A MULTI-AGENT SYSTEM FOR INTELLIGENT BUILDING CONTROL

Norm Approach

Jarunee Duangsuwan and Kecheng Liu
Informatics Research Centre, The University of Reading, Building 4, Whiteknights, PO Box 241, Reading, RG6 6WB, U.K.

Keywords: EDA model, Norm aware agents, Intelligent agents, Intelligent buildings, Multi-agent systems, Norms.

Abstract: Most previous research in the intelligent buildings have proposed the controlling systems that can change building environmental conditions automatically in order to save energy consumption and also to increase an occupant's satisfaction. Decreasing energy consumption and increasing occupant comfort are important factors to indicate an intelligent building's performance because it is a particular way to improve productivity resulting in the business benefits. By applying agent technology, an intelligent building control system provides a practical application that can minimize energy consumption levels, while keeping a satisfying response to an occupant's comfort. This paper 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. The multi-agent system is proposed to combine the comfort condition control with an energy saving strategy.

1 INTRODUCTION

According to a definition of intelligent building (Himanen 2003), an intelligent building is a building equipped with an integration of advanced technology, especially the computer-based artefacts and systems, in order to support automatic adaptation to the changing environment conditions, and to provide comfortable living conditions for the current occupants as well. Most previous research in the intelligent building control systems have been designed 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 environment. Furthermore, an intelligent agent has the following characteristics: reactivity, pro-activity and social ability. Therefore, such characteristics make an intelligent agent has capable of autonomous actions in the environment in order to meet its goals. A multi-agent system (D'Inverno and Luck 2004) comprises at least two agents. The agents in the multi-agent system can interact with others so that this interaction must result from one agent satisfying the goals of another. The projects contributed by Magnus Boman et al. (Boman, Davidsson et al. 1998; Boman, Davidsson et al. 1999; Davidsson and Boman 2000; Davidsson and Boman 2005) have been implemented in the multi-agent system approach to implement building control system. Such projects have the main goal to increase energy saving and to meet customer preference by automatic control of lighting and temperature according to occupant's requirement. The multi-agent system composes of four categories of agent. Personal comfort agents record the personal preferences and try to increase occupant's satisfaction. Room agents represent and control a particular room to maximize energy saving and to make occupant feel satisfy at the same time. Environmental parameter agents monitor and control the environmental parameters in a particular room. Badge system agents keep a track of location in the building where the occupants are situated.These agents are the BDI agents that are based on the theory of practical reasoning stating that the agent's goals drive the agent's behaviours. However,the multi-agent system lacks the capability of learning and predicting the occupants' behaviors.

For intelligent building approach, an important issue concerns with the energy saving policies. Although, the multi-agent system for intelligent building control proposed in our research is designed

Duangsuwan J. and Liu K. (2010).
A MULTI-AGENT SYSTEM FOR INTELLIGENT BUILDING CONTROL - Norm Approach.
In *Proceedings of the 2nd International Conference on Agents and Artificial Intelligence - Agents*, pages 22-29
DOI: 10.5220/0002720000220029

to adapt the environment factors such as temperature, lighting, humidity according to the preferences of occupant. However, such factors are set under optimal energy. For a simple case, when a private area such as office room is occupied by a person, the environmental conditions should be adjusted according to the current occupant's satisfaction. Furthermore, in a multi-occupant scenario, making decision about the conditions is more complex than a single-occupant scenario because the conditions should be set by the certain values in order to make most occupants in the room feel comfortable as much as possible. Basically, by using the average values to set the environment conditions is the simple and reasonable method. However, for our research it has been conducting on a particular agent model that can make decision via normative reasoning, and can be membership of multi-agent system supporting the building control system in order to provide both condition recommendations for occupants' comfort conditions and saving energy conditions. We decide to enhance the EDA model proposed by (Filipe 2000) to construct a multi-agent system for controlling an intelligent building because the model allows agent to make decision under normative consideration. The EDA model has been contributed by combination between norms and corresponding attitudes for supporting the organizational semiotics approach. By the original EDA model, it was proposed for normative reasoning in business domain, and most agents were referred to human-agent. However, the agents in our research domain are both human-representing agents such as occupant agents and artefact-representing agents such as zone agents then the traditional EDA model has been adjusted to support our research domain. The following section begins by reviewing background of relevant literature on BDI agent model, norms, and normative agent. The framework overview of multi-agent system for intelligent building control in a single-occupant scenario, and an extended-EDA model are represented in section 3. The final section provides a conclusion and the future of our work.

