Designing adaptable smart home environment based on resident's activity

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Abstract
The main objective of this research is to design an adaptable smart home environment that is based on resident's activity and behavior. In today's world, smart homes are becoming the norm and many people use smart appliances on daily basis. The main purpose of smart home is to make a life more comfortable for residents that lives in it. But different people have different needs, so smart home should recognize their needs and adapt towards them. Previous studies focused on designing a smart home and how to make it more effective. These studies are not considering that smart home should continue to learn and adjust. Related to smart home adaptability, there is space for improvement and this research is trying to focus more on adapting smart home towards residents needs. Smart home system designed in this research features the following steps: collecting data via sensors, analyzing it, predicting behavior and adapting towards residents needs. The main result achieved in this research is a designed smart home system that is able to predict residents' behavior at a specific time of the day. Perspective for designing a smart home has been shifted towards adaptability to specific residents, instead of creating a solution based on standardized user. Adaptable smart home environment is even more important for residents that needs special assistance, like elderly people or people with disabilities. The suggested prediction system for smart home environment has the main goal to increase resident satisfaction and to make smart home more comfortable for living.

Keywords: Adapt towards residents needs, predict residents behavior, prediction system for smart home

1. Introduction
Living in a smart home or having some smart elements in your home has become normal in today's world. There are many possible options and many different devices that can make your home smarter. Together, all those devices and tools have something in common – they are universal and they work the same for everyone. But people have different needs and smart home should offer unique options tailored to resident's specific needs.

Smart home is the integration of technology and services through home networking for a better quality of living. It uses different technologies to equip home parts for more

intelligent monitoring and remote control and enabling them for influential harmonic interaction among them such that the everyday house works and activities are automated without user intervention or with the remote control of the user in an easier, more convenient, more efficient, safer, and less expensive way [1]. A smart home is called "intelligent", because its computer systems can monitor many aspects of daily life [2].

The main goal of this paper is to design a smart home environment that is automatically adapting to benefit resident's life in that environment. That is achieved by collecting and analyzing previous resident behavior. The value of this research is in changing perspective from making smart home environment that fits average resident, to a completely personalized environment based on resident's habits. User behavior data is collected with sensors. Collected data is analyzed and user behavior can be predicted based on previous behavior.

The expected result of this research is to design adaptable smart home environment that is changing towards resident's habits. Designed system is able to predict what action is expected from resident at specific time of the day. Smart homes should be more personalized and able to change towards specific resident's expectation. Based on its activity, smart home should be able to define which resident is using it. Since one of the main objectives of smart home is to make residents life more comfortable, it is important that it can understand resident's needs.

2. Literature review

There are many areas related to smart home that have space for improvement. Many researchers are interested in energy management within the smart home. In paper [3], current home energy management systems (HEMS) are analyzed and their role within smart grid. Researchers reviewed current architectures and functional modules of smart HEMS and advanced infrastructures and home appliances in smart houses are analyzed and reviewed.

Also, it is investigated how various home appliance scheduling strategies can reduce residential electricity cost. In paper [7], researchers implemented a day-ahead electrical load prediction approach for energy management systems (EMS). Their algorithm was designed so it can be part of any generic EMS and it is not associated with a prepared statistical or historical databases.

There is a lot of space for improving security in smart home applications, as it is described in paper [6]. Researcher concern was that different available smart home programming frameworks for third party programmers can also expose users to security risks. They did a security analysis of "Smart Things" smart home programming platform. They analyzed static source code analysis of 499 "Smart Things" apps and 132 device handlers. The result was that there are many potential security problems which have not being exploited yet.

Benefit of analysis of behavior data collected in smart home are mentioned in paper [8]. Researchers examined the actual benefit of smart home-based analysis by monitoring

daily behavior in smart home and predicting clinical scores for residents. They used a clinical assessment using activity behavior approach (CAAB) to model a smart home based on resident's daily behavior and predict the corresponding clinical scores. In paper [9], researchers created an intelligent environment that is adapting inhabitants need and assisting the person who needs special care.

