AGENT BASED FRAMEWORK TO SIMULATE INHABITANTS' BEHAVIOUR IN DOMESTIC SETTINGS FOR ENERGY MANAGEMENT

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Abstract: Inhabitants' behaviour is a significant factor that influences energy consumption and has been previously incorporated as static activity profiles within simulation for energy control & management. In this paper an agent-based approach to simulate reactive/deliberative group behaviour has been proposed and implemented. It takes into account perceptual, psychological (cognitive), social behavioural elements and domestic context to generate reactive/deliberative behavioural profiles. The Brahms language is used to implement the proposed approach to learn behavioural patterns for energy control and management strategies.

1 INTRODUCTION

Europe's energy consumption within buildings is 40% of the total energy (two-thirds of this is in heating and cooling), however a major portion up to 90% is needlessly wasted (heel, 2009). By the year 2030, 70% (6 billion) of the world's population will live in urban areas resulting in huge sustainable housing and energy demands. Hence the associated energy loss from buildings is emerging as a potential crisis (world urbanization prospects, 2007). A solution to address this problem is energy efficiency (saving from current energy waste) which is cheapest, cleanest and immediately available, cost-effective energy (ogilvie, 2009).

Energy control and management for heating and cooling and lighting, etc. is an active research area. The focus is for new buildings to comply with low energy consumption standards and for renovated buildings to improve energy efficiency as proposed by the Euro ACE and European National Strategy (Jensen et al., 2009). Centralized and distributed approaches in buildings for power management solutions have also been proposed to improve energy efficiency, (Ha et al., 2006), (Abras et al., 2006). We argue that understanding inhabitants' behaviour is the key for energy consumption and saving. Inhabitants' behaviour can either optimise energy utilization, taking into account comfort needs, or it can needlessly waste energy. Energy waste related to human behaviour is not yet fully explored for energy efficiency. The literature suggests that behaviour strongly influences energy consumption patterns and is an important factor for energy waste reduction in buildings (Raaij and Verhallen, 1982), (Andersen et al., 2009). Various surveys, studies and energy audits have been conducted to analyze how behaviour is affected by certain factors and how it affects energy consumption (Seryak and Kissock, 2000), (Ouyang and Hokao, 2009), (Masoso and Grobler, 2009). (Mahdavi and Proglhof, 2009) conducted a study in order to find the user control actions taking into account indoor/outdoor environment. (Bourgeois et al., 2006) developed a sub-hourly occupancy-based control model (SHOCC) to track individual instances of occupants and occupant controlled objects to investigate lighting energy use in a single occupancy building using ESP-r[1]. (Dong and Andrews, 2009) developed an event based pattern detection algorithm for sensor-based modelling and prediction of user behaviour. They connected behavioural patterns (Markov model) to building energy and comfort management through EnergyPlus simulation tool for energy calculations.

[1]ESP-r is an integrated modelling tool for the simulation of the thermal, visual and acoustic performance of buildings and the assessment of the energy use and gaseous emissions.

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The models discussed above focus on user behaviour in non-domestic spaces such as offices and they concern single users rather than group reactive/deliberative behaviour. Simulations based on static profiles or single user behaviour are limited in extending results to real life. A better management that coordinates and orchestrates the use of all kinds of energy according to inhabitant's needs and comfort remains an important progress factor. In this paper we focus specifically on domestic situations and model dynamic (reactive/deliberative) group behaviour which we believe is the key for reliable simulation in energy efficiency. The purpose of the proposed approach is to identify the sensitivity of behaviour for energy control and management which shall help in developing the smart environments as well as testing the design of new buildings or houses more suited to humans according to their behaviour. A smart environment is one that is able to acquire and apply knowledge about environment and its inhabitants in order to improve their experience in that environment (Cook et al, 2007). A simulation has been run in order to access human behaviour with energy consumption which otherwise cannot be done without some experimentation.

The conceptual framework proposed in this article includes two components: ***(i)*** a logical component for inhabitants' dynamic group behaviour (reactive/deliberative) simulation and ***(ii)*** a physical component for energy calculations. An agent based approach is used to model humans interacting with their environment in the proposed logical component. An agent based approach is well suited since agents are a natural and intuitive way to model humans and their characteristics and are a key towards implementing group behaviour. Agents like humans evolve in the environment, perceive it and act accordingly.