2 RELATED STUDIES

2.1 BDI Model

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 of this 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, motivation, 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 task allocated to the agent. Furthermore, the desires 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.

2.2 Norms

Norms have been used in several words such as 'pattern', 'standard', 'type', but the meaning of norms is been defined unclear because it is used in many different senses (Wright 1963). Wright categorized norms into three main types: rules, prescriptions, and directives. Rules, e.g. rules of a game, rules of grammar, are the explicit standardized patterns 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. According to (Stamper, Liu et al. 2000), a norm is a field of force that has been used to govern the behaviors of the members in a society. Stamper et al. divide norms 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). Perceptual norms concern with the ways of seeing the world, the ways to receive signals from the environment via human being's senses through media such as light, sound and taste. Cognitive norms can help to incorporate the beliefs and knowledge of a culture, to interpret what is perceived, and to obtain an understanding based on existing knowledge. Evaluative norms are required to evaluate the state of affairs, and also to explain why people have certain beliefs, values and objectives. The evaluation may be based not only on the physical boundary but also on a social boundary. Behavioural norms determine human being's behaviours within regular patterns. These norms determine how agent should behave under given certain conditions, and define what an agent should perform to achieve a state of affairs under given certain conditions. Denotative norms direct the choices of signs for signifying, these depend on the culture that may be a community or a social group.

According to norm classification by Wright, the building policies are categorized as the prescriptions or regulations issued by norm authority such as a building owner, a local council, a government and so forth. The regulations must be complied with norm subject such as the occupants, the facility administrators, the building managers, and so on in order to control energy consumption. Usually, the policies are expressed as pre-defined rules so these rules are static and can represent as following simple form:

IF *nobody is present in the room*
THEN *the lighting and heating should be turned off*
IF *a room is the public area AND at least one person appears in the area*
THEN *lighting is turned on AND the temperature is set to 20 degree Celsius*

Furthermore, the character, which is a component of prescription, expresses the effects of norm so the policies can be prohibited, permitted or obligated. Therefore, the examples of rule represented in table1 are declared to identify these effects.

Table1: The examples of rule.

Category	example	
Obligation	IF	An occupant appears in a room AND he is a room owner
	THEN	The BMS is obligated to set the current room conditions according to the current person's preferences
Prohibition	IF	Nobody in present in the room
	THEN	The lighting and heating are forbidden to turned on
Permission	IF	Time of weekdays is 6pm AND room is occupied
	THEN	The room temperature are permitted to set 20 Celsius

In addition, we distinguish the policies into four priority levels:

Safety: to ensure that the environmental conditions are set at the safe level, for example the temperature of the building should be set at a particular level in the winter to protect the water pipes from freezing and cracking.

Security: to ensure that the environmental conditions keep at a security level, for example in case of an emergency circumstance such as fire alarm, the emergency door should be opened.

Energy saving: to ensure that a low energy consumption is achieved by dynamical controlling so that if a room is unoccupied, the heating and the lighting are switched off.

Comfort: to ensure that the room conditions are set according to the occupants' preferences

For the first two levels, we assume that the controlling system is set to keep the both levels all time then the later two levels are under our considerations. Although the building policies are defined to control energy consumption, the most important aspect of an intelligent building is to take consideration about personal preferences of the people living or working in the building. The personal preferences represented as the dynamic rules provide comfort conditions that obtain from behaviour learning of occupant in a particular room. However, the goals of the building policies and the personal preferences are conflict. In addition, another conflicting goal situation is the adjustment of environmental conditions in a shared area such as a meeting room, a common room where the occupants have the different preferences. For the first conflict, we provide an agent that acts as a negotiation agent to solve the conflict. The agent determines whether the energy saving policy is not affect the comfort of the current occupants, partially affect the current occupant's comfort conditions but with in the limit of occupant's preference thresholds, or fully affect the current occupant's comfort conditions which means the current conditions beyond the limit so it can be summarized as follows:

1) If the occupant's preferences are not affected then the energy saving policies are applied to set the currently environmental conditions *(energy saving level)*.

