AN EXTENDED-EDA MODEL FOR INTELLIGENT BUILDING CONTROL

Jarunee Duangsuwan
Informatics Research Centre
University of Reading, United Kingdom

Kecheng Liu
Informatics Research Centre
University of Reading, United Kingdom

ABSTRACT

By applying agent technology, the intelligent building control system provides a practical application that can minimize energy consumption, while keeping a satisfying response to the building occupants' comfort. Most of previous research in this field has proposed the controlling system that can adapt buildings not only to the changing environment to saving energy conditions but also to occupant's well being and satisfaction can be achieved in order to optimize intelligent building's performance. This article proposes an abstract extended-EDA (Epistemic-Deontic-Axiologic) model which is enhanced capability in order to make decision under norms: obligations, permissions and prohibitions. The model is represented in terms of an individual agent that is prepared for the multi-agent system of intelligent building control.

KEYWORDS

EDA model, norm aware agents, intelligent agents, intelligent buildings, multi-agent systems, norms.

1. INTRODUCTION

According to various definitions of an intelligent building (Himanen 2003), an intelligent building is a building equipped with an integration of advance technology, especially the computer-based artifacts and systems, in order to support automatic adaptation to the changing environment conditions, and also providing comfortable living conditions for the current occupants as well. Many previous researches in intelligent building control system have designed the system by employing agent technology. An agent is software that continually processes the input it gets from its environment to determine the output it should send back to the system. Furthermore, an intelligent agent has the following characteristics: reactivity property, pro-activity and social ability. Therefore, such characteristics make intelligent agent has capable of autonomous action in the environment in order to meet its goals. A multi-agent system (D'Inverno and Luck 2004) comprises two or more agents. Such agents can interact with one another so the interaction must result from one agent satisfying the goals of another. In our research, one main factor to be considered is adapting the environment factors such as temperature, lighting, humidity and etc. according to the occupants' preferences. In a simply case, when a room is occupied by a person, the building environments are changed to the present occupant's satisfaction. For the multi-occupant scenario, making decision about the environments is more complex than the single-occupant scenario because the environments should be set by certain values in order to make most occupants in the room feel comfort as much as possible. Basically, by using the average values to set the environment conditions is the simple and reasonable method. We decided to enhance the EDA model proposed by (Filipe 2000) for implementing a multi-agent system for controlling an intelligent building because the model allows agent to make decision under normative consideration. However, the EDA model has been proposed for normative reasoning in business domain which the most agents are referred to human-agent. Because the agents in our domain are both human-representing agents such as occupant agent and artifact-representing agent such as zone agent, the EDA model has been adjusted to support our domain.

2. RELATED STUDIES

The BDI model (Wooldridge and Jennings 1995) proposed by Rao and Georgeff in 1991 is an agent model that emphasizes an intentional notion of agency. The original model is developed by Michael E. Bratman via a theory of human practical reasoning stating that an agent's behaviour is driven by its goals. According to (Jarvi 2004), the practical reasoning is reasoning directed towards actions, so it involves to the process of determining what to do. By contrast, the theoretical reasoning most directly affects beliefs. Therefore, the BDI model is behaved in the same way like human practical reasoning by adopting mental attitudes of Belief (B), Desire (D) and Intention (I), respectively representing the information, motivational, and deliberative states of the agent. Beliefs represent the information of the agent about the world, in other words its beliefs about the world. Desires of agent refer to the motivational state of the agent or may be thought of as the tasks allocated to the agent. They represent objectives or situations that the agent would like to accomplish or bring about. However, all of agent's desires may not be achieved. The agent's intentions represent desires which the agent has chosen and committed to. The BDI agents have been applied by the researches of ISES (Information/Society/Energy/System) project to form the multi-agent systems (Davidsson and Boman 2000; Davidsson and Boman 2005). The multi-agent systems have been implemented for automatic control of lighting and temperature to achieve the goal of energy saving and customer preference.