The research objectives of this work are to dynamically simulate user behaviour in domestic settings, and further identify the context, beliefs and facts that impact energy related behaviour. The proposed framework will help in developing energy efficient strategies to be implemented through social campaigns, ubiquitous computing or centralized/ distributed approaches.

This work is part of the SIMINTHEC (SIMulation and INteroperable software tools for the management of THermal and EleCtrical energy in buildings) project. The goal of SIMINTHEC is to design a multi-simulation environment to improve energy management in buildings by validating and improve energy-saving policies and programs. It includes five modules: 2 modules concerned with thermal and electrical aspects, 1 module on energy saving policies and control algorithms, 1 module on inhabitants' behaviour simulation and 1 module for predicting the outdoor environment. Proposed agent based framework to simulate dynamic group behaviour, supports the "inhabitants' behaviour simulation" module, circled in Fig.1 with interoperability among all modules.

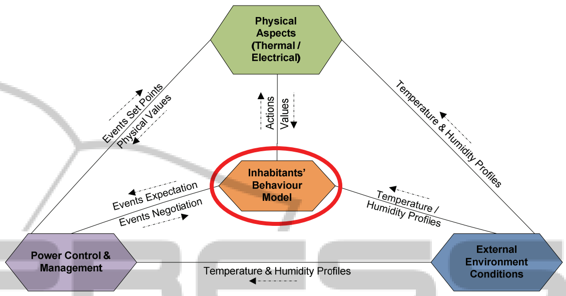

Figure 1: Interoperability between modules in SIMINTHEC.

2 LITERATURE REVIEW

The following section covers three aspects: behaviour influence on energy consumption, home context and Human Behaviour Representation (HBR) models for possible integration in reactive/ deliberative group behaviour simulation.

There are multitude of factors of human behaviour that influence energy consumption. For example public information on the energy problem, energy supply and energy efficiency, energy related personal interests, economical differences, home characteristics (no of rooms, degree of insulation), lifestyle consciousness about energy saving and environmental problems, social norms and lack of knowledge about energy use (Raaij and Verhallen, 1982, Ouyang and Hokao, 2009).

A survey conducted by (Andersen et al., 2009) showed that window opening, heating, lighting and solar shading behaviour of occupants is affected by gender, perceived illumination, noise level and air quality. (Seryak and Kissock, 2000) conducted a study on university residential houses and showed that the same house occupied during 2 academic years by different occupants show different energy consumptions because of behavioural differences. (Masoso and Grobler, 2009) conducted an energy audit on six randomly selected buildings in Africa. The results showed that more energy is consumed during non working hours than during working hours because of the occupant's behaviour of leaving lights and other equipment on at the end of the day. (Ueno et al., 2006) presented an on-line energy consumption information system to make the occupants aware of the impact of their energy consuming behaviour of different appliances, power and gas consumptions of the whole house, room temperature, comparison with other houses and comparison with past data. The system helped in reducing power consumption of houses by 18% at the end of the study.

In addition to behaviour, context is another important factor affecting the energy related activities of occupants. "The context of a task is the set of circumstances surrounding it that are potentially of relevance to its completion" (Henricksen, 2003). In context aware systems the contextual elements necessary to represent behaviour are categorized as individuality (state), activity (human needs expressed as 'what' and 'how'), location (spatial arrangements) and time (current time or any virtual time, working hours, weekends, intervals) and relations (social relations and functional relations) (Zimmermann et al., 2007). In the home environment user behaviour is considered as one of the most important contextual factor amongst others including time, space, environment and object (Ha et al., 2006). These authors presented a user behaviour modelling approach (5W: what, when, where, why & who and 1H: how) by mapping it in a home context (user, time, object, space & environment) (Fig.2).

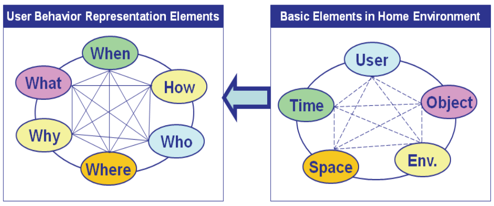

Figure 2: 5W1H approach to map user behaviour in the home.