2) If the occupant's preferences are partially affected then the standard conditions are used to set the currently environmental conditions *(default conditions set by BMS supporting both energy saving and occupant's well being).*

3) If the occupant's preferences are fully affected then the currently environmental conditions are adjusted according to the occupant's preferences *(comfort level).*

In case of a shared area, the conflict occurs whenever at least two persons present in the shared area. Therefore, we adopt norm approach, which is a partial factor of decision making about the currently environmental conditions, to reconcile contending preferences from the different occupants. We employ norms in two main tasks: 1) to assign the priority to a particular occupant 2) to assign the weight to normative goals and individual goals. Whenever a room is occupied by more than one person, we claim that a human being society, either formal or informal, is set up, and leads to assigning of role for each person in the society. For instance, in a private area, such as an office room scenario, an informal society is formed when anybody comes into the room then the role of this scenario is categorized into owner and visitor(s). On the other hand, in a common area such as a meeting room, the members of conference compose with a chairman, a secretary, a president, a board of director etc. These roles are considered as a formal role because it is defined by the organizational structure in terms of a hierarchical relationship. In a common room where anyone takes a break for drinking, eating, relaxing etc., an informal society occurs. Therefore, the society is a lateral or peer-to-peer relationship. By using a role concept, it will be adopted to classify the different priority between particular occupants. The high the occupant presents in the level of a hierarchical relationship, the high the occupant gets priority in the public area. Therefore, a relative ordering on the values of occupants' preferences is created.

Norms represent what the members in society ought to do, and their fulfilments can be seen as a benefit of the overall system. However, in some circumstances, individual goals conflict with the norms. In a multi-occupant situation, each occupant has the personal preferences that can be seen as the individual desires. By contrast, the normative goals are the certain environmental conditions that make all occupants as comfort as possible. Therefore, two steps of conflicting resolutions are needed. The first step is to resolve conflict among the occupants for finding the optimal preferences the make most occupants feel comfortable. The optimal preferences are evaluated by the system whether they fall in which level: saving energy level or comfort level. If the result falls in saving energy level then the second step is not happen because the individual goals are not conflict with the normative goals. In contrast, the second step is initiated to resolve the conflict. In our research, we adopt negotiation to reconcile the conflict then a goal of negotiation is to maximize occupant comfort and minimize energy consumption.

2.3 The BDI Model and Norms

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

Broerson et al. (Broersen, Dastani et al. 2001) have proposed BOID architecture that composes with four basic components. The architecture focuses on conflict resolution among informational and motivational attitudes. The possible conflict is classified into two types: internal and external conflicts. The internal conflicts occur within beliefs, obligations, intensions, and desires, and can be categorized into four unary subtypes: B, O, I, D. The external conflicts occurring between these components can be distinguished into multi subtypes: BO, BI, BD, OI, OD, ID, BOI, BOD, BID, OID, BOID. The conflict resolution mechanism is based on Thomason's idea of prioritization which can determine the type of an agent simultaneously. The BOID architecture is discussed more detail in (Broersen, Dastani et al. 2001). Lopez et al. (Lopez, Luck et al. 2001; Lopez and Marquez 2004) have proposed a framework representing the adoption of norms towards the BDI agent. The authors present an abstract normative agent architecture designed by merging the BDI agent architecture to three components that can make the agent reason about norms. Furthermore, the processes are included: norm adoption, norm deliberation, and norm compliance. Norm adoption is a process that decides whether norms must be adopted or not. If the norms should be adopted, then they can be represented in terms of norm instances. Norm deliberation decides which intended norms are fulfilled or unfulfilled by agents. Norm compliance process applies both intended norms and rejected norms to update the agent's goals which are affected by norms. After the goals are updated, the intentions of agent might be changed. The outcomes from those three processes have proposed as the three mental attitudes that are norm instances, intended norms, and rejected norms. Besides, motivation is a component which agents employ for assigning the preference values over their goals. However, these components of norms must be partly considered by the agents when a normative decision must be taken at that time.

