Energy Saving in a Smart Waiting Room Using Context-aware Services Adaptation

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***Abstract*—Smart spaces have become an active research field over the last few years. The main objective of such spaces is to provide intelligent services to the user for improved comfort and energy saving. The recent advances in sensors network and embedded systems have helped a lot in the realization of smart spaces. In order to provide adapted services to the users, such spaces should operate in a proactive manner and according to the current context. The degree of intelligence of such spaces could be enormously enhanced with the context-awareness aspect. Defining context and establishing its components are basic steps for context-aware services adaptation in a smart space. In this paper, we propose a context-aware services adaptation for a smart waiting room which could improve both person's comfort and energy saving in such spaces. We describe the context using a clear and concise definition and use the naïve Bayes machine learning technique for the adaptation.**

Keywords-waiting room, context; service; adaptation; naïve Bayes.

I. INTRODUCTION

The main aim of smart spaces or intelligent environment is to assist inhabitants (resp. occupants) to live comfortably by not bothering them from concentrating on setting and configuring home appliances. The most common definition of a smart space is the one proposed by Cook and Das [1]: "Smart space is able to acquire and apply knowledge about its environment and to adapt to its inhabitants in order to improve their experience in that environment". Smart spaces should provide intelligent services in order to improve the quality of life, energy saving and safety of inhabitants. Smart spaces should provide adapted services in a proactive manner (without explicit intervention from user). In order to improve the intelligence of these spaces, services should be provided according to the current context. One example of smart spaces is the waiting rooms where people can wait (generally sitting) for some kind of services. An important issue in such spaces is energy saving. In several cases appliances of the waiting room such as light bulbs, cooling/ heating system and TV or radio/music player operate even when there is no person inside the waiting room which causes a great loss of energy. Context-awareness has become an important aspect of smart spaces. It could enhance both the person's comfort and energy saving of the waiting room and helps it to operate smartly by adapting services according to the current context. Context-aware services adaptation should be preceded by an important and basic step which consist of defining the context element and establishing its components. Several approaches for context-aware services adaptation were proposed for either pervasive systems or smart spaces. Most of them have the following same weakness point: not based on a clear definition of context and do not propose a clear method for context elements establishment which limit their use and affect the quality of services adaptation. In this paper, we propose a context-aware services adaptation for a waiting room which could enhances energy saving and comfort of waiting persons. Our approach is based on a clear definition of context and clear steps to extract context elements. The adaptation task is done using the naive Bayes machine learning technique.

The rest of this paper is organized as follows. Section II provides some background information about related work. Section III describes the overall environment of an exemplary waiting room. In Section IV we discuss details about context identification. Section V presents our context-aware services adaptation approach. The conclusion and future work will be given in Section VI.

II. RELATED WORK

Several approaches for context-aware services adaptation for smart spaces have been proposed over the last few years. Most of them were proposed for a particular type of smart spaces namely smart homes.Li et al.[2] developed a context-aware lightning control system for smart meeting rooms. They used an ontology-based context modeling approach and a rule based system for context reasoning. Madkour et al. [3] used a Weighted Case Based Reasoning (WCBR) for enabling context awareness. They illustrated the elaboration of an adaptive and autonomous control of heating Ventilation and Air Conditioning (HVAC). Ni et al. [4] proposed a case-based reasoning technique for services adaptation in a smart home. Chahuara et al. [5] presented an audio-controlled smart home based on a framework composed of knowledge representation module using a two level ontology, a situation recognition module based on the Semantic Web Rule Language *(*SWRL*)* logic reasoner and a decision making module based on the markov logic network (using weighted logic rules) to deal with uncertainty and imprecision of context information. Miraoui et al. [6] proposed a context-aware services adaptation approach for a smart living room using two machine learning techniques namely naive Bayes and neural network. Humayun et al. [7] presented a context-aware application which can provide service according to the predefined choice of user. It uses Mahalanobis distance based k nearest neighbor's classifier technique for inference of predefined service. They combined the features of supervised and unsupervised machine learning in the proposed application. This application can also adapt itself when the choice of user is changed by using Q-learning reinforcement learning algorithm. Badlani & Bhanot [8] proposed an adaptive smart home system for optimal utilization of power, through Artificial Neural Network (ANN). Kumar et al. [9] presented a semantic policy adaptation technique and its applications in the context of smart building setups. Humayun et al. [10] presented a machine learning based context-aware system which can provide service according to the trained model. Two effective learning algorithms: Back propagation Neural Network, and Temporal Differential (TD) class of reinforcement learning are used for prediction and adaptation respectively.