It is evident from the above studies that human behaviour is the most important factor affecting the energy utilisation in buildings. In an urge to study this most important factor in more detail, to find out its different aspects affecting energy related activities directly or indirectly and to find a way to represent it for energy control and management, a study of existing human behaviour representation models has been conducted.

HBR models capture the covert and overt human behaviour patterns and represent them in some way using some representation mechanism. Most of the HBR models share the aspects of both cognition and performance. HBR models were analysed to find those that could represent reactive/deliberative and group behaviour including context elements. Atomic components of thought (ACT) (Anderson et al., 2004) focuses on cognition (thought processes), perception and motor elements. (Freed, 1998) & (Firby, 1989), suggested Architecture for procedure execution (APEX) to model human behaviour in complex, dynamic environments, but focus only on individual tasks. (Sloman, 2001) presented Cognition and affect project (CogAff) that captures the reactive, deliberative & reflective mechanisms. Cognition as a network of tasks (COGNET) (Zachary et al., 1998), mainly focuses on cognitive behaviour of humans, assuming that humans are capable of doing multiple tasks simultaneously. (Card et al., 1983) and (Kieras and Polson, 1985), proposed cognitive complexity theory (CCT) which is a simple model of cognition as it represent human performance only on the sequential tasks and show how humans use their task knowledge to interact with the devices. Concurrent activation-based production system (CAPS), (Thibadeau et al., 1982) and (Just et al., 1999), is a production system where a declarative knowledge base consists of facts having a numerical activation value. Production is fired when an element is matched with the condition and the activation value exceeds a specific threshold. (Eggleston et al., 2000) presented the Distributed cognition (DCOG) model, according to which cognition is distributed across the environment. Agents having different skilful behaviour use different strategies to accomplish the same task and environment does affect individual performance. Executive process/interactive control (EPIC), (Kieras and Meyer, 1995), focuses on perceptual, cognitive and motor processes that represent the procedures required to perform complex tasks. It also captures multitasking. Man-machine integrated design and analysis system (MIDAS), (Corker and Smith, 1993), focuses on human system interactions. It makes an assumption that the "human operator can perform multiple, concurrent tasks, subject to available, perceptual, cognitive and motor resources" (Pew and Mavor, 1998). Micro systems analysis of integrated network of tasks (Micro Saint), (Pritsker et al., 1974), include task as a basic element, divided in subtasks until an elemental level is reached. It also uses operator oriented concepts to accomplish tasks as a mission. However it does not capture the psychomotor element of human behaviour. (Deutsch et al., 1997) and (Young and Deutsch, 1997), suggested Operator model architecture (OMAR) with an assumption that human behaviour is proactive and reactive where tasks occur concurrently within and among multiple operators. State, operator, and result (SOAR) (Laird and Newell, 1983), states that behaviour is captured as a search or movement through the problem space at a particular time and a goal state which represents a solution for the problem. The knowledge is modelled in terms of goals, states and operators, where operators are used to change or transform the state of the system. Business redesign agent-based holistic modelling system (Brahms), (Sierhuis et al., 1999), (Sierhuis et al., 2007), (Clancey et al., 1998) & (Seah et al., 2005) is a modelling/simulation environment to analyze work practices in organizations and represents people, things, places, behaviour of people over time, tools and artefacts used, when they are used. It focuses on communication between co-located and distributed people to support social behaviour.

Brahms supports social and behavioural elements necessary for dynamic group behaviour, however the objective for logical simulation as presented in section-1 is to find a model which can map human behaviour process for reactive/deliberative group behaviour and the context. The mapping between user behaviour elements, context and Brahms is presented in Fig.3 below:

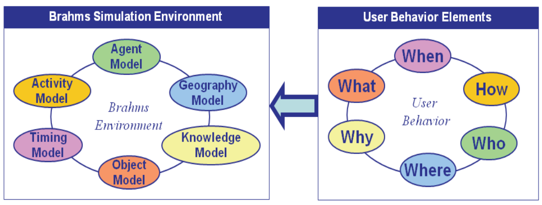

Figure 3: 5W&1H approach mapped to Brahms.