3 MULTI-AGENT SYSTEM FOR INTELLIGENT BUILDING CONTROL

3.1 Agents in the Multi-agent System

Due to the nature of intelligent buildings, when a person is present in a room, the building control system is 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 occupant's preferences retrieved from a repository of the system. However, an occupant can change the currently environmental conditions to desired conditions when she/he feels dissatisfaction. The agent who observes the occupant behaviours and lifestyle must be provided for learning occupant preferences and anticipating what the occupants want. Although the system allows the occupants to change the environmental conditions, the conditions are controlled under the system's goals that support 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 system consists of a collection of agents that monitors and controls the building. The system is situated in some environment, and that is capable of autonomous action in the environment in order to achieve its objectives. The following agents have been proposed and will be implemented in our research: 1) *Occupant agent* corresponds to a particular occupant in a multi-agent system. The occupant agent presents some personalities or characters, monitors and adapts to the user's activities, learns the user's styles and preferences. The agent aims to maximize user's preferences by learning these preferences from observing user's behaviours. The occupant agent can reside on the various tools for example; a personal computer, a badge, a mobile phone, a radio frequency identification (RFID) technology and so on. 2) *Zone agent* corresponds to and controls a particular zone. Basically, there are many sensors embedded in each zone such as temperature sensors, lighting sensors, blind sensors etc. In addition, the zone agent acts as a negotiating agent to reconcile the conflict between its goals and the occupant agent's goals. We define the smallest logical unit in the building as a single room so a zone is a single room, or composes with more than one room. 3) *Manager agent* directly interfaces to building management system (BMS) by sending the final decision for governing the location's environment to BMS. 4) *Environmental control agent* monitors and controls different environmental parameters in each zone. For example, a temperature agent can read the temperature sensor, and can control the actuator in a zone.

3.2 Single-occupant Scenario

Normally, the preferences of a particular occupant are set when the occupant enters the room at the first time. As illustrated in figure1, when an occupant signs into the system, an occupant agent corresponding to the occupant provides a zone agent with the personal information and preferences. The zone agent decides the new conditions under building policies and occupant's comfort. Hence, these conditions are passed to a manager agent for changing to BMS-format commands. The manager agent sends these commands to the BMS to enforce these commands requested by the multi-agent system. However, if an occupant does not change the environments, for example by changing the temperature or by adjusting the heating, a system assumes that the current environments are comfortable for the occupant. By contrast, as represented by figure2, if an occupant changes the current conditions by using the occupant agent, the new changed conditions are observed and learned by the occupant agent. The occupant agent calculates the new preferences that will forward to the zone agent for evaluation whether the new preferences conflict with the building policies or not. If the conflict occurs; for example, the occupant agent A desires to set temperature at 20°C. The A's desire may conflict with a normative goal of the zone agent Z which set the temperature at 25°C for energy conservation (building policy); then the zone agent reconciles the conflict. Subsequently, a result of reconciling is sent to the occupant agent for updating the occupant's preferences, and is sent to the environmental control agents to adjust the environmental conditions.

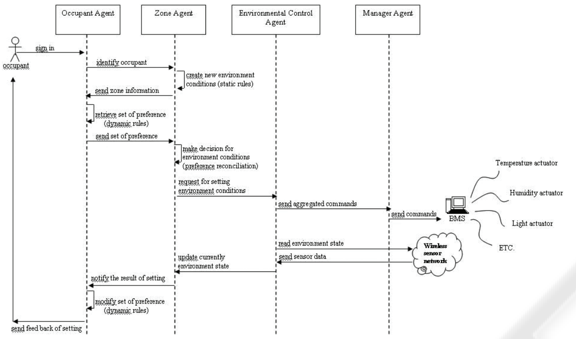

Figure 1: Sequence diagram of multi-agent system for IB in a single occupant scenario.

