Paper No: 200

A Methodology to Develop a User-Behaviour Tool to Optimize Building Users' Comfort and Energy Use

Gulben Calis[1], Aitor Corchero Rodriguez[2], Türkan Göksal-Özbalta[1], Regina Enrich Sard[2], Aitor Arnaiz[3], Ignacio Lazaro[3], Nikos Sakkas[4]
[1]Ege University, [2]Eurecat, [3]IK4-Tekniker, [4]Apintech Ltd.
gulben.calis@ege.edu.tr

ABSTRACT

The total amount of energy spent in buildings is quite significant, reaching up to 40% of the world's total energy usage. Accordingly, the EU has set goals requiring zero CO2 emission in buildings by 2020 to respond to the increasing energy demand and started continuously supporting innovative research approaches for improving energy efficiency in buildings. However, innovative approaches cover the challenges in specific parts (specific facilities, building functionalities, etc.) of both new buildings and renovation of existing buildings. Therefore, main challenge in current building facilities is scaling up of the building innovative approaches in combination with the building usage. So, it is crucial to influence the complex interaction between users and buildings. To reinforce the building configuration and adaption according to the occupants' behaviour, this paper presents a methodology to construct a building-user interaction. This methodology aims at developing data mining algorithms and semantic models with stream reasoning capabilities that allows occupants and facility managers to monitor and control the energy consumption, to detect the energy inefficiencies and to generate recommendations to reduce energy consumption whilst increasing occupant comfort. The proposed methodology is modular which could be integrated in the existing building management systems and that is promising to reduce energy use in existing buildings.

Keywords: User behaviour, data mining, semantic modelling, energy efficiency.

INTRODUCTION AND PROBLEM STATEMENT

The rapid increase in energy consumption and carbon dioxide emissions require the governments and the society to be aware of the need to conserve natural resources. In this sense, the most common strategy is to move towards more sustainable and energy efficient paradigms. As an example, one of the EU priorities is to be more sustainable towards 2020 and beyond through promoting strengthen directives and policy frameworks as for example Communication on Energy Union (COM (2015)080) [1], the SET-Plan Integrated roadmap, 'Towards an Integrated Strategic Energy Technology (SET) Plan' (COM (2015) 6317) [2], 'New deal for consumers' (COM (2015)339) [3] and the accompanying 'Guidelines for self-consumption'.

Towards achieving more sustainable and energy efficient paradigms, buildings play a central role. Building energy consumption accounts for about 40% of total final energy consumption and around 55% of electricity consumption in the EU-28. Considering the rest of EU sectors, building energy consumption is followed by transport (32%), industry (26%) and agriculture (2%) [4]. A similar pattern is seen worldwide where buildings account for over 41% of national energy consumption in US (22% for residential buildings and 19% for commercial buildings) [4]. In China, building energy consumption reaches 34% of the total energy consumption [5]. Therefore, it is important that buildings in the developed countries continue to provide energy savings.

Energy savings in buildings can be produced along the entire building life cycle (planning, construction, utilization and end of life). However, the literature showed that life cycle energy use mostly depend the operation energy of the buildings [6]. Therefore, important energy gains can be produced through reducing its operating energy significantly using latest advances in technology and management systems. Thus, building operations (especially public buildings) are managed by Building Management Systems (BMS). These systems are capable of automatically control the operation of energy systems and to monitor the energy consumption. These mentioned automation in the energy monitoring and control is carried out by data mining and machine learning techniques such as decision trees [7], time series analysis [7], neural networks [8] and optimization algorithms among others [9, 10]. Moreover, Multi-Agent System architectures and complex event processing technology have been also applied to be more efficient the actuation over the building and fault diagnosis [11]. However, these systems might not fully operate efficiently mainly due to increasing demand on maintaining occupant comfort. Furthermore, BMS lack interoperability between facilities due to the lack of communication standards in building information modelling and data modelling. Spite of the last years communication data models like Industry Foundation Classes (IFC) have been developed, there exist a gap into its adoption in commercial tools. To avoid this interoperability lack, several authors [12, 13] have tried to semantic modelling the building facilities in order to deal with the building operational complexity and also support the construction of a more integrated decision support system. However, these systems have caused data exhaustion and reasoning inefficiencies due to the plausible weakness in semantics in matter of temporal and geospatial combined reasoning [14, 15]. Therefore, the fact is that these systems operate as isolated islands according to fixed schedules and maximum design occupancy assumptions. Also, these systems make use of code defined occupant comfort ranges increasing energy consumption even more [16].