Workframes (activity model) and throughtframes (knowledge model) are key elements in Brahms. Thoughtframes are used to model the reasoning behaviour of agents and are represented as production-rules creating new beliefs of agents or objects whereas workframes (rule-based) perform agents and objects activities (simple or composite). Brahms includes an agent model that represent agents along with group hierarchy, and a communication model to exchange beliefs about agents and objects. It also provides means to model locations and objects (geographical and object models), that are important to establish the environment in which agents operate. Brahms can be used to model human beings interacting with a complex habitable environment as powerful, active, intelligent agents rather than passive participants for energy efficiency and it can represent the complexities found in real world human-environment interaction scenarios. The literature shows that behaviour inclusion within energy control and management is focused on either static profiles or predictive models (sensor based inhabitants' occupancy detection). However they are based on single user interactions and do not embed reactive/deliberative decision making. In this paper inhabitants perception, cognition and reactive/deliberative group behaviour is simulated using home context (5W1H) and mapping it to Brahms. It provides an opportunity to learn context, beliefs and activities that influence energy consumptions and could play significant role in energy efficiency within domestic settings. Our proposed approach is different from the existing research to the extent that we have demonstrated dynamic behaviour simulation and results obtained shall be applicable to the real life situations.

3 PROPOSED FRAMEWORK

To simulate inhabitants' reactive/deliberative group behaviour an integrated definition (IDEF) model with three levels of abstraction (Fig.4, Fig.5 and Fig.6) is proposed:

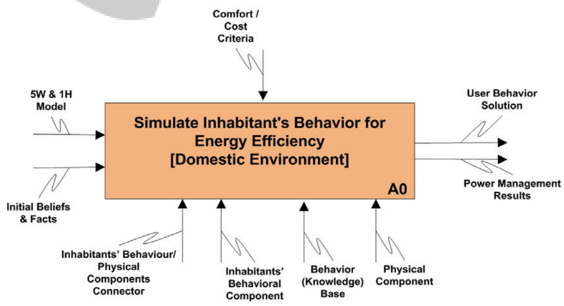

Figure 4: Behaviour simulation for energy efficiency.

IDEF models processes as functions with inputs (left arrows), outputs (right arrows), controls/constraints (top arrows) and means/methods (bottom arrows) at different levels of abstractions. Function A0 (Fig.4) represents the highest level of abstraction where 5W1H (domestic context) and initial beliefs serve as input, comfort/cost criteria as control, user behaviour and power management as output and behaviour base, Inhabitant's behaviour and physical components and connector to interoperate the outputs of these two components as means/methods. Inhabitants' in the 5W1H model fed as input to function "A0" correspond to the agents and their surrounding environment.

Sub-functions A1 (simulate dynamic inhabitants' behaviour) and A2 (calculate energy performance) as presented in Fig.5. These represent the conceptual framework of the abstract function A0. It is the second level of functional abstraction towards learning context and beliefs/facts from energy related group behaviours within domestic settings:

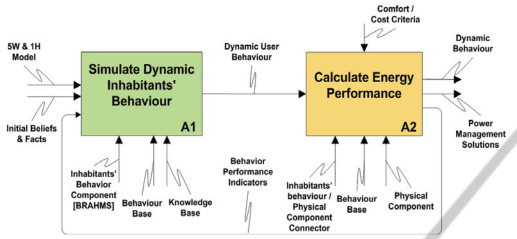

Figure 5: Conceptual framework for behaviour simulation.

(i) **Simulate dynamic inhabitants' behaviour (A1):**

The 'Simulate dynamic inhabitant's behaviour' component is the core element to simulate reactive/deliberative group behaviour using an agent based approach. 5W1H (context), initial beliefs and facts (single user activity profiles) are inputs. "A1" is implemented and simulated using Brahms language/environment for dynamic group behaviour scenario as presented in section 4 and its output (dynamic user behaviour) serves as input to sub-function A2 for energy calculations.

(ii) **Calculate energy performance (A2):**

The Physical component uses cost/comfort criteria and the inhabitants' behaviour/physical component connector to calculate cost integrated with behaviour. The Behaviour base serves as a data structure to store dynamically generated behaviours. The objective is to identify the context, beliefs and facts that influence energy consumption patterns to formulate energy control and management strategies. This part is under implementation and is not presented in this article.

The functional description of sub-function "A1" as reactive/deliberative inhabitants' group behaviour is detailed below along with the sub-functions in Fig.6. Since our approach is based on Belief Desire Intention (BDI) agents, we can keep track of the initial and changing beliefs of agents about contextual elements, such as the state of objects (what), inhabitants (who), physical location of inhabitants (where) and current activities (how).