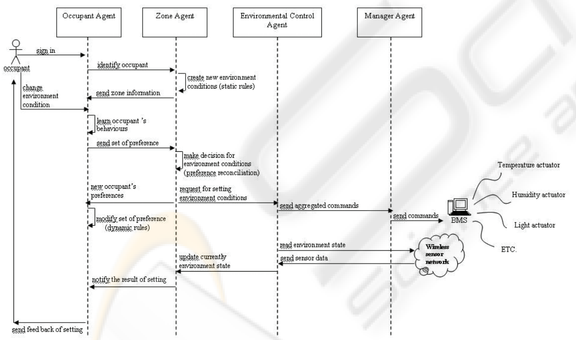

Figure 2: Sequence diagram of multi-agent system for IB in a single occupant and learning scenario.

For a multi-occupant scenario described in section 2.2, a conflict of preference may or may not occur. According to the capability of an intelligent building control system, the environmental conditions of a building are set at the optimal comfort conditions. We assume that if the occupants do not take any actions, they prefer the current conditions then a conflict does not happen. However, if someone requests to change the current conditions, negotiation among occupants is needed. We adopt norms to resolve the conflict occurring between the normative goals and the individual goals. A particular occupant in a multi-occupant scenario has the individual preferences then a preference conflict among the occupants may happen. Therefore, the negotiation that will be implemented by the blackboard concept is used to reconcile the occupants' conditions. We implement the negotiation between the occupants by using blackboard system that can be compared with technologies such as message queues and databases where a simple API for the manipulation of entry objects: insert, read, delete can be used when some type of object is available at (Creswell http://www.dancres.org/cottage/javaspaces.html).
The preliminary negotiating design has been proposed in (Duangsuwan and Liu 2008) but in this paper we pay attention to how to use norm approach reaches a joint preference of the occupants. To design agent architecture for negotiating and making decision under norm consideration, we were inspired by the EDA model so an extended-EDA model has been proposed to enhance the EDA model.

3.3 The Extended-EDA Model

The concept of EDA model has been contributed by combination between norms and corresponding attitudes. The main components of model are epistemic component (E-component), deontic component (D-component), and axiologic component (A-component). Furthermore, two external components are included: a perception interface obtaining and interpreting external events from the environment, and an action interface sending the output actions to the environment. The EDA model has its own beliefs represented in E-component that 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 is declared in terms of the interesting behaviours of agent. A-component is an evaluating component for assigning a preference relationship among the available plans in D-component. The component provides a dynamically value-setting method for agent in order to assign the importance of norms. Therefore, the constituted obligations are assessed through axiology then the committed intentions are established.

The EDA agent is allowed to reason about norms then the components and processes involving norms are included into the extended-EDA model. From our perspective, norms are the external forces that might influence the agent capabilities or behaviours. Initially, an agent may hold a set of capabilities and certain desires to deploy these capabilities but by adopting norms, the agent's capabilities are partly determined by obligations which the agent must comply with, prohibitions that restrict some kind of capabilities which the agent can pursue, or permissions that expand the capabilities for the agent to choose. A multi-agent system forms an agent society. Whenever an agent joins a society or an organization, it will be bound to certain rules and regulations. The adoption of norms will specify agent with a specific social position or role. This role is annotated with certain duties, privileges, authority, responsibility etc. Therefore, the agent's behaviours are behaved according to the adopted norms ascribed to an agent's role. The building regulations and policies are presented as the external forces pushed by the building owners or administrators to save commercial cost, or pushed by the government to encourage efficiency of energy consumption.