Latest trends in BMS rely on including the user behaviour and interaction with the building as a new variable. There exist is a need to understand interactions between users and building systems, which can significantly reduce the total building energy use [17]. Among various factors influencing building energy consumption, occupant behaviour plays an essential role and is difficult to investigate analytically due to its complicated characteristics [18]. It should be noted that occupant behaviour refers to actions and reactions of building users that have a direct or indirect impact upon building energy consumption. Studies have shown occupant behaviour could affect the energy consumption in buildings by a factor of 3 [19] and in some cases up to a factor of 10 [20]. However, existing BMS cannot include user behaviour in their operating systems due to the complexity of understanding the driving factors that could impact occupant behaviour in interacting with different building systems and modelling these behaviours.

Under this framework, the HIT2GAP-EU funded project (http://www.hit2gap.eu/) is aimed at reducing the gap between the real energy consumption of the building and the simulated one through elaborating an intelligent BMS. This BMS will be composed by intelligent modules to analyse the building facilities and consider also the user interaction as a main driver to contribute to achieve energy gains. In this overall architecture, the "***User Behaviour Tool (UBT)***" will be in charge of analysing the behaviour of the building facilities and building occupants to recommend suitable building operational strategies. The novelty of the proposed system is to convey building facilities with user behaviour under an intelligent system capable of dealing with huge torrents of information and dynamically adapt behaviour according to the building performance and user-interaction. In this sense, the proposed intelligent system will use streaming semantic reasoning to filter relevant events from the huge torrents of data available in the building according to the user state. These relevant user or state will serve as input point to adapt building facilities considering also the building occupancy. For this adaptation, data mining algorithms will be used to elaborate dynamic semantic rules that filter the incoming information and support detection of energy abnormalities. The decision support regarding to perform the building adaptation will be done using semantic reasoning based on the relevant events, the dynamic rules and also user comfort definitions extracted from standard comfort models and implemented as semantic axioms and facts. As a result, building adjustments (e.g. set-points) will be proposed by facility according to the building occupancy and state. To achieve this, the document firstly provides the main functionalities of the User-Behaviour Tool and identifies data requirements ("***User-Behaviour Tool: Functionalities and Data Requirements***" section). Based on the elicitation of the requirements, "***The Architecture of the User-Behaviour Tool***" section will depict the proposed system to recommend building managers suitable control strategies moving the overall building behaviour towards zero-energy and low carbon paradigms. At last but not least, "***Conclusions and Future Work***" section will rely on describing main conclusion and future work to be performed under the HIT2GAP-EU funded project framework.

USER-BEHAVIOUR TOOL: FUNCTIONALITIES AND DATA REQUIREMENTS

Due to increasing energy demand, especially for commercial and public buildings, the installation of building automation systems with more actuation possibilities could confer a large energy-saving potential. The focus is generally on the integrated control of HVAC, lighting and shade/blind positioning of an individual building/floor/zone so that different separations can be actuated independently from each other. Accordingly, independent actuation enables making adjustments on set-points as well as actuation, which increase the possibility of reducing the corresponding energy use. However, these systems lack information about user comfort levels and have default settings mainly based on thermal comfort standards, which might not represent the preference of users within a particular environment. Accordingly, specific conditions of a building might lead users to take actions for increased comfort levels such as opening windows for increased thermal comfort or turning on lights for increased visual comfort.

