Robustness against Data Availability Problems in Urban Energy Planning Support Software

Najd Ouhajjou
Wolfgang Loibl
Peter Palensky

Energy Department
AIT-Austrian Institute of Technology
Vienna, Austria

Amin Anjomshoaa
Stefan Fenz
A Min Tjoa

Institute of Software Technology and Interactive Systems
Technical University of Vienna
Vienna, Austria

***Abstract*—Using an existing decision support system in different data availability situations is a challenge. This is due to the significant variance in terms of what data can be acquired as input for such systems. In urban energy planning, the problem of data availability is even more crucial because of the large amount of data that is required. This problem affects the portability and the viability of such systems. i.e. they can only be used in one single specific situation at a certain point of time, as long as data are available in the same way. This paper presents an ontology-based approach for developing and keeping such systems more robust against data availability problems. The methodology allows integrating the initial requirements of the system, the domain semantics, and a multiple level-of-detail answering mechanism. The results presented in this paper are validated against an application in modeling a modular ontology-based urban energy planning support system. The proposed solution, in this paper, allows the flexibility of these systems in terms of input data. Furthermore, it allows better traceability of how the system fulfills the initial requirements.**

Keywords—ontology; energy planning support; software development methodology; decision support; semantics

I. INTRODUCTION

Urban energy planners target cities to reduce the amount of greenhouse gas (GHG) emissions in the world. The choice of cities as a target is due to the fact that their energy consumption results in 71% of all energy-related direct GHG [1]. However, urban energy planners face the complexity of cities they are challenged to quantify the impact of their decisions, especially given the diversity of data availability in different cities. The research problem addressed by this project is to design an ontology-based planning support system that: (i) models the complexity of the city in terms of interaction of components and also conflicting interests of stakeholders; (ii) a system that works under different data availability conditions in different cities.

II. RELATED WORK

The review of existing software in urban energy planning is based on a list of criteria that have been defined in a previous work [2]. These criteria are as the following: (a) Support of perspectives of different stakeholders. (b) Presenting output in a level of abstraction that all stakeholders understand. (c) Integration of calculation and considering their systemic impact on the city. (d) System viability through robustness against data availability. The later criterion is particularly highlighted in this research project.

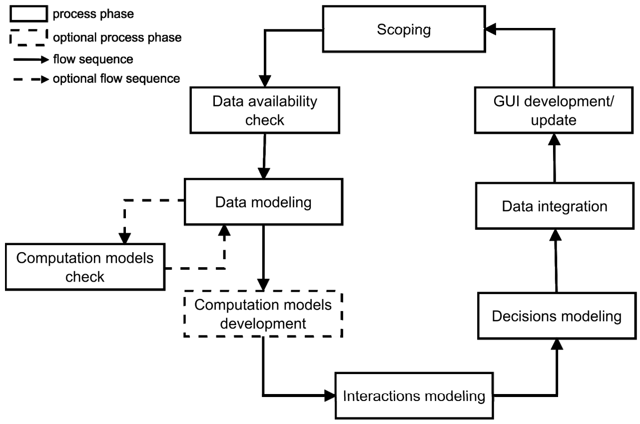

Fig. 1. Main phases of the development methodology

A list of available energy planning related tools is carefully described in [3]. Software tools that are closer to the scope of our target system are UrbanSim [4], CitySim [5], EnergGIS [6], CommunityViz [7], SynCity[8]. However, these tools do not fulfill all at once the characteristics of urban energy planning support systems described above. In particular, they do not operate under different data availability conditions.

III. DEVELOPMENT METHODOLOGY AND APPLICATION

The adopted methodology is based on gradually building an ontology that includes: domain concepts, stakeholders' information-requirements, domain knowledge, and system upgrade/customization concepts. The methodology is structured in nine iterative phases, based on a reference ontology development methodology[9], and refining a process that was proposed in a previous related work [2]. Fig. 1 depicts the different phases of the methodology in their sequential order, where a dashed-line arrow represents an optional sequence flow and a dashed-line box represents an optional phase.

In the scoping phase, questions that the system answers are formulated. Then a data availability check is conducted to estimate the level-of-detail (LOD) of data that is modeled in

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the next phase. Existing computation models are reviewed if they can be re-used, within the current data availability conditions. In the data modeling phase, the data requirements of the existing models are formalized. Else, in the absence of re-usable models, algorithms are defined by domain experts, to reach the answers to the questions defined in the scoping. Then computation models are developed. In the interaction modeling phase, interacting components within the data model are identified and integrated within the same data model (as a sort of metadata). Then, the domain experts' knowledge about how to interpret the output is captured and embedded in the ontology, as inference rules. Finally, data are integrated in the ontology using an existing tool [10], and served as RDF data to be accessed and processed by a web interface that is developed in the GUI development phase.

The above methodology has been applied in modeling a building-integrated solar PV planning support software. An ontology has been developed to integrate data from computation models that have been also developed, in the absence of existing re-usable ones. Fig. 2 shows the fragment of the ontology that is most relevant to the presented topic about robustness against data availability problems. It shows that any indicator class, bundling a set of indicators, is linked to an *Answer_LOD* object that defines the LOD of each indicator in terms of the calculation method being used, and therefore a time, space, and technology LODs are deduced. The consistency of the different calculation methods is ensured through modeling the interaction relationships as shown in the same figure. The traceability to the initial requirements of each answer (together with its LOD) is ensured by keeping a link to the scoping phase by integrating the actors and questions in the ontology.

