The design space of building user-centered AI user interfaces for smart heating systems

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ABSTRACT

Smart heating systems are one of the core components of smart homes. A large portion of domestic energy consumption is derived from HVAC (heating, ventilation and air conditioning) systems, making them a relevant topic of the efforts to support an energy transition in private housing. For that reason, the technology has attracted attention both from the academic and the industry communities. User interfaces of smart heating systems have evolved from simple adjusting knobs to advanced data visualization interfaces, that allow for more advanced setting such as time tables and status information. With the advent of AI, we are interested in exploring how the interfaces will be evolving to build the connection between user needs and underlying AI system. Hence, this paper is targeted to provide early design implications towards an AI-based user interface for smart heating systems.

KEYWORDS

user-centered AI, user interface, smart heating system

1 INTRODUCTION

Smart heating systems are one of the central components of smart homes. Modern smart thermostats offer even more advanced functionality with AI technology, allowing the heating systems to "adapt" automatically, instead of being adjusted [5]. Recent research into smart heating systems has covered both the user side as well as the technological perspective [3]. It is important to better understand how users interact with heating systems, and how designers can "produce HCAI by integrating artificial intelligence algorithms with user interface designs in ways that amplify, augment, enhance, and empower people[7]." Hence, our research is aimed at exposing how users interact with heating systems – both classical and smart heating – and what their needs and challenges are, in order to investigate the design space of more advanced user-centered AI user interfaces for smart heating systems. We want to address two research questions: What are the needs of users towards controlling heating systems? What can we learn from that in terms of the design space for building user-centered AI user interfaces for smart heating systems?

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2 METHODS AND FINDINGS

2.1 Understanding users: User Model

We are in the process of conducting a user study on heating users in Germany, investigating user needs based on qualitative interviews. The goal of the smart heating system is to balance comfort and energy-efficient [4]. Within our interview data, we have identified three levels of comfort situations that the interviewees desire and that would need to be provided by smart heating systems. It goes from comfort level 1 – the basic comfort needs to comfort level 3 – more advanced comfort needs.

2.1.1 Comfort Level 1: achieve the target temperature and keep a comfortable humidity. All of the interviewees are aiming for a basic comfort level, which holds the room temperature and humidity within a certain target range. This is done using the classical thermostat, which however only shows 1-5 levels without precise information on how this affects room temperature, which is unsatisfying for the users. *" So not just you put it between one and five, but maybe you could have finer settings ... "* (R4) Even for users of smart heating systems, the temperature shown in the interface is not always that helpful, because heat is not evenly distributed in rooms and can differ according to where it is measured. *" So I need to set the temperature in the office to 22 to 23 degrees so that I reach a temperature of 20 and 21 in the office. So I've learned that I need to set it two to three degrees over my target temperature."* (R3) However, all of the interviewees prefer to have precise information about the room temperature and also want to maintain a comfortable humidity level, requiring to open windows regularly. *" And we return the heating down when we open the windows to ventilate the room."* (R4)

2.1.2 Comfort Level 2: preheat before arriving home and turn off when leaving home or not in the specific room. Having rooms preheated before arrival is a central requirement for all users in terms of comfort. As most heating systems take time to warm up the air, its important to management the schedule to avoid times where the room is still cold. At the same time, turning off heating is important to save energy. *" The most part is I try to lower the temperature when I'm away and if, let's say I come home in one or 2 hours, I can then preheat this remotely."* (R3)

2.1.3 Comfort Level 3: achieve well-adapted personal thermal comfort in daily situations. Well-adapted personal thermal comfort is the main expectations of users towards smart heating systems, where they clearly need to exceed the properties of classical heating. This requires the systems to learn the habits of users and make adjustments based on the user's condition. *" We only wanted to turn on between eight in the morning and eight in the evening, and*