The UBT aims at detecting wasteful user behaviour practices in a building in order to generate cross-dimensional recommendations for optimized user comfort and energy efficiency. The functionalities of the user-behaviour tool were determined via a survey among HIT2GAP consortium consisting of 22 partners representing different stakeholders including facilities managers, construction companies, end-users and BMS providers. Different use-cases were analysed and the main functionalities of the user-behaviour are identified as follows:

- Maintaining ambient comfort of thermal and visual levels for the working environment,
- Supervising HVAC system, its energy consumption and generating recommendations towards reducing energy consumption
- Programming and optimizing the HVAC equipment operation
- Operating lighting systems based on occupancy
- Treating aggregated user complaints, preferences and associated troubleshooting

The tool takes into consideration aggregated/anonymized users' indoor environmental condition preferences and their state (i.e. stressed, excited) as well as air quality requirements. The preferences and perceived comfort of users will be obtained via online questionnaires and will be associated with the current status of building systems (i.e. thermal comfort conditions and illuminance). In addition, wearable devices will be utilized to extract information on the user state. Therefore and in order to model user behaviour, current statuses of the building including energy consumption, indoor and environmental conditions have to be collected. In addition, sensor and actuator information as well as their current status have to be integrated in the model to further generate and/or implement recommendations aiming at reducing energy consumption. As can be seen in Figure 1, physical and contextual parameters both at the mid-term and immediate level have direct impact on the user behaviour. These parameters and corresponding data can be categorized under 4 main groups: (i) Data for defining building / facility (i.e. building type, elements, infrastructure), (ii) Data for defining building systems (i.e. HVAC type, lighting systems), (iii) Measured and/or predicted data (i.e. environmental conditions, energy consumption), (iv) User behaviour and state data (i.e. user profile , preference of users). Overall, these data have to be collected in order to provide a comprehensive approach to modelling user behaviour and building performance.

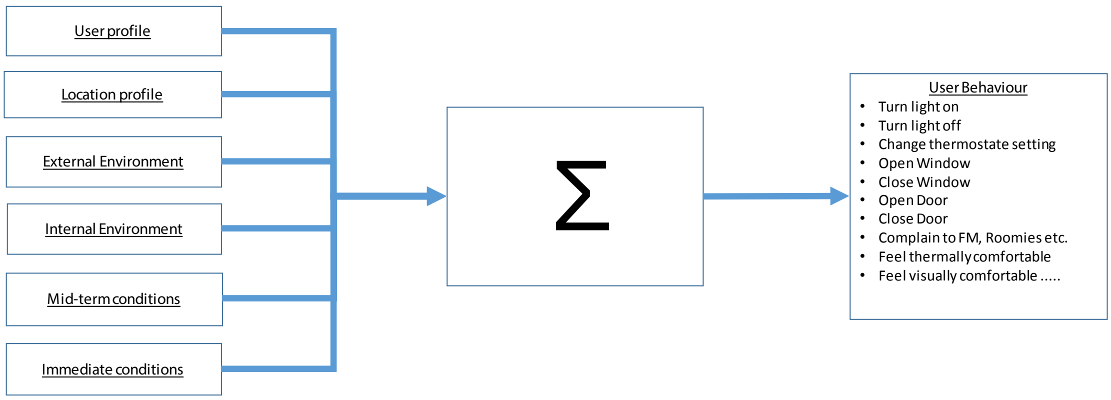

Figure 1 Predominant parameters on the user behaviour

THE ARCHITECTURE OF THE USER-BEHAVIOUR TOOL

The main focus of the UBT is to provide different stakeholders (Facility/Maintenance Managers and Building Managers) a framework to tackle efficient decision according to the building status and the occupant's behaviour and state. Indeed, the benefits for the Facility/Maintenance Managers will be an integrated framework for supervising the building interventions and early reaction to building operation abnormalities that could occur. From the Buildings Managers perspective, the UBT will facilitate the accomplishment of policies at regional, national and pan-European. For the end-users or building occupants, the benefits of the module will mainly be focused on adapting building behaviour according to their preferences. Therefore, the UBT will provide suitable recommendations and building control strategies for the benefit of building occupants' comfort through adapting and making efficient the building operations.

Hence, the proposed UBT (Figure 2) will collect the Facility Manager (FM) and Energy Manager (EM) requests. These requests activate the "***User Behaviour Models***" that indeed uses the information from BMS, user sensors, and occupant preferences through the semantic model ("***Building and User Knowledge Base***"). It should be noted that user sensors will collect data in the form of events to be real-time analysed and semantically filtered. Mentioned sensor data will correspond with presence/movement information and user state. This event information will be combined with building specific data such as occupant presence/movement, indoor environmental conditions (temperature, CO_2, relative humidity etc.), lighting, window opening/closing behaviour, thermostat adjusting behaviour. In addition, online questionnaires will be used to gather occupant preferences, which then will be used to identify comfort ranges of occupants per profile.