III. SMART WAITING ROOM

A. Description of a typical waiting room

A waiting room is a special place where people can wait (generally sitting) for a service. One can find waiting rooms in several locations: at doctor's office, at a lawyer office, at several government offices, at banks, etc. The main aim of a waiting room is to keep people waiting for their services in a comfortable state. An exemplary waiting room is composed of a set of appliances and furniture which can be mainly categorized in three classes: a) light system, composed of a set of light bulbs and window blinds, b) cooler/ heater system which is composed of a heater and a cooler or embedded in one air conditioner which can either make cooling or heating, c) entertainment system, which is composed of a TV and/or a radio/music player and d) a set of chairs (Fig. 1).

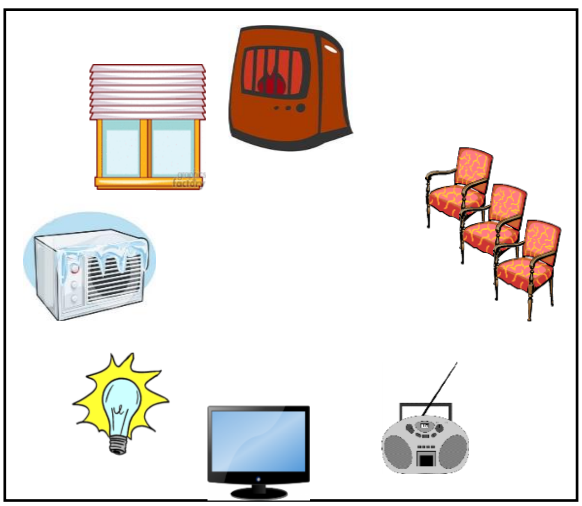

Figure 1. Main components of an exemplary waiting room

B. Expected running of a smart waiting room

In order to improve waiting people's comfort and saving energy, a smart waiting room should provide services according to the current context and proactively (without explicit user intervention) in an unobtrusive manner. In the initial and final state (the waiting room is empty), all the appliances should be off in order to save energy. As soon as at least one person enters the waiting room (state 1), the light system composed of window blinds and a set of light bulbs starts to adjust the inside light. When the system perceives at least one person sitting, it moves to state 2. In addition to running the light system, the smart waiting room should start the heating/cooling system to adjust the temperature inside the waiting room. After a few seconds, the entertainment system composed of the TV or the radio/music player should start and the waiting room goes to state 3. At any state, if the smart waiting room system perceives no one inside the waiting room, it should go to the initial state and put all appliances off or go to temporary state (state 3) during office hours where all appliances should be set at low energy consumption. Fig. 2 shows the state diagram of the overall operation of the smart waiting room.

IV. CONTEXT IDENTIFICATION

Context-awareness is a highly desirable property for smart spaces which allows them to provide proactively (without explicit intervention of users) adapted services according to the context of use. The first step of developing context-aware systems consists of defining context in a clear manner and establishing its components. In spite of the great number of definitions proposed for context, until now there are no agreed definition. Most of these definitions remain vague and general and do not provide clear steps or method to extract context elements. Some of the proposed definitions were based on enumerating contextual information (localization, nearby people, time, date, etc.) like those proposed in [11] [12] [13]. Others were based on providing more formal definitions in order to abstract the term, like the one proposed by Dey [14]. In our previous work [15], 16], we have made a survey of existing definitions of context and proposed a service-oriented definition of context for pervasive and ubiquitous computing environments which could be easily adapted to smart spaces. Our definition states that the context is: "Any information that triggers a service or changes the quality (form or mode) of a service if its value changes." This definition is sufficiently abstract and helps to limit the set of contextual information. We believe that this definition is more expressive, because it is simple, clear, and complete; in addition, it covers all aspects of the context. Establishing context elements is a three-steps process consisting of: 1) specify for each equipment the provided service and the set of information that could trigger the service, 2) specify for each service the set of forms through which the services can be provided. We should also specify for each form of service the set of information whose change will change the form of a service and 3) make the union of the two previous sets to get the final list of contextual information and define the set of possible values for each context element. This information will compose the global context.