Table 1: Interviewees

Code	Gender/Age/Highest Degree	Buy/Rented	Living Situation
R1	Male/31/Master	Rented	The house is 30-40 years old with 15 apartments. He uses traditional central heating system.
R2	Female/34/Ph.D.	Rented	The apartment is about 60 years old. She uses traditional central heating system.
R3	Male/33/Ph.D.	Rented	The house is 40 years old with 5 apartments and 3 offices. He used smart heating system.
R4	Female/31/Staatsexamen	Rented	The house is 60-70 years old. She uses traditional central heating system.
R5	Male/32/Master	Rented	It is an old building with history. He uses traditional central heating system.

in the night it shall drop or whatever. So we don't have this right now. You have to do this manually. " (R2)

2.2 Understanding systems: System Model

For smart heating or smart thermostats, the main challenge lies in adapting the heating depending on the usage context and predictions of patterns and schedules of the inhabitants. Research has shown that identifying and surfacing the right internal models is a central part of the user experience design [8]. Building on that notion, we want to explore what aspects from the internal models of smart heating systems should be made visible to the users in the interface. While this can possibly become very complex, involving information about data pre-processing, model selection, model training etc., we use occupancy prediction and temperature forecasting as examples[9] [6]. For occupancy prediction, usually, there are different ways in which smart systems can predict occupancy. Often, this includes the use of cameras, wearables/mobile devices, and security systems with presence sensors [9] . For making predictions on the basis of such data, the most widely used approaches include Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN). As the occupants' behaviours will be influenced by many parameters, the model will try to figure out which inputs have the greatest influence, and select the parameter that matters the most. For temperature forecasting, there are several input variables [6] - weather condition, outdoor air temperature, solar radiation, and outdoor air humidity, occupancy status. Artificial Neural Networks (ANN) and Support Vector Machines (SVM) are the two main techniques. When using ANN approach [1], through analysis, among all of the input variables, the outdoor temperature is the highest important factor.

3 THE DESIGN SPACE OF USER-CENTERED AI INTERFACES FOR SMART HEATING SYSTEMS

Shneiderman[2]mentions that HCAI should focus on "amplifying, augmenting and enhancing human performance in ways that make systems reliable, safe and trustworthy" and also place an emphasis on the user experience which means putting human at the centre of design thinking. Based on our preliminary findings, from the user model, we capture 3 patterns from user needs - 3 kinds of comfort levels; From the system model, we capture the internal operation of the AI system of smart heating. How the interface can be taken as a channel between the user model and system model to fulfil the above-mentioned goal? We identified three design implications for building user-centered AI interface in smart heating systems.

3.1 Connect comfort level with AI internal model

Traditionally, the target temperature is the only information that is displayed on the interface of the control device. We can see from the system model in temperature prediction, the data is the final destination of the prediction, however, from the interview, we can see it neglects several things that users care on the user model, for example, the suitable humidity that can indicate when to open the window, drops in the temperature due to the need to open windows, the estimated time to arrive at the set target temperature, etc. All these things are related to the comfort that the users care about and should be shown on the interface and also with different comfort level-related settings.

3.2 Display AI internal model in the interface

In section 2.2, we put up a question - what aspects of the internal models of smart heating systems should be made visible to the users in the interface. Traditionally, AI functions have been hidden and systems are just showing the results of predictions or actions that are taken. As we can see, in different AI models, the features are used differently and result in different weights and features . Also, for example, in the occupancy prediction, the data resource is varied from camera to mobile device. With selected important features/factors and data resources visible in the interface, it can build users' trust towards prediction, because it can help them understand how the system works.

3.3 Provide input to involve user feedback into AI model

Interface as a channel between the user and the system can be treated as a bridge with several functions. It can show the system status as a monitor to the users in order to build trust; It can involve users' feedback with input channels. For instance, whether the prediction temperature is satisfactory actually can provide a reference towards the effectiveness of the AI model. For the functions like occupancy prediction, providing input channels to build interaction between the AI system model and users can increase the efficiency of the AI model. Users can provide their feedback towards their activity or the occupancy number to the AI model in real-time.

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