Smart home controlling system is also an area of smart home that can be improved. In paper [5], researchers tried to reduce the impact of wireless interference on a smart home control network and unnecessary energy consumption in smart home. They implemented a prototype for smart home control network with smart control algorithm. They did an in-depth analysis of operation principles in home control systems.

3. Designing adaptable smart home environment based on resident's activity

This paper is focusing on modeling adaptable smart home environment. On the following figure, data flow in a designed smart home environment is shown.

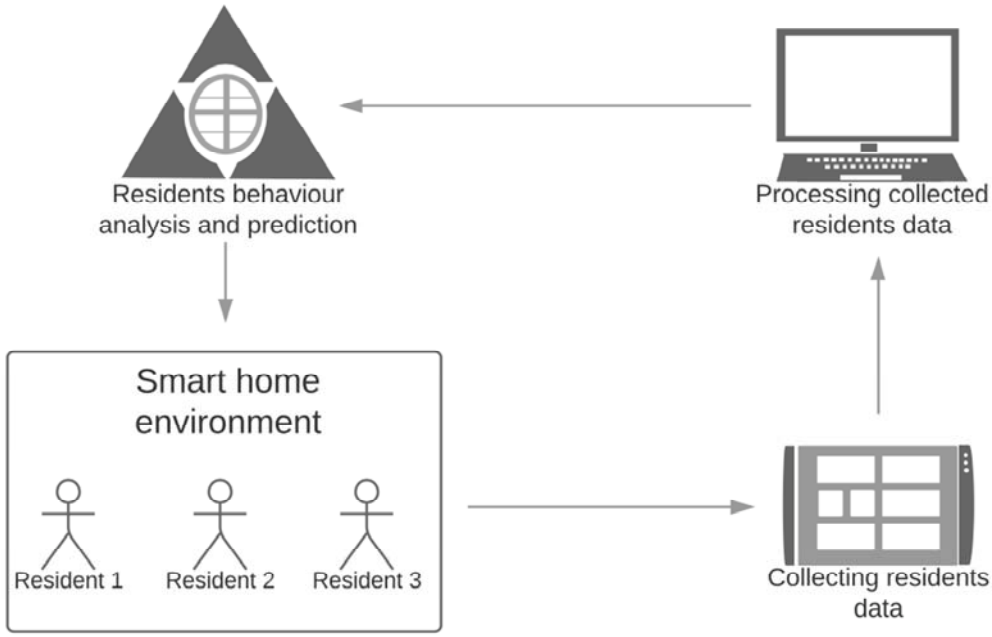

Fig. 1. Adaptable smart home data flow

Smart home on figure above collects information from residents using sensors. Collected data is processed and analyzed and resident's behavior is predicted based on collected data. Based on predictions, smart home is adjusting towards expected resident's behavior. As we can see on figure 1, designed system is based on following steps: (i) collecting data using sensors, (ii) processing collected data (iii) analyzing and predicting resident's behavior and (iv) adapting towards expected behavior.

Collecting data is done using sensors. Sensors are placed on specific places in smart home in order to track complete resident's motion. Smart home is defined as a home that has

programmable electronic controls and sensors that regulate heating, cooling, ventilation, lighting, and appliance and equipment operation in a way that responds to interior climate conditions in order to conserve energy [10] [11]. Sensors and monitors detect environmental factors including temperature, light, motion, and humidity. Control functionality is provided by software on computing devices or through dedicated hardware interfaces. Sensors and monitors are networked, usually wirelessly, using standardized communication protocols [12]. Smart home technologies (SHTs) comprise sensors, monitors, interfaces, appliances and devices networked together to enable automation as well as localized and remote control of the domestic environment [13]. Controllable appliances and devices include heating and hot water systems (boilers, radiators), lighting, windows, curtains, garage doors, fridges, TVs, and washing machines [15]. Smart home consists of different features that are oriented to individual users of the smart environment. The range of options that can be adjusted for user is wide. Current trends in home automation includes remote mobile control, wearable devices, automated lighting, automatic temperature adjustments, energy management, mobile or email notifications, streaming media, remote video surveillance and much more [19].

