupled with a smart lock activating the “nobody’s home” mode when the door is locked etc.

3. Notifications, reminders, and user support. Most thermostats feature various notification functions, for example, to remind the user that it is time for conditioning maintenance or that the cooling system needs new air filters. Other models will warn user about problems with the heating or cooling systems or allow to contact the support center responsible for maintenance of the thermostat.

Here, we will observe examples of thermostats of smartness levels 1 and 2.

Siemens REA23 (Fig. 1), like many similar models by other manufacturers, belongs to smartness level 1. This device is used in standard heating systems, e.g. radiator- or convection systems, and offers the following basic functions [10]:

- keeping set temperatures.
- accurate room-temperature adjustment.
- constant autotuning of PID-control algorithm.
- availability of 2-position control.
- broad scheduling options.
- one temperature setting for each heating period.
- one 24-hour operation mode with one heating period.
- remote control.
- sensor calibration and reset function.
- freeze protection.

The thermostat works in self-learning mode, thus adjusting the adaptive PID-controller automatically. Still, temperature regulation schedule is user-defined, not automatically composed according to user behavior.

Figure 1: Siemens REA23.

Nest Learning Thermostat (Fig. 2) belongs to smartness level 2. The device fits in the user's schedule and preferences [11, 13-15].

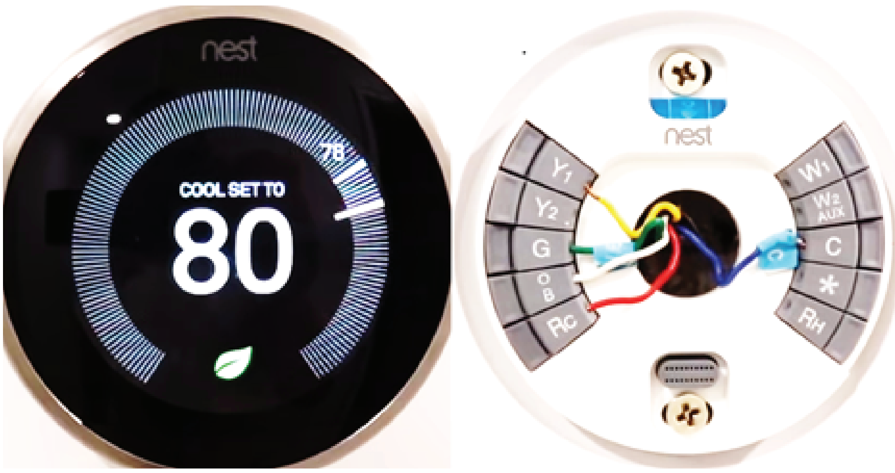

Figure 2: Nest Learning Thermostat

Being self-programmed for a week, Nest thermostat creates a customized schedule according to the temperature tuning by the user [11, 13-15]. The device constantly adapts itself to all the changes in the user's schedule, since the Auto-Away function automatically recognizes when there is nobody home. Then the thermostat automatically controls temperature to prevent heating an empty house [11, 13-15]. To indicate the economy of this approach, the Nest Leaf technology will show the effectiveness of the settings and temperature mode [11, 13-15].

Similar functions are implemented in smart thermostats by Honeywell (Fig. 3), Ecobee SmartThermostat (Fig.4) and many others [12-15].

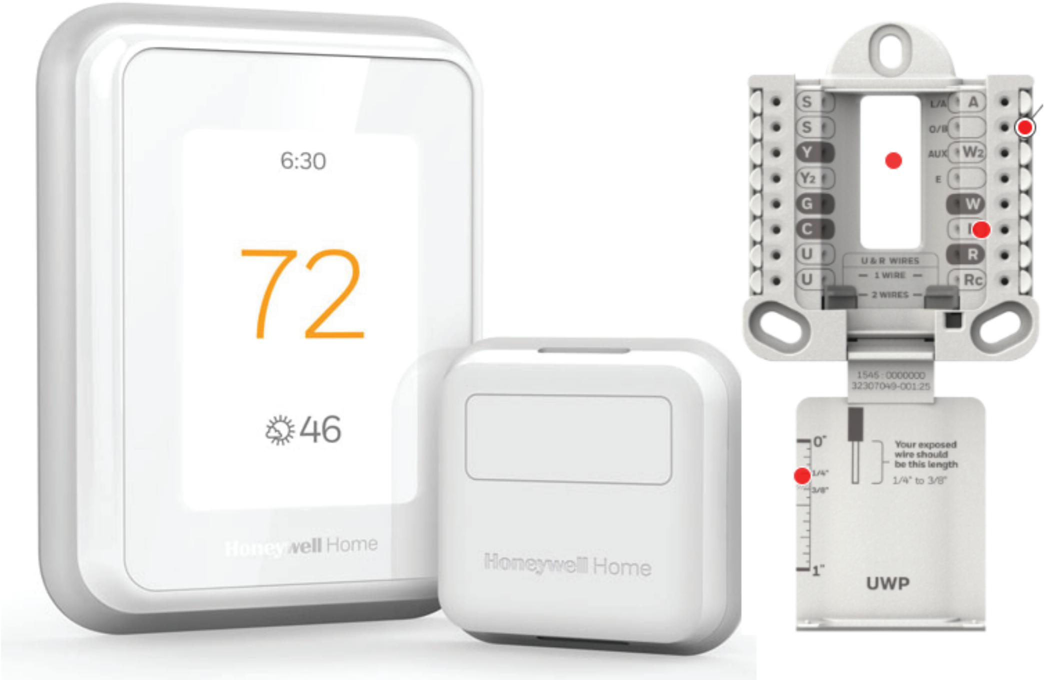

Figure 3: Honeywell T9

Figure 4: Ecobee SmartThermostat

However, we have tested the thermostats and concluded that the primary application of these devices is automation of living premises in the conditions of the USA and Europe and that they are not fully suitable for the heating and water supply systems of Russia. Moreover, these devices do not provide automation of whole building. In many buildings, the heat transfer agent temperature is controlled through mixing the streams of the heat transfer agent from the feeding pipe with the stream from the return pipe. Meanwhile, the consumption of the heat transfer agent in the heating system is constant which is more efficient and convenient than temperature control across the whole building or in separate rooms by adjusting the heat transfer agent consumption with valves or taps. A regulating controller provides automatic temperature control within the building relying on the readings from a sensor of indoor and outdoor air temperature. This controller also decreases temperature over weekends and holidays and at night and eliminates overheating in autumn and spring. In fact, this is a thermostat of smartness level 1 being used for a whole building. It seems actual to develop a self-learning smart thermostat capable of supporting a large building; it should analyze user behavior and effect control both at the level of a whole building and at the level of single rooms.

3. Conclusion

In this view, we believe it is actual to develop self-learning algorithms for smart thermostat. The main development's tasks are:

- development of a thermal model of a typical room to enable model-oriented design.
- development of intelligent learning algorithms for the thermostat to analyze user behavior.
- development of algorithm selecting control channels within a building.
- implementation of maximal-economy and maximal-comfort modes at user's choice; the energy save mode should choose among available energy sources offering different cost rates.
- implementation of algorithms based on a specific controlling device.

Acknowledgement

This research has been performed under contract with Iridium LTD, *Mathematical Support of Smart Thermostat Algorithm. Stage 1.*

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