(i) **Get context information (A1):**

This function gets the information of three important context elements i.e. inhabitant (who), object (what) and location (where). The inhabitants are represented by agents and it captures their beliefs and facts, e.g. who is the inhabitant/agent, what are the different characteristics of the inhabitants/agents and how they perceive the environment around them etc. The second important context element is the 'physical location' of inhabitants/agents and objects (physical objects and appliances) in domestic settings. The third context element 'object' provide information about the appliance in use by the inhabitant or that are involved in some activity along with its state (on/off etc.). Output from this function serves as input to the function 'Update knowledge base'.

(ii) **Update knowledge base (A2):**

This function takes 'Knowledge base' as its mean which corresponds to memory where all the beliefs, facts and context information is stored and updated. It takes initial beliefs, facts and context information from the 'Get context information' function. Changed beliefs and facts are updated every time some activity is performed by the 'Perform activity' function or based on some new beliefs from the function, 'Generate psychological state'. Output of updated beliefs and facts serve as input to functions 'Generate psychological state', 'Compute activity' and 'Calculate energy and save context'.

(iii) **Generate psychological state (A3):**

This function corresponds to human psychology which varies from individual to individual based on certain beliefs and facts. The psychological state is generated based on the beliefs and facts and context elements available to it from the "Update knowledge base" function. It also captures two important aspects of humans i.e. "feel and want". For example based on the fact that the temperature rises slowly in the room, a person starts feeling hot when a certain amount of temperature is reached and may want to open the window based on his belief that the temperature is very high. This belief will further influence the "Compute Activity" function for the selection of appropriate activity. It takes the social behaviour from the function 'Compute social behaviour' as control/constraint to generate changed beliefs based on some social influence. For example, having a belief that temperature is very high, inhabitant does not open the window due to the fact that other people present in the room don't feel as much hot and do not want him to open the window. Every time the beliefs are changed, they are updated in the "Update knowledge base" function.

(iv) **Compute activity (A4):**

Compute activity function represents a reactive behaviour and is associated with the selection of an appropriate activity like single user activity without deliberation, single user activity with deliberation or group activity with or without deliberation based on the changed beliefs and facts as input from 'Update knowledge base' function and psychological influence as control from 'Generate psychological state' function.

Since the inhabitants select some activity to be performed based on the context under the psychological influence, this function selects which activity (single user/group) is to be performed. It takes as input the beliefs, facts and context information from the "Update knowledge base" function and inhabitant who will be involved in the activity from the "who" model. The 'why/how' model serves as means which contains the information about activity. If selected activity is a single user activity and does not require deliberation, it is directly fed to the 'Compute activity time' function otherwise it is submitted to the 'Compute deliberative behaviour' function. In case of group activity it is always fed to the function 'Compute social behaviour' for group agreement. The 'why' model depicts the reason or cause of computing some activity. There could be certain causes to select some activity which affect the energy consumption patterns of inhabitants. These causes can be categorized into primary and secondary causes. For example a primary cause to turn on the electric lamp in the corridor is that the inhabitant is passing by there and it's dark, whereas the secondary cause may be some aesthetic sense.

(v) **Compute social behaviour (A5):**

Social behaviour of inhabitants significantly affects the energy consumption patterns in domestic settings. For example inhabitants having dinner together may consume less energy than everybody going to the kitchen and turning on the light and hot plate at different times. This function takes input from the 'Compute activity' function in case of a group-activity and uses 'who' model as input which will let this function know about the inhabitants who will be involved in the group activity to perform group agreement. Output in case of group agreement could be fed to the function 'Compute activity time' if deliberation is not required otherwise it serves as input for the function 'Compute deliberative behaviour'. The psychological state of inhabitants affects the social behaviour which corresponds to some group agreement or no group agreement. Similarly the social rule of having dinner together which is stored as agent beliefs can be bypassed by some agent or all of them upon the perception of some new facts and beliefs.