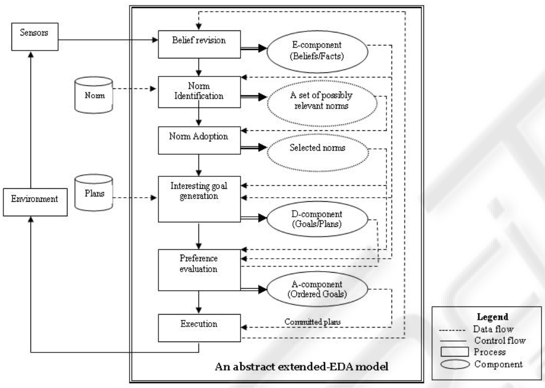

Figure 3: An abstract extended-EDA model.

We propose an abstract extended-EDA model including the new components for norm reasoning. Figure 3 illustrates the proposed model prepared for a multi-agent system to control the intelligent buildings. The figure represents the internal components and processes of a particular agent which is the member of a multi-agent system. The new two components, relevant norms and selected norms, are added and merged to the EDA model. In addition, the processes are depicted in order to present data and control flow among the components. Similar to other agent models, changing of the environment is observed by the sensors and is sent towards the system for updating the beliefs in E-component via *belief revision process*. E-component stores beliefs or facts that correspond to the information that an agent have about the world. The first process involving norms is ***norm identification*** that responses to verify that which norms in a norm base defined in advance relate to the current beliefs held by an agent and may be adopted for an agent's reasoning later. A set of possibly relevant norms is an outcome that will be sent towards the next process. ***Norm adoption process*** decides whether which norms must be adopted to normative decision. The result of this process is represented in terms of *instantiate norms*.

D-component represents goals, objectives, or any states of affairs which an agent want to bring about. According to the EDA model concept, D-component is where the interesting behaviours of agent are defined. The behaviours may be represented as the partial plans at different levels. A goal is a very high abstract plan, whereas a sequence of elementary actions defines a plan at the instance level. However, ***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 whether what goals are brought about by an agent under the currently selected norms. All candidate goals, which agent has to bring about, will be kept in D-component. The partial plans for achieving these goals are pre-defined in a plan library which is a repository of all plans that an agent knows. Once one of these plans is adopted for execution, it is considered an intention and an agent is committed to do it.

To make decision when goal conflicting occurs, the agent's goals are associated with preferences because they are used to make decision in our model not only to choose the goals for pursuing, but also to decide the goals for preferring and achieving first. The EDA is modelled to support this scenario by proposing the A-component. The generalized goals in D-component need to be assigned the value of preference by ***preference evaluation process***. An outcome from this process is a preference set which is different for each agent, thus an agent shows their individual preferences towards the particular goals. We represent the relevance between a preference set and the particular goals by using the relationship that will be created and stored in A-component. Because decision making of the EDA agent depends both on the available goals in D-component and a preference relationship in A-component, both components are combined to choose a goal. When a goal is chosen, it becomes an intention. A-component concerns with deciding 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.

4 CONCLUSIONS

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

REFERENCES

Boman, M., P. Davidsson, et al., Eds. (1998). Energy Saving and Added Customer Value in Intelligent Buildings. Proceedings of the 3rd International Conference on the Practical Applications of Agents and Multi-Agent Systems (PAAM-98).

Boman, M., P. Davidsson, et al. (1999). Artificial Decision Making Under Uncertainty in Intelligent Buildings. the Fifteenth Conference on Uncertainty in Artificial Intelligence, Stockholm, Sweden.

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.

Broersen, J., M. Dastani, et al. (2001). An alternative classification of agent types based on BOID conflict resolution. Proceedings of the 13th Belgium-Netherlands Artificial Intelligence Conference: 79-87.

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.

Creswell,D.(http://www.dancres.org/cottage/javaspaces.html). "Getting started with JINI TM 2.x." Retrieved 20 May 2009.

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.

Dignum, F. (1999). "Autonomous Agents with Norms " Artificial Intelligence and Law 7: 69-79.

Duangsuwan, J. and K. Liu (2008). Multi-agent Control of Shared Zones in Intelligent Buildings. Computer Science and Software Engineering, 2008 International Conference on.

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.

Lopez, F. L., M. Luck, et al., Eds. (2001). A framework for norm-based inter-agent dependence. Proceedings of the 3rd Mexican International Conference on Computer Science.

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., 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.