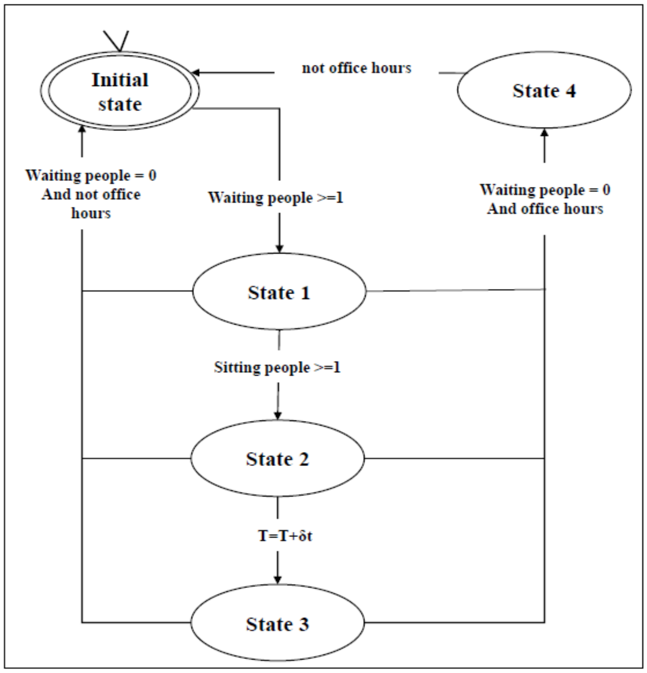

Figure 2. The state diagram of the overall operation of the smart waiting room

By applying our context definition and context components establishment method to the smart waiting room, we have got the result of each step as indicated in Table I, Table II and Table III.

TABLE I. CONTEXT ELEMENT ESTABLISHMENT (STEP 1)

Equipment	Service	Triggering information
heater	heating	Seated person
cooler	cooling	Seated person
window blinds	lighting	Person presence
light bulbs	lighting	Person presence
TV and Radio/music player	entertainment	Seated person

TABLE II. CONTEXT ELEMENT ESTABLISHMENT (STEP 2)

Equipment	Service's Forms	Forms changing information
heater	Off, low, average, high	Indoor temperature, time
cooler	Off, low, average, high	Indoor temperature, time
window blinds	Closed, mostly closed, half-opened, mostly opened, closed	Indoor light, outdoor light, time
light bulbs	Off, low average, high	Indoor light, outdoor light, time
TV and Radio/music player	On, Off	Seated person

TABLE III. CONTEXT ELEMENT ESTABLISHMENT (STEP 3)

Context element	Possible values
Person presence	Yes, no
Seated person	Yes, no
Indoor temperature	Very low, low average, high, very high
Indoor light	Dark, low, average, high
Outdoor light	dark, low, average, high
Time	Office hours, not office hours

It is clear that our method for context elements establishment which is composed of the above three steps is easy to perform and leads to the set of global context required for services adaptation inside the waiting room. The possible values of each context element (values domain) could be adjusted according to the implementation.

V. CONTEXT-AWARE SERVICES ADAPTATION

The aim of context-aware services adaptation is to render appliances of the waiting room operating in a proactive manner with minimum human intervention and to provide services with minimum energy consumption. Based on the previous context definition and its element's establishment, we propose in this Section a context-aware services adaptation for a waiting room. The waiting room should operate according to the current context which is composed of the following elements: person presence, seated person, indoor temperature, indoor light, outdoor light and time.

Whenever a person enters the waiting room, the light system should start adjusting the ambient light by setting the window blinds and light bulbs according to the rules presented in Table IV. There are also two particular context situations related to energy saving (Table V). The first one is when there is no person inside the waiting room and it is outside of office hours so the light system should be set off. The second one is when there is no person inside the waiting room and it's during office hours so the system should set the light on its minimum energy consumption mode which is window blinds opened and light bulbs off. The symbol "?" means whatever value.

The cooler/heater system should operate according to the current context whenever the system perceives at least one person seated inside the waiting room. The possible context-aware configurations of the cooler/heater system are given by Table VI. Alike the light system, there are also some particular context situations related to energy saving. The first one is when there is no person inside the waiting room and it's not office hours so the cooler/heater system should be set off. The other ones are when there is no person inside the waiting room and its office hours so the system should set the cooler/heater on its minimum energy consumption mode, which is shown in Table VII.