(vi) **Compute deliberative behaviour (A6):**

The deliberative behaviour of an agent is caused due to some changed beliefs and facts which influence the performance of the selected activity. This function captures deliberation on different elements like cost, comfort etc. for the selection of an appropriate alternative activity. Deliberation is a reasoning mechanism where an inhabitant decides which activity to be performed keeping in view the consequences of all possible choices. Deliberative behaviour affects energy consumption e.g. having multiple options to lower the temperature in the room as it's very hot inside, one of the inhabitants believes that opening window can be a good solution and moves to open the window. He then realizes a storm outside. This new perception of a bad weather outside by the agent at the 'Compute activity' function will update the changed beliefs and facts in the "Knowledge base". Based on the changed facts and beliefs in the "Knowledge base" which serves as means to this function or the past experiences which are saved in the "Behaviour base" an inhabitant may change his mind to turn on the air conditioning system instead. The choice of alternative actions based on cost, comfort, information etc. is stored in a database called 'behaviour base' which could help the inhabitant for future choices where he could maximize the comfort while minimizing cost if he likes to do so.

The selected activity after deliberation is finally sent to 'Perform activity' function.

(vii) **Compute activity time (A7):**

This function computes the time when some activity is to be performed by the inhabitants, e.g. the start and end time etc. It computes activity duration and sends this information to 'Perform activity' function. It receives activity information as input from the 'Compute activity' or 'Compute social behaviour' functions and the timing information from the "when" model, however activity time is computed only upon the receipt of the activity information.

(viii) **Perform activity (do/how) (A8):**

Based on the single, group, reactive, deliberative behaviour the activity is performed by this function and the information is used to calculate the energy consumption of this activity. It takes as input, a single/group activity and its associated time from 'Compute activity time' function and outputs the changed beliefs and facts to 'Update knowledge

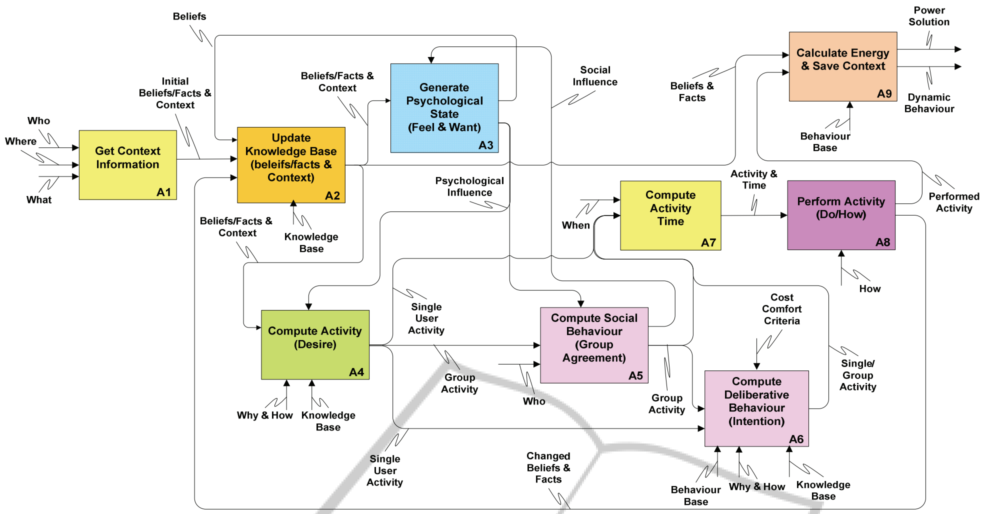

Figure 6: Functional model for dynamic behaviour simulations.

base' and activity completion information to 'Calculate energy and save context' functions respectively.

It is important to note here that activity performed is not physically executed but simulated for execution and is represented as start and end time. Upon completion of the activity i.e. end time, outputs are further submitted as respective inputs.

(ix) **Calculate energy and save context (A9):**

This function collects information about the performed activity and other context elements (beliefs and facts) from 'Perform activity' and 'Update knowledge base' functions and calculates the energy consumed after performing the activity. Information about the activity performed, context elements and energy consumed is also saved in the behaviour base which could further be utilized to make choices based on cost/comfort criteria. Finally the dynamic behaviour and power solution is provided as output. The power solution will provide a series of calculated energy requirements on varying dynamic group behaviour within domestic settings. It will help in identifying min/max energy demand to balance the supply and demand equation as well.