Collected resident's information are prepared and analyzed. Collected data can be analyzed using different data classifiers. Data is extracted to appropriate format and separated into training data and test data. Based on prepared data the system is predicting resident's behavior. The system is able to guess what resident will do at specific time of the day. After that, smart home is automatically adjusting based on expected resident's behavior.

In this paper collected data from sensors by CASAS (Center for Advanced Studies in Adaptive Systems) is used. Data is collected in smart home with woman volunteer resident [13]. Example of smart home environment with positioned sensors is shown on the following figure.

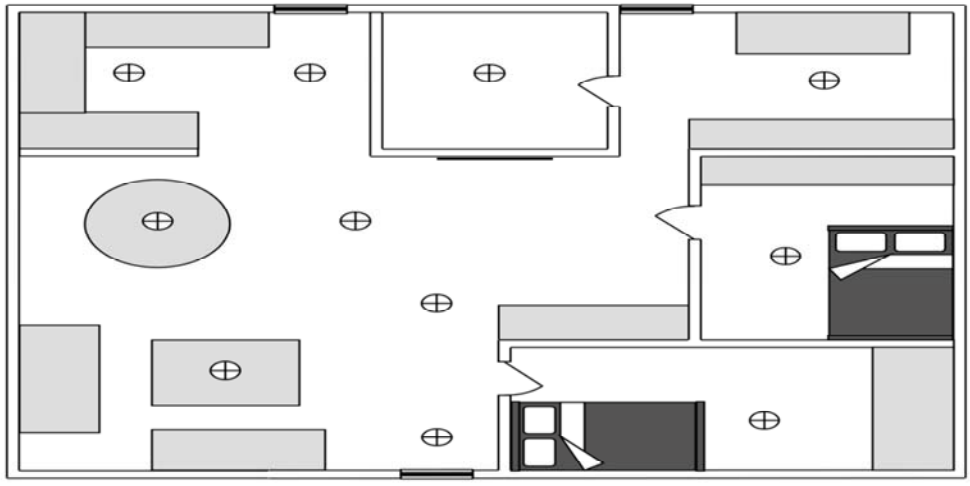

Fig. 2. Smart home with positioned sensors on specific places in apartment

As it is shown on previous figure, sensors should be positioned so they can track resident's behavior. Values read from sensors are collected and stored in a database that an intelligent agent uses to generate useful knowledge such as patterns, predictions, and trends [14]. In this paper only motion sensor from kitchen is used. Collected data is prepared and analyzed using Naive Bayes classifier. Based on resident's activity in the kitchen we are predicting when resident will use kitchen again. Prediction system built in this paper is using training data collected in two-weeks period at resident's home. The system is doing prediction for every day in following two-weeks period. Predicted data is compared with the real data that is collected within next two weeks.

Sensor that is used in this research is located in the kitchen (sensor: MO19). Data collected from sensor is processed and list of all times when mentioned kitchen sensor is used is extracted.

List of all times that had activated kitchen sensor is collected. These times are used to prepare training data for classifier. Training data contains one record per hour if sensor was activated within that hour. After that, preparation of data is done. Preparation depends on the format in which sensor data is collected. If data is stored in some database, data is easier to prepare. If data is stored in a file, then there is usually more data preparation involved. It is important to know in which format the expected output is needed. In example described in this paper, one record per hour is registered if kitchen sensor was activated.

The Naïve Bayesian classifier is used for creating predictions. Based on Bayes' theorem with independence assumptions between attributes. A Naïve Bayesian model is easy to build, with no complicated iterative parameters estimation which makes it particularly useful for very large datasets. Despite its simplicity, the Naïve Bayesian classifier often does surprisingly well and is widely used because it often outperforms more sophisticated classification methods [17].