TABLE IV. CONTEXT-AWARE LIGHT SYSTEM CONFIGURATION

In light	Out light	Window blinds	Light bulbs	Person presence	Seated person	Time
Dark	Dark	Closed	High	yes	?	Office hours
Dark	Low	Opened	Average	yes	?	Office hours
Dark	Average	Mostly opened	Low	yes	?	Office hours
Dark	high	opened	Off	yes	?	Office hours
Low	Dark	Closed	High	yes	?	Office hours
Low	Low	Opened	Average	yes	?	Office hours
Low	Average	Mostly opened	Low	yes	?	Office hours
Low	high	Half opened	Off	yes	?	Office hours
Averag e	Dark	Closed	High	yes	?	Office hours
Averag e	Low	Opened	Off	yes	?	Office hours
Averag e	Average	Mostly opened	Off	yes	?	Office hours
Averag e	high	Half opened	Off	yes	?	Office hours
High	Dark	Closed	Off	yes	?	Office hours
High	Low	Opened	Average	yes	?	Office hours
High	Average	Half opened	Low	yes	?	Office hours
high	high	Mostly closed	off	yes	?	Office hours

TABLE V. ENERGY SAVING MODE OF THE LIGHT SYSTEM

Indoor light	Outdoor light	Window blinds	Light bulbs	Person presence	Seated person	Time
?	?	opened	off	no	no	office hours
?	?	closed	off	no	no	Not office hours

The entertainment system composed of the TV or music/radio player is triggered whenever the system perceives at least one person seated in the waiting room. Otherwise, it should be set off both during office hours or out of office hours in order to save energy as mentioned in Table VIII.

The above tables of possible appliances configuration will form the training set for a naïve Bayes classifier chosen as a machine learning technique for the context-aware services adaptation of the smart waiting room. The Bayesian Classification represents a supervised learning method as well as a statistical method for classification. For each new sample they provide a probability that the sample belongs to a class. Training is very easy and fast, no need for complicated training process as in neural networks. Naïve Bayes is fast and space efficient. It can provide an optimal decision making system even in presence of violating independence assumption. We have used the free machine learning tool Waikato Environment for Knowledge Analysis(WEKA) [17] to implement the context-aware adaptation system.

TABLE VI. CONTEXT-AWARE COOLER/HEATER SYSTEM CONFIGURATION

temperature	Cooler	heater	time	Person presence	Seated person
Very low	off	high	Office hours	yes	yes
Low	off	average	Office hours	yes	yes
Almost low	off	low	Office hours	yes	yes
Average	off	off	Office hours	yes	yes
Almost high	low	off	Office hours	yes	yes
High	average	off	Office hours	yes	yes
Very high	high	off	Office hours	yes	yes

TABLE VII. ENERGY SAVING MODE OF THE COOLER/HEATER SYSTEM

temperature	Cooler	heater	time	Person presence	Seated person
?	off	off	Not office hours	no	no
Very low	off	low	Office hours	no	no
Low	off	low	Office hours	no	no
Almost low	off	low	Office hours	no	no
Average	off	off	Office hours	no	no
Almost high	low	off	Office hours	no	no
High	low	off	Office hours	no	no
Very high	low	off	Office hours	no	no

TABLE VIII. CONTEXT-AWARE ENTERTAINMENT SYSTEM CONFIGURATION

TV or radio/music player	time	Person presence	Seated person
On	office hours	yes	yes
off	Office hours	no	no
off	Not office hours	no	no

In order to make a principal step toward our system validation, we performed three series of tests. Each one is composed of ten possible context situations. We have got satisfactory results with acceptance rate of 92%. Such rate was very encouraging.

VI. CONCLUSION AND FUTURE WORK

Context-awareness could enormously improve the quality of services for smart spaces. It helps to provide proactive services which enhance both user's comfort and energy saving. The most important task in building context-aware systems consists of defining the context in a clear manner and establish its components. In this paper, we have proposed a context-aware services adaptation for a particular smart space namely smart waiting room using the naive Bayes learning machine technique. Our approach could help a lot the energy saving in such space in addition to improving person comfort. Our future work consists of applying the same approach for other types of smart spaces, such as smart office, smart classroom, etc.

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