The semantic model ("***Building and User Knowledge Base***") stores current building occupants' contextualized information with the aim at deriving new knowledge from the stored information by applying semantic reasoning combined with rules reasoning. Thus, this new knowledge can be corresponded with the application of the FM/ EM decision-making procedures, identifying comfort levels, detecting complex abnormalities, etc. The available and generated information (knowledge) from the knowledge base is shared with the "***User Behaviour Models***". These models derive new thresholds and semantic information (e.g. new set points, operational strategies, etc.) through knowledge discovery algorithms to support the generation of the mentioned complex abnormalities and indeed generate recommendations. These thresholds will be included into the reasoning in the form of semantic rules that dynamically will provide specific building behaviour. Hereafter, these kinds of rules will support the decision-making and the generation of recommendations. During the generation of these recommendations, the FM/ EM or even the models can use external simulation tools to refine the recommendations with the user experience. The final model recommendations are stored in the semantic model that indeed returns it to the mentioned stakeholders. As a result, the knowledge base can interact to the user behaviour models to enhance the recommendations and generate effective knowledge based on the actual state of the building and users. This module can be capable of real-time actuation over the building by the identification and remediation of complex behavioural events (e.g. semantic rules/restrictions over the events) to avoid energy inefficiencies meanwhile the user comfort is maintained or enhanced.

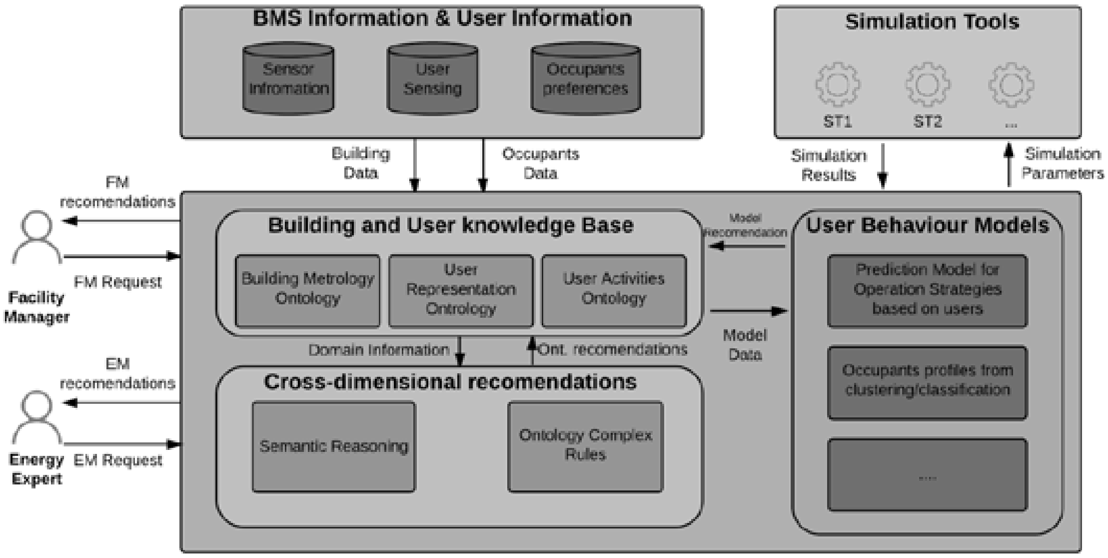

Figure 2 Concept and Approach of the proposed User Behaviour Module

Consequently, the recommendations are derived from information directly acquired from the occupants via health monitors and questionnaires. Both inputs are analysed by the user behaviour models and combined with building information to generate a dynamic, adaptable and holistic recommender and decision support system. As mentioned, the main components of the UBT are the (i) "***Building User Knowledge Base***" as a model to contextualise the building and user-related information; (ii) "***Cross-dimensional recommendations***" as a recommender and decision making system to derive suitable building operation according to user comfort and state; and (iii) "***User Behaviour Models***" as a set of data mining and machine learning algorithms for inferring dynamic rules for the "***Building User Knowledge Base***".