Activity information fed from 'Perform activity' function consists of name, start time and end time. 'Calculate energy cost and save context' function in the presence of this information and beliefs and facts calculates energy using activity duration and appliances with associated energy costs. This function calculates energy performance based on theoretical and actual energy costs, theoretical energy cost is computed based on static activity profiles and actual energy cost represent the cost computed based on dynamically simulated behaviour profiles. The difference between the theoretical and actual energy cost gives energy performance. This function outputs complete behaviour profile generated dynamically and its associated power management solution.

4 SCENARIOS' DESCRIPTION

We have collected a workday activity profile (24h) of a family in France through an activity journal (Fig.7) with contextual information.

Date:											
First Name:			Age:				Role in the Family:		Professions:		
Movement			Principal Activity				Secondary Activity			With Whom	Action on window, store,
From	To	Time	Activity Name	Start	End	Type	Activity name and equipment used	Start	End		

Figure7: Activity journal for data collection.

To demonstrate reactive/deliberative group behaviour a simple scenario from the collected profile is implemented using the Brahms language following the model proposed in section 3:

"Stephan (father) comes back home from LAB at 19h48 and walks through the corridor to the kitchen for dinner. Anna (daughter) and Erik (son) are watching television in the lounge. They walk to the kitchen for dinner at 19h50. Katherine (mother) is already in the kitchen and is preparing the table for dinner and is interacting with the fridge in parallel. Stephan drinks water from the refrigerator. They have dinner together from 19h50 till 20h30. Stephan,

Katherine and Anna move to the living room after finishing the dinner and start watching television there. Erik moves to the study room.

The temperature increases slowly due to the presence of all family members in the living room. Stephan feels hot and wishes to open the window to reduce the temperature. Before opening the window he asks Katherine and Anna. They agree and Stephan goes to the window to open it. He realises that there is a storm outside and opening window is not safe, so he evaluates between two options to identify the most comfortable (i) turn the AC on using the remote control, (ii) open the door which is linked to the study room. He decides to turn on the AC as opening door might disturb Erik".

To implement the above scenario we need to model human cognition, reactive/deliberative behaviour (group agreement), context (5W1H) and dynamism (temperature increase slowly). Results from the simulation represent human behaviour at multiple levels of detail and interactions between agents and objects. Sub-functions "A1 to A9" (Fig.6) are implemented and simulated in Brahms with results in section 5. Sub-function "A9" will be deve loped as a plug-in to be integrated with the Brahms simulation for energy calculation.

5 SIMULATION RESULTS

The scenario in section 4 is implemented and simulated using the model (section 3) with the Brahms language. It starts with Brahms code (using composer), compiled (using builder) to create '.xml' files and simulation results are generated as a text file using the Brahms simulation engine. The simulation text file is converted into a MySQL database by agent viewer in order to graphically analyze the simulation results as presented below in Fig.8. Only a part of the simulation results is shown here that takes into account the reactive, deliberative and group behavi-