Norms claimed by (Torre 2001) is used for linking the gap between agent level and multi-agent system level. This means that a role of norms and obligations can support agent society then many previous researchers tried to enhance agent's ability by proposing a novel agent model that can make decision under norms: obligations, permissions and prohibitions. Although BDI is the most widely known model that uses to implement an agent for individual and intentional decision processes, this model was not been represented nothing about the social aspects of agents being in multi-agent systems. However, the BDI model has some limitation such as lacking of policy and norm supporting ability so many researchers have proposed the extended-BDI models in order to enhance the agent capabilities for example; extension of BDI model with norm(Dignum 1999), the Belief-Obligation-Intention-Desire model(Broersen, Dastani et al. 2001) ,normative agent architecture (Lopez and Marquez 2004), EDA model(Filipe 2000), etc. These extending architectures are the normative model addressing the usage of norms and policies for reasoning and social interacting. The agent that can reason about norms and obligations is called normative agent (Verhagen 2000)or deliberate normative agent (Castelfranchi, Dignum et al. 1999) while the latter has explicit knowledge of the enacted norms for reasoning.

3. NORMS AND NORM REPRESENTATION

Norms have been used in several words such as 'pattern', 'standard', 'type', but the meaning of norm is been defined unclear because it is used in many different senses(Wright 1963). Wright categorized norms into: rules, prescriptions, and directives. *Rules*, e.g. rules of a game or grammar, are the explicit standardized patterns, and then the rules can determine which are right or wrong. *Prescriptions or regulations*, e.g. military commands, traffic rules, are commands or permissions that are issued by a norm-authority to a norm subject. For *directives or technical norms*, there are concerned with the *means* that is used for attaining a certain end. 'Directions of use' is an example of directives. The prescriptions compose of six components: the character, the content, the condition of application, the authority, the subject(s), and the occasion. The *character* is the effect of norm which can be obligation norms, permissive norms, and prohibitive norms. The *content* refers to action or activity prescribed in norms. *The condition of application* is the state of affairs in which norms should be applied. The authority is the agent who issues norms. *The subject* is the agent who receives and applies norms. The occasion of norm involves to a location, time clarifying the occasion for which the norms are made. In addition to (Stamper, Liu et al. 2000), norm is a field of force that has been used to govern the behaviors of the members in a society. Stamper et al. divided norm according to social psychology classification into perceptual, evaluative, cognitive and behavioural norms. These four types of norms are respectively associated with four distinct attitudes: ontological, axiological, epistemic, and deontic. Besides, these norms are elaborately outlined in (Liu 2000). By applying components of the prescription norm, many researches constructed the norms which are visible and recordable. The typical norm proposed by (Stamper and Liu 1994) is formed by the following format : *whenever <situation> then <agent> is*

<deontic attitude> to <action>. However in (Liu and Dix 1997), the similar format is used for representing the business rules defined as behaviour norms prescribing what people must, may, or must not do. From the norm structure proposed in (Wright 1963), and general form of norm in (Liu and Dix 1997), we have adapted to a norm specification defined in the extended-EDA model as tuple: **N = (*n*, C, R, A, TC)**. Where ***n*** is a label that identify the type of norm, which can be an obligation, permission or prohibition; C is a trigger condition(s) that make norm active; **R** is a role identifier for a norm addressee (agent); A is the activity specification that can be either an achievement of a state of affairs or a performance of an action; and **TC** is the terminating condition(s) that make norm inactive. Then, norm is represented in following form:

Whenever some trigger condition occur (**C**) ***if*** human-agent is (**R**), ***then*** intelligent-agent/acting agent is deontic operator (***n***) to achieve some state of affairs or to perform some actions (**A**)

4. THE FRAMEWORK OF INTELLIGENT BUILDING CONTROL

By nature of intelligent building, when a person presents in a room, the control system is be initialized by setting the room conditions via a standard set of preferences. In case of the existing occupant who is recognized by the system, the environmental conditions are adjusted according to the preferences retrieved from repository of the system. However, the occupant can change the current environmental conditions to desired comfort conditions when he feels dissatisfaction. Although the system allows the occupant can change the conditions, both scenarios are controlled under the system's goal that supports both energy conservation and occupant comfort. To decrease energy consumption without affecting the comfort of the building occupants, it is necessary to determine an occupant breakdown of the energy consumption in the building. In our research, a multi-agent system used to implement the controlling intelligent building system consists of a collection of agents that monitor and control the building. The system is situated in some environment, and that is capable of autonomous action in the environment in order to achieve its design objectives. The following are agents proposed and will be implemented in our research: *occupant agent, zone agent, manager agent, and environmental control agents*. Normally, the personal preferences of particular occupant are set when a person enters the room for the first time. When an occupant signs into the system, an *occupant agent* corresponding to the occupant provides the *zone agent* with the personal information and preferences. The *zone agent* decides the new environment conditions under building policies and occupant comfort. Then, these conditions are passed to the *manager agent* for changing to BMS-format commands. The *manager agent* sends the BMS-format commands to the BMS to enforce these commands requested by the multi-agent system. However, if occupants do not change the environment, for example by changing the temperature or by adjusting the heating, the system assumes that the current environments are comfortable for the occupant. By contrast, occupant can change the current conditions by using the *occupant agent*. Therefore, the new changed conditions are sent to the *zone agent* for reconciling all appropriate conditions.