Building-User Knowledge Base

The building-user knowledge base of the UBT is aimed at representing (i) the building infrastructure and systems; (ii) the user behaviour and state; and (iii) the decision paths and flows that take place in the building. For that purpose, the building knowledge base will consider current standard semantic models related to buildings such as IFC-OWL [21] and SAREF [22]. In terms of building sensors, abstraction will be conducted through W3C-SSN [23] and Geo-SPARQL [24] for representing building geometry. Finally, user behaviour will take advantage of the conversion the developed models ("*Functionalities and Data Requirements for the User Behaviour Tool*" section) into semantic resources over the Schema.org [26]. The main novelty of this combination between existent and non-semantic resources will permit the knowledge base to be standard and linked with open building data. Moreover, the construction of this semantic model will advance in providing comprehensive abstractions and data fusion (integration) for the building and energy domain. Therefore, this paradigm will advance towards adopting semantic sensor web paradigms [25].

Cross-Dimensional Recommendations

Cross-Dimensional recommendation is aimed at taking advantage of the building-user knowledge base to derive the proper recommendations based on the incoming building information. This cross-dimensional recommendation will be generated through semantic reasoning with temporal and spatial reasoning capabilities. The semantic reasoning to be applied will comprise the use of streaming reasoning to select critical events at different time stamps [27]. These crucial streams of data will be stored in a semantic data store or semantic repository (Sesame [28], Virtuoso [29], StarDog [30], etc). The spatial reasoning will be conducted through the geo-reasoners applied over the information stored in the semantic repository.

More complex reasoning and cross-recommendation will be performed through the dynamic rules reasoning. In the one hand, dynamic rules coming from the "User behaviour models" and encapsulated in SWRL [31] or SPIN [32], will be incorporated into the elaborated knowledge base. Moreover, rule-based reasoning over the building will be performed using JENA-SWRL [33] for SWRL rules or SPIN engine for SPIN rules.

The novelty of the cross-dimensional recommendations generation will be focused on the combination between temporal and spatial reasoning at low level. Moreover, other highlighted benefits will come from the generation of cross-dimensional recommendations using OWL reasoning and rule-based reasoning.

User Behaviour Models

User-Behaviour Models will be focused on applying data mining and machine learning algorithms in order to detect energy abnormalities and user behaviour and comfort abnormalities. With this aim, this specific part of the module will apply a Knowledge Discovery in Databases (KDD) methodology [34] to encode adaptive knowledge in the form of SWRL or SPIN rules.

This methodology will use (i) forecasting techniques; and (ii) classification techniques to infer mentioned kind of rules. Forecasting techniques (e.g. Linear Regression, Multi-Variate Forecasting, etc.) will be applied in order to predict user behaviour and then, detect possible abnormalities of uncomforted building states. Finally, classification techniques will permit to generate a decision tree with the efficient and inefficient building activities based on user information combined with the building information.

The novelty of this part of the UBT is the generation of dynamic and adaptive knowledge to be applied over the current building state (facts). Moreover, this approach will permit also to move to more holistic decision systems not only including intra-building information but also with the possibility to include other building decision making procedures.

CONCLUSIONS AND FUTURE WORK

This study presented a framework to integrate user-behaviour in the operation strategies of building systems. The proposed framework also has the capability to be integrated with building simulation tools for improving the accuracy of energy performance of the buildings in the design phase. The framework includes three main components: the preferences and state of the users which must be met in order for the user to be comfortable and satisfied with their environment; the behaviours which users can perform in order to increase their satisfaction levels in the environment; the building systems with which users can interact to affect the building energy consumption. The proposed UBT provides novelties and benefits at social, technological and energy perspective. From social perspective, UBT module will provide the building occupants and building managers to convey on behalf the energy efficiency and sustainability of the building operation. From the technologic perspective, the UBT presents answers to most common challenges and needs proposed to the adoption of semantics in building management and semantic sensor web research lines. In this sense, the application of semantic stream reasoning to detect initial relevant events and more cross-dimensional recommendations and higher level (like a divide and conquer approach) will permit to create a reinforced decisions combining all building processes and information. From the energy perspective, this presented conceptual model will permit to interrelate different stakeholders' energy decision-making procedures to enable holistic decision-making. As a conclusion, the adoption of the framework will enable buildings to be more energy efficient, moving towards the accomplishment of the EU energy challenges in matters of zero-energy buildings, low carbon and circular economy paradigms.