For testing purposes, prediction is done for every hour within a day. Collecting and preparing of the test data is compared to the real data that is collected during the following two-weeks period (following days after data is collected and analyzed). In the following output, most informative features and output of prediction for testing data are shown.

Output 1. Output of prediction for testing data

Most Informative Features

time = '19'	*IN : OUT*	=	*9.8 : 1.0*
time = '04'	*OUT : IN*	=	*9.6 : 1.0*
time = '03'	*OUT : IN*	=	*9.6 : 1.0*
time = '05'	*OUT : IN*	=	*9.6 : 1.0*
time = '02'	*OUT : IN*	=	*9.6 : 1.0*
time = '01'	*OUT : IN*	=	*9.6 : 1.0*
time = '08'	*IN : OUT*	=	*5.5 : 1.0*
time = '20'	*IN : OUT*	=	*5.5 : 1.0*

time = '00' OUT : IN = 5.3 : 1.0
time = '18' IN : OUT = 3.6 : 1.0
['OUT', 'OUT', 'OUT', 'OUT', 'OUT', 'OUT', 'OUT', 'OUT', 'IN', 'IN', 'IN', 'IN', 'OUT', 'IN', 'IN', 'IN', 'IN', 'IN', 'IN', 'IN', 'IN', 'IN', 'OUT', 'OUT']

On the output shown above, most informative features are printed first. Most informative features in this case represents hours with the most certain prediction by this classifier. As it is shown on the output above, it is most likely that resident will be in the kitchen in time period between 19:00h and 20:00h. Under list of features, the prediction is printed for full day. As we can see, the resident goes often to the kitchen (except in the period from 22:00 - 08:00 when it probably sleeps). This result is compared to the real collected data in two-weeks period (following days after data is collected and analyzed). The accuracy achieved was 75.694%.

Based on predictions when resident will visit which room, smart home system can be proactive and prepare the room for resident. The room can be prepared by increasing heating to the specific level or increasing cooling to the specific level. Also, depending on the time of the day, light level can be adjusted at the specific time when resident is expected to enter the room.

4. Discussion

Many studies are focused on designing a smart home environment and how to make it more effective. The studies are usually not considering that smart home should continue to learn and that it should try to be proactive towards resident, so it can save resident's time and make more comfortable environment for living. Even thought smart homes usage is growing, there is enough space for improvements in current solutions.

There are many researchers that are basing their papers on reviews of current solutions in smart homes. As mentioned in [15] the holistic framework was incorporated using different components from IoT architectures/frameworks proposed in the literature, in order to efficiently integrate smart home objects in a cloud-centric IoT based solution.

Some researchers are focusing their research on analyzing how far are current smart homes from projected smart homes and can smart homes deliver on the promise of independent living of older adults [16]. Their aim is to answer that question by reviewing and discussing older adults' perspectives on independence and their views on smart home technology.

There are researches as [18] that are considering multiple residents and how to recognize specific resident's behavior. Their goal is to recognize the sequence of actions by a specific person using sensor readings. They presented an overview of existing approaches and current best practices for activity recognition in multi occupant smart homes.

The suggested prediction system for smart home environment has the main goal to increase resident's satisfaction and to make smart home more comfortable for living. We acknowledged that the proposed solution has also some limitations. The main

disadvantage of the proposed system is that time is the only considered factor. There are many other factors that should be considered, like working hours, weekends, holidays and all other dates when resident is not using home as expected.

5. Conclusion

At the time of writing there are not many consideration how smart home should adjust towards resident and how it can use data that it collects through sensors to benefit resident and make stay in smart home more pleasant and comfortable.

This can be more important for users that needs special assistance, like elderly people or people with disabilities, which can benefit the most from prediction systems and recommendation systems usage within smart home environment. It is important to mention that it might be even necessary to have an adaptable smart home in the future, as home itself can be of major help for some people groups.

In the future, this research can be used as a base for creating adaptable smart home system that will be able to recognize different residents in a smart home and based on their behavioral patterns to adapt according to the specific resident that is currently living in it.

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