5. THE EXTENDED-EDA MODEL

The EDA model has been contributed by combination between norms and corresponding attitudes to support the organizational semiotics approach. The model composes with three main components namely: epistemic (E-component), deontic (D-component), and axiologic (A-component). Furthermore, the two external components are included: a perception interface and an action interface. The perception obtains and interprets external events from the environment, whereas the action interface responses to send the output act to the environment. The EDA model has its own beliefs stored in E-component which contains current beliefs or facts about the world. The obligations, rights and behaviours of agent are set in D-component where a set of plans are declared in terms of the interesting behaviours of the agent. A-component evaluates a preference relationship among the available plans in D-component and then provides the dynamically value-setting method for agent in order to assign the importance for norms. Therefore, the constituted obligations are assessed through axiology and the committed intentions established.

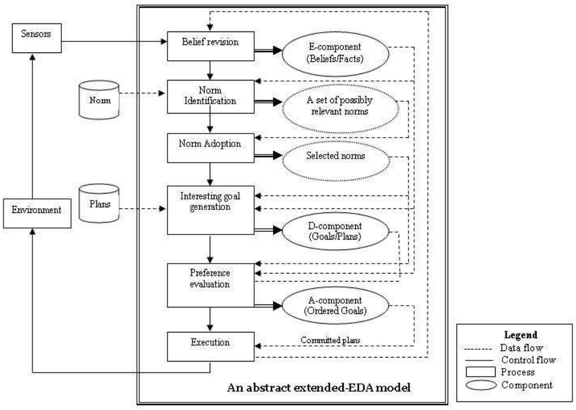

Figure 1. An abstract extended-EDA model

An abstract extended-EDA agent model employed in a multi-agent system to control the intelligent buildings represents the internal components and processes of a particular agent which is the member of the multi-agent system. The components, *relevant norms* and *selected norms*, are included to the EDA model. Furthermore, the processes are depicted in order to present data and control flow among the components. As showed in figure 1, when the environment changes, it is observed by the sensors and sent to the system for updating the beliefs in E-component via *belief revision process*. E-component stores the beliefs or facts that correspond to information agent have about the world; for example, the indoor/outdoor weather, the general information of room, the general information of current occupant(s), and etc. Because the EDA agent is allowed to reason about norms, the components and processes involving norm are included into the extending model. From our view, norm is a social concept which is established within a society to regulate the actions/behaviours and interactions of its members. Therefore, norms are an external force that might influence the agent capabilities. Initially, an agent may hold a set of capabilities and certain desires to deploy these capabilities but by adopting norms, agent's capabilities are partly determined by obligations which agent must comply with, prohibitions that restrict some capabilities that agent can pursue, or permissions that expand the capabilities for the agent to choose. The multi-agent system forms an agent society. Whenever agent joins a society, it will be bound to certain rules and regulations. The adoption of norm will specify agent with a specific social position or role that is annotated with certain duties, privileges, authority, responsibility etc. Therefore, the agent behaviours are behaved according to the adopted norms ascribed to agent's role. The building regulations and policies are presented as the external forces pushed by the building owners to save commercial cost, or pushed by the government to encourage efficiency the consumption of energy. Such policies are recorded by a norm base defined in advance. *Norm identification* responses to verify which norms are related to the current beliefs held by agent and may be adopted for agent's reasoning later. The set of possibly relevant norms are the outcome of the process. *Norm adoption* decides which norms must be adopted for normative decision. Instantiate norms are the output of this process.

D-component represents goals, objectives, or any states of affairs that the agent want to bring about. The goal of the EDA agent is a very high abstract plan, whereas a sequence of elementary actions defines a plan at the instance level. However, *the goal generation* has one more step further because it creates the goals based on norms. By merging goals from goal generation process to the selected norms, it can decide what goals an agent want to bring about under the currently selected norms. All candidate goals, which agent has to bring about, will be kept in D-component. Partial plans for achieving these goals are pre-defined in a plan library, which is a repository of all the plans that agent knows. Once one of these plans is adopted for execution, it is considered an intention and the agent is committed to do it.