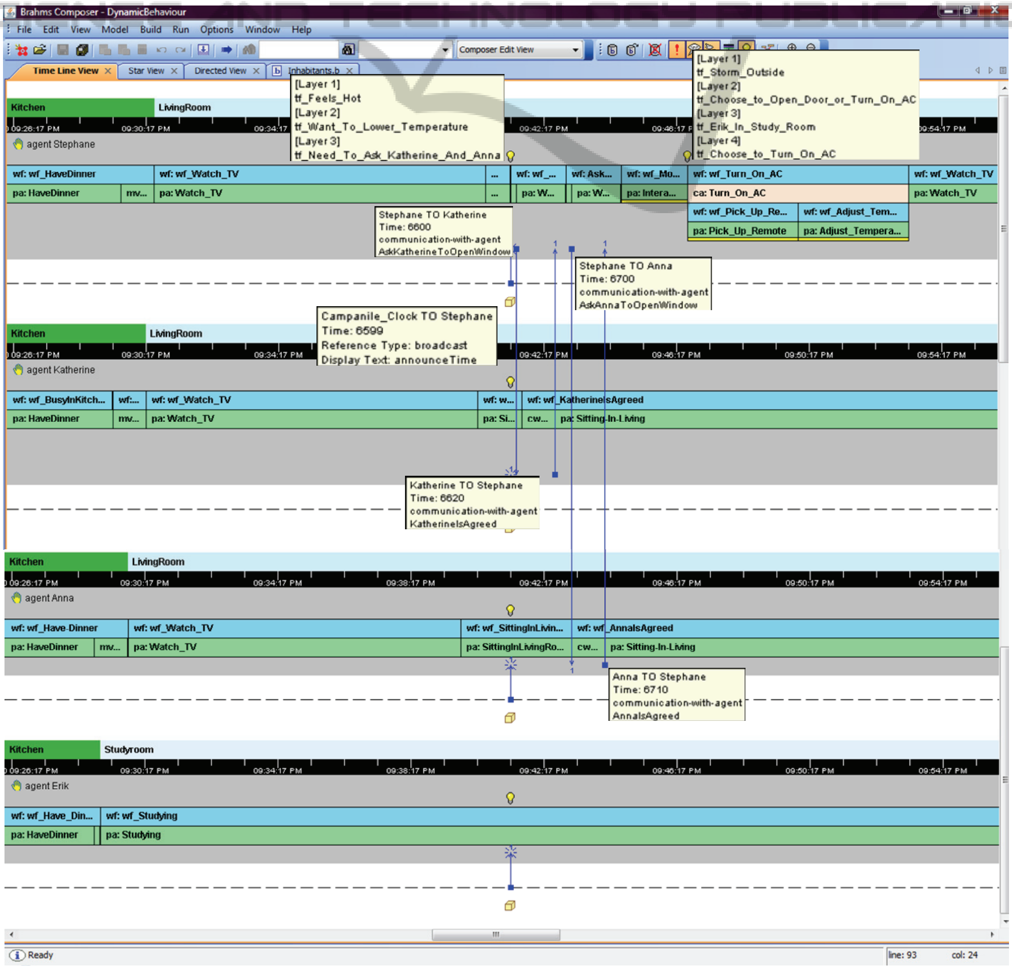

Figure 8: Communication and Group reactive/deliberative behavior.

our. Communication activities taking place between agents Stephan, Anna and Katherine are represented by vertical lines and the bulb represents the Brahms throughtframe (tf).

It is evident from the Fig. 8 that agents Stephane, Katherine and Anna have moved to the living room after having dinner in the kitchen. The first throughtframe with reference to the agent Stephane highlights the temperature increase in living room beyond 30 degrees and Stephane feels hot and want to lower the temperature. In order to establish dynamic group behaviour in the presence of Katherine and Anna, Stephane decides to go for group agreement and to establish this he starts communication with other agents.

This belief gives rise to the deliberative behaviour and now he wants to choose between opening the door or turning on the air conditioner based on Erik's presence in the study room.

However, changing the parameter with no storm outside will not trigger the thoughtframes used for further reasoning and the simulation results will be different. Horizontal lines beneath the primitive activities (pa) show the interaction with some appliance/object.

6 CONCLUSIONS

From the results, we have demonstrated the simulation of reactive/deliberative group behaviour within domestic settings (complex scenario). Perception, cognitive, social and psychological elements are dynamically simulated to generate behaviour of inhabitants' over time. We are working on a Java plug-in to connect to the behavioural pattern generated from Brahms for energy calculations and learning context, beliefs and facts that influence energy consumption within the domestic environment. We are also working on the sub-function "A9" to calculate energy related to the dynamic behaviour profiles generated from simulation and build a database (behaviour base) of context, beliefs, facts and activities having strong influence on the energy consumption. During simulation, agents are provided with potential consequences of possible actions learned from previous simulations in anticipation to find energy efficient behaviour and savings.

7 FUTURE WORK

In this article dynamic behaviour is demonstrated with data collected from a single family, however future work will include data collected from a set of reference households. Dynamic behaviour simulation could be extended to model patterns for different classes of household behaviours and analysis of energy impact due to correct behaviour (ergonomy). Simulation results as presented in section 5 start with the initialization of beliefs and facts as static values; hence based on fixed initial values we could have one behavioural pattern; however adjusting the list of beliefs and facts dynamically after each simulation within parametric space could be interesting to identify generalized energy related behaviour. Design of experiment (DOE) and data mining techniques if employed would help to reduce the number of possible combination of facts and beliefs to start simulations and optimize the computational time in terms of reduced number of experiments.

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