The model shown in Fig. 2 allows having indicators for different locations that are not necessarily calculated using the same methods. For example, if monitoring data are available for a specific area in a city, more accurate calculation methods can be used, while the rest of the city still use different methods that require less detailed data. The consistency and integration of the different methods are insured by the developed ontology. Similarly, if the system is to be used in a different city, other calculation models can be plugged to replace the ones which data requirements are not met.

IV. CONCLUSION

The developed building-integrated planning support system fulfills the four requirements of urban energy planning support (a), (b), (c), and (d), which are described in the related work section. For validation purposes, the system that has been developed was tested in a district of about 1200 building in the city of Vienna. A special focus has been assigned to robustness against data availability problems. The available data within the area where the system was tested was not enough to re-use any existing computation models. Therefore, specific computation models have been developed and mechanisms of upgrading the system have been integrated within the ontology. (i) The ontology comprises levels-of-detail concepts i.e. it is possible to plug different computation models to the system and provide answers to the same questions in different LODs. (ii) The ontology integrates the

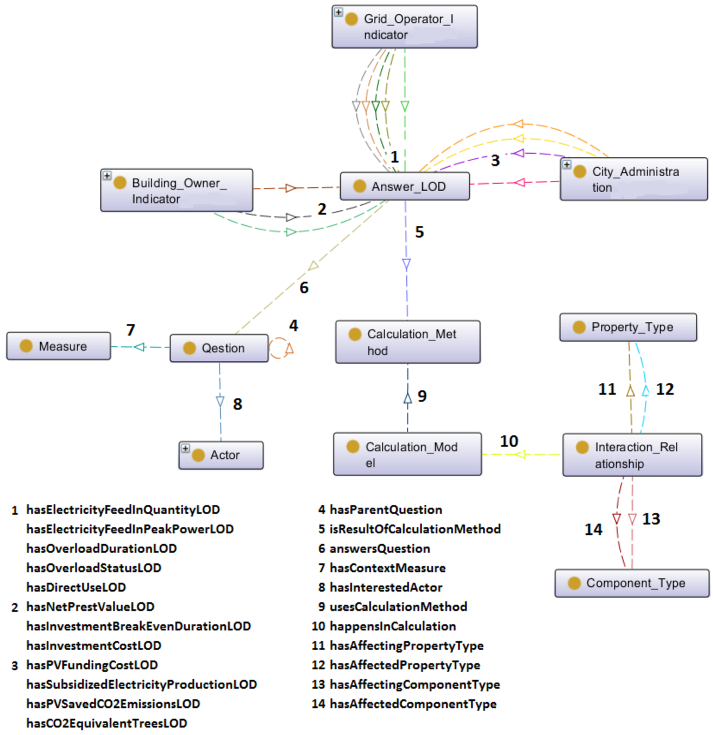

Fig. 2. Ontology fragment: Multiple LOD answering model

initial user requirements and it is traceable which computation models (operating in different LODs) answer which questions. (iii) Interactions between different components are also integrated within the ontology, allowing consistency in operations of different models, regardless of their LOD.

REFERENCES

[1] IEA, "World Energy Outlook 2008," *IEA*. [Online]. Available: http://www.iea.org/weo/2008.asp. [Accessed: 09-Mar-2012].

[2] N. Ouhajjou, P. Palensky, M. Stifter, J. Page, S. Fenz, and A. M. Tjoa, "A modular methodology for the development of urban energy planning support software," in *IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society*, 2013, pp. 7558–7563.

[3] D. Connolly, H. Lund, B. V. Mathiesen, and M. Leahy, "A review of computer tools for analysing the integration of renewable energy into various energy systems," *Appl. Energy*, vol. 87, no. 4, pp. 1059–1082, Apr. 2010.

[4] P. Waddell, "UrbanSim: Modeling urban development for land use, transportation, and environmental planning," *J.-Am. Plan. Assoc.*, vol. 68, no. 3, pp. 297–314, 2002.

[5] D. Robinson, F. Haldi, J. K\ämpf, P. Leroux, D. Perez, A. Rasheed, and U. Wilke, "CitySim: Comprehensive micro-simulation of resource flows for sustainable urban planning," in *Proc. Building Simulation*, 2009.

[6] L. Girardin, F. Marechal, M. Dubuis, N. Calame-Darbellay, and D. Favrat, "EnerGis: A geographical information based system for the evaluation of integrated energy conversion systems in urban areas," *Energy*, vol. 35, no. 2, pp. 830–840, Feb. 2010.

[7] M. Kwartler and R. N. Bernard, "CommunityViz: an integrated planning support system," *Plan. Support Syst.*, pp. 285–308, 2001.

[8] J. Keirstead, N. Samsatli, and N. Shah, "Syncity: an integrated tool kit for urban energy systems modelling," p. 21, 2010.

[9] M. Fernández-López, A. Gómez-Pérez, and N. Juristo, "Methontology: from ontological art towards ontological engineering," 1997.

[10] C. A. Knoblock, P. Szekely, J. L. Ambite, A. Goel, S. Gupta, K. Lerman, M. Muslea, M. Taheriyan, and P. Mallick, "Semi-automatically mapping structured sources into the semantic web," in *The Semantic Web: Research and Applications*, Springer, 2012, pp. 375–390.