Whenever the conflicts between goals are occurred during decision making, such goals are associated with preferences used not only for choosing which goals to pursue, but also for deciding which goals to prefer and to achieve first. The extended-EDA is designed to support this scenario by proposing the A-component. Because decision making of the extended-EDA agent depends on both the available goals in D-component and a preference relationship in A-component, both components are combined to choose goal(s), and when a goal is chosen, it becomes an intention. Therefore, the generalized goals in D-component need to be assigned the value of preference by *preference evaluation process*. The outcome is a set of preferences which is different for each agent, thus agents show their individual preferences towards a particular goal. We represent the relevance between preference set and particular goals by using the relationship that will be created and stored in A-component. The A-component decides whether which goals are placed in agenda. The goals in the agenda become intentions of agent. The intentions are executed, and then the actions are sent out to the environment.

6. CONCLUSION

We designed a framework of multi-agent system used to control the environmental conditions of an intelligent building. A particular agent in the system is modeled under an extended-EDA architecture that is enhanced capability for supporting normative decision making. Different from the previous systems, we added norm concept that promotes an increased flexibility towards the policies and the preferences of occupants in the building. Therefore, the system gives a good supporting for extensions and adaptations in the building's policies that optimize the energy consumption, and also make the building's occupants feel comfort as much as possible by using the ordering preferences to set the environment conditions in a particular area. In the future, we will deploy our extending model to test the framework of the system which will be implemented by eclipse software to build an agent-based prototype for verifying the proposed model.

REFERENCES

Broersen, J., M. Dastani, et al. (2001). The BOID Architecture - Conflicts Between Beliefs, Obligations, Intentions and Desires. In Proceedings of the Fifth International Conference on Autonomous Agents, ACM Press**:** 9-16.

Castelfranchi, C., F. Dignum, et al. (1999). Deliberate normative agents: principles and architecture. In Proceedings of the Sixth International Workshop on Agent Theories, Architectures, and Languages (ATAL-99), Springer Verlag**:** 364-378.

D'Inverno, M. and M. Luck (2004). Understanding agent systems, Springer.

Davidsson, P. and M. Boman (2000). A Multi-Agent System for Controlling Intelligent Buildings. Proceeding of the Fourth International Conference on MultiAgent Systems. Boston, MA**:** 377-378.

Davidsson, P. and M. Boman (2005). "Distributed monitoring and control of office buildings by embedded agents." Information Sciences **171**(4): 293-307.

Filipe, J. B. L. (2000). Normative Organisational Modelling Using Intelligent Multi-Agent Systems. Staffordshire, Staffordshire University.

Himanen, M. (2003). The Intelligence of Intelligent Buildings : The Feasibility of the Intelligent Building Concept in Office Buildings. Department of Surveying. Helsinki, Finland, Helsinki University of Technology**:** 498.

Jarvi, J. (2004). BDI & Reasoning. http://www.cs.uta.fi/sat/lectures/lecture-28-02/sat-lecture-28-02.pdf

Liu, K. (2000). Semiotics in Information Systems Engineering, Cambridge University Press.

Liu, K. and A. Dix (1997). Norm Governed Agents In CSCW. The first international Workshop on Computational Semiotics, Paris.

Lopez, F. L. and A. A. Marquez (2004). An architecture for autonomous normative agents. Computer Science, 2004. ENC 2004. Proceedings of the Fifth Mexican International Conference in.

Stamper, R. and K. Liu (1994). Organisational dynamics, social norms and information systems. System Sciences, 1994. Vol.IV: Information Systems: Collaboration Technology Organizational Systems and Technology, Proceedings of the Twenty-Seventh Hawaii International Conference on.

Stamper, R., K. Liu, et al. (2000). "Understading the roles of signs and norms in ogranizations : A semiotic approch to infomation systems design." Journal of Behaviour & Information technolgoy **19**: 15-27.

Torre, L. V. D. (2001). "Contextual Deontic Logic: Normative Agents, Violations and Independence." Annals of Mathematics and Artificial Intelligence **37**: 33-63.

Verhagen, H. J. E. (2000). Norm Autonomous Agents. Department of Computer and Systems Sciences. Stockholm, Sweden, The Royal Institute of Technology and Stockholm University.

Wooldridge, M. J. and N. R. Jennings (1995). Intelligent agents: Theories, Architectures, and Languages. Germany, Springer-Verlag.

Wright, G. H. V. (1963). Norm and action - A logical enquiry. London, Routledge & Kengan Paul.