ACKNOWLEDGEMENTS

This research is based upon work supported by the European Commission under Grant No. 680708. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the European Commission.

REFERENCES

[1] COM (2015)080, ***A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy***, 2015

[2] COM (2015) 6317, ***Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation***, 2015

[3] COM (2015)339, ***New Deal for Energy Consumers***, 2015

[4] Klein, L., Kwak, J., Kawulya, G., Jazizadeh, F., Becerik-Gerber, B., Varakantham, P. and Tambe, M., 2012, ***Coordinating occupant behavior for building energy and comfort management using multi-agent systems***, Automation in Construction, March 2012, pp. 525-536.

[5] Zhao, L., Zhang, J. and Liang, L., 2013, ***Development of an energy monitoring system for large public buildings***, Energy and Buildings, November 2013, pp. 41-48.

[6] Ramesh, T., Prakash, R. and Shukla, K.K., 2010, ***Life cycle energy analysis of buildings: An overview***, Energy and Buildings, Vol 42, Issue 10, pp. 1592-1600.

[7] Papantoniou, S., Kolokotsa, D. and Kalaitzakis, K. ***Building optimization and control algorithms implemented in existing BEMS using a web based energy management and control system***, Energy and Buildings, Volume 98, 1 July 2015, pp. 45-55. ISSN 0378-7788, http://dx.doi.org/10.1016/j.enbuild.2014.10.083.

[8] Ferlito, S., Atrigna,M., Graditi, G., De Vito, S., Salvato, M., Buonanno, A. and Di Francia, G., ***Predictive models for building's energy***

consumption: An Artificial Neural Network (ANN) approach, AISEM Annual Conference, 2015 XVIII, Trento, 2015, pp. 1-4.doi: 10.1109/AISEM.2015.7066836

[9] Xiao, F. and Fan, C., ***Data mining in building automation system for improving building operational performance***, Energy and Buildings, Volume 75, June 2014, Pages 109-118, ISSN 0378-7788, http://dx.doi.org/10.1016/j.enbuild.2014.02.005.

[10] Saleem, F. and Al-Malaise, A. S. ***Implementation of data mining approach for building automated decision support systems***, International Conference on Information Society (i-Society-2012), London, pp. 127-130.

[11] Fangwen, C., Yahui, W., Li, S., Chao L. and Mingjia, D. ***The design of the building electrical fault diagnosis system based on multi-agent***,"The 27th Chinese Control and Decision Conference (2015 CCDC), Qingdao, 2015, pp. 3345-3349.

[12] Venugopal, M., Eastman, C.M., Sacks, R. and Teizer, J., 2012, ***Semantics of model views for information exchanges using the industry foundation class schema***, Advanced Engineering Informatics, Volume 26, Issue 2, April 2012, pp. 411-428, ISSN 1474-0346, http://dx.doi.org/10.1016/j.aei.2012.01.005.

[13] Venugopal, M., Eastman, C. M. and Teizer, J., 2015, ***An ontology-based analysis of the industry foundation class schema for building information model exchanges***, Advanced Engineering Informatics, Volume 29, Issue ***4, October 2015, pp. 940-957, ISSN 1474-0346,*** http://dx.doi.org/10.1016/j.aei.2015.09.006.

[14] Corry, E., Pauwels, P., Hu, S., Keane, M. and O'Donnell, J., 2015, ***A performance assessment ontology for the environmental and energy management of buildings***, Automation in Construction, Volume 57, September 2015, Pages 249-259, ISSN 0926-5805, http://dx.doi.org/10.1016/j.autcon.2015.05.002.

[15] Costa, G. and Madrazo, L., 2015, ***Connecting building component catalogues with BIM models using semantic technologies: an application for precast concrete components***, Automation in Construction, Volume 57, September 2015, Pages 239-248, ISSN 0926-5805, http://dx.doi.org/10.1016/j.autcon.2015.05.007.

[16] Hong, T., D'Oca, S., Turner, W.J.N. and Taylor-Lange, S.C., 2015, ***An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs framework***, Building and Environment, Volume 92, October 2015, pp.764-777.

[17] Hong, T., D'Oca, S., Turner, W.J.N., Taylor-Lange, S.C., Chen, Y. and Corgnati, S.P., 2015, ***An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema, Building and Environment***, Volume 94, December 2015, pp. 196-205.

[18] Yu, Z, Fung, B.C.M., Haghighat, F., Yoshino, H. and Morofsky, E., 2011, ***A systematic procedure to study the influence of occupant behavior on building energy consumption***, Energy and Buildings, Volume 43, Issue 6, pp.1409-1417.

[19] Fabi, V., Andersen, R. V., Corgnati, S. P., and Olesen, B. W., 2013, ***A methodology for modelling energy-related human behaviour: Application to window opening behaviour in residential buildings***, Building Simulation, Volume 6, No 4, pp. 415-427.

[20] Sieminski, A., 2013, ***International energy outlook 2013***, US Energy Information Administration (EIA) Report Number: DOE/EIA-0484.

[21] Terkaj, W. and Šojić, A., 2015, ***Ontology-based representation of IFC EXPRESS rules: An enhancement of the ifcOWL ontology***, Automation in Construction, Volume 57, September 2015, Pages 188-201, ISSN 0926-5805, http://dx.doi.org/10.1016/j.autcon.2015.04.010.

[22] Daniele, L., den Hartog, F. and Roes, J., 2015, ***Created in Close Interaction with the Industry: The Smart Appliances REFerence (SAREF) Ontology***, Lecture Notes in Business Information Processing, Volume 225, pp. 100–112.

[23] Compton, M., Barnaghi, P., Bermudez, L., García-Castro, R., Corcho, O., Cox, S. Graybeal, J., Hauswirth, M., Henson, C., Herzog, A., Huang, V., Janowicz, K., Kelsey, W.D., Le Phuoc, D., Lefort, L., Leggieri, M., Neuhaus, H., Nikolov, A., Page, K., Passant, A., Sheth, A and Taylor,

K., 2012, ***The SSN ontology of the W3C semantic sensor network incubator group, Web Semantics: Science, Services and Agents on the World Wide Web***, Volume 17, December 2012, pp. 25-32, ISSN 1570-8268, http://dx.doi.org/10.1016/j.websem.2012.05.003.

[24] Battle, R. and Kolas, D., 2012, ***GeoSPARQL: Enabling a Geospatial Semantic Web***, ***Semantic Web Journal***, Volume 0, No. 0, pp. 1–17.

[25] Sheth, A., Henson, C.and Sahoo, S. S., 2008, ***Semantic Sensor Web***, ***IEEE Internet Computing***, Volume 12, No 4, July-Aug. 2008, pp. 78-83, doi: 10.1109/MIC.2008.87

[26] Schema.org website: http://schema.org/

[27] Whitehouse, K., Zhao, F. and Liu, J., 2006, ***Semantic Streams: A framework for composable semantic interpretation of sensor data***, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), Volume 3868 LNCS, pp. 5–20.

[28] Sesame Web page: www.openrdf.org/

[29] Virtuoso Web page: http://virtuoso.openlinksw.com/

[30] StarDog Web page: http://stardog.com/

[31] Horrocks, I., Patel-schneider, P. F., Boley, H., Tabet, S., Grosof, B. and M. Dean, 2004, ***SWRL : A Semantic Web Rule Language Combining OWL and RuleML***, ***W3C Memb. Submiss. 21***, May 2004, pp. 1–20.

[32] Knublauch, H., Hendler, J. A. and Idehen, K., 2011, ***SPIN - Overview and Motivation***, ***http://www.w3.org/Submission/spin-overview/.***

[33] McBride, B., 2002, ***Jena: A semantic web toolkit***, IEEE Internet Computer, Volume 6, No. 6, pp. 55–58.

[34] Fayyad, U., Piatetsky-Shapiro, G. and Smyth, P., 1996, ***The KDD process for extracting useful knowledge from volumes of data***, Communication. ACM, Volume 39, No. 11, pp. 27–34.