Proceedings of the 2014 Federated Conference on
Computer Science and Information Systems pp. 1133–1137
DOI: 10.15439/2014F317
ACSIS, Vol. 2

Towards Semantic-based Process-oriented Control in Digital Home

Tatiana Atanasova
Institute of Information and
Communication Technologies-BAS
Acad. G. Bonchev 2, 1113
Sofia, Bulgaria
Email: atanasova@iit.bas.bg

***Abstract*—The purpose of this work is to investigate the specifics in the development of technologies for heterogeneous data and process integration in digital home and to show possible solutions during design of integrated applications. The analysis of the integrated data can be useful for the development of improved algorithms for monitoring and control of digital networked home.**

I. Introduction

THE tendency for bringing more intelligence into building automation can be seen. It is observed that smart environments have growing demand. The technology development provides a new kind of lifestyle and designing of smart environment attracts attention of researches, home techniques manufacturers, mobile operators, civil engineers and other organizations. The scope of arising problems in digital networked homes is very wide and covers different scientific, technological and psychological aspects [8], [9], [13], [18], [20]. Difficulties results from rapid growing of heterogeneity of electronic devices and communications networks in modern buildings. Home appliances are evolving from purely components devices to complex systems that content processors, sensors and use interfaces. The complexity of the underlying infrastructure is increasing too. The broadband is widely available now in living environment, personal digital devices became very popular, local networks and wireless technologies get emergent interest.

Smart home digital systems have network functions and can be supplemented with connection to the Internet. Network access needs to be available on a range of devices over Wi-Fi and cellular links as well as wired connections. This gives a possibility to monitor and control various home appliances by network and to extend their capabilities through connections in the cloud. Thus home networked system transfers significant functionality from it to the cloud and allows simplifying its design and integration with other systems and services.

The research work reported in the paper is partly supported by the project AComIn "Advanced Computing for Innovation", grant 316087, funded by the FP7 Capacity Programme (Research Potential of Convergence Regions).

Technologies themselves are rapidly changing. The next generation networks are moving to Software-Defined Networking (SDN) where the network's data layer is decoupling from the control layer. SDN is relatively new field in research and consider involving intelligent control methods in network management. This will contribute to a better communication between the various actors involved with various objectives. These new tendencies can be observed in digital networked home environment too – in intention to construct intelligent control and monitoring methods.

However, a lot of problems still have to be resolved, for example: how all these house's devices will communicate, how they will be managed, aggregated, and how the data will be distributed. Besides that, methods for automation in living environment are focused at present on the construction of relatively static structures, designed in advance.

Uniform technology and methods for integrated interoperation of heterogeneous digital systems in living environment that are orientated to optimal using of resources and ensuring of comfort conditions are not developed yet.

The investigation in this paper is focused on problem formulation and directions, in which methods and tools have to be developed for inter-operation of heterogeneous digital systems in smart living environment that have extendible functionality.

First some problems connected with heterogeneous data and information sources are outlined. After then we consider involving semantics into infrastructures. Finally some proposals for solutions are suggested. The extended functionality can be oriented to improving subjective perception of quality of life as well as optimal using of resources in digital homes.

II. Data and Processes Integration

A. Levels of integration

The integration of heterogeneous data and processes can be accomplished at several levels (fig. 1).

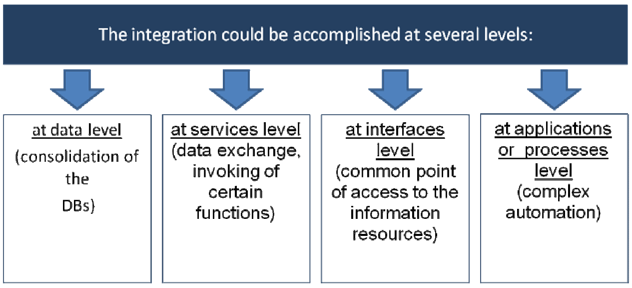

Fig. 1 Integration levels

The existing devices, systems and local networks in a digital house are usually realized with different technologies, regarding the volume of information that is transferred from the integrated devices. We have to take into consideration the heterogeneous data processes and the signals to be conveyed: Ethernet, RF TV and radio signals for wireless-end-connectivity [18] in the distributed building network and necessity of integration of various interfaces for different devices. When new objectives and tasks arise it may be hard to provide interaction between the diversity of the existing appliances.

Each device can be connected with a particular service or a set of services. Thus a multiservice network [12], [15] is established. The multiservice network gives a base for existence of multiple traffic types within the house.

The service may be shared between different devices and dynamically assigned to some of them depending on inhabitants' desires. For very simple example, music or video call may follow the indwellers everywhere in the house. The service can be transferred from one device to another with inference about possibilities for the transfer and service delivery.

Besides certain functionality, the data and process integration requires the construction of an infrastructure, providing safety and security.

B. Ontologies

The semantic description and realization of methods for semantic processing may be the key to achievement of common integration objectives. Several researches suggest an idea to enhance sensors and actuators with a semantic description of their capabilities [8], [9], [13], [20].

Ontologies as a core of semantics can be used for the purposes of information integration, sharing and reuse. The main components of ontology are concepts, relationship, rules and instances. Concept is a class of objects (entities) in the area. Relationships describe the interactions between concepts or properties; they can be in form of taxonomy or associative relationship. Taxonomies systematize concepts as a hierarchical tree, and the associative relationship disposals the concept on the tree.

Instances are specifications of concepts, together with the taxonomy and the relationships they form the knowledge domain. Axioms are used to restrict the values of classes or objects (examples).

Ontology may have logic inference, and then it is so-called formal ontology. Formal ontology must have axioms that restrict the possible interpretations of logical expressions. Web Ontology Language (OWL) can been used to describe each element in the ontology.

Ontologies are created in various forms - from lexicon to dictionary terms, or as first-order logic.

In a broad sense, they can be distributed over three categories: general, domain or applied ontology.

The domain ontology focuses on the refinement of a more narrow meaning of the terms used in a certain area, and may represent a basic reality, in this specific area, but independent of a specific task.

Applied ontology is a specific sub-ontology that contains concepts and relationships which are relevant only to the definite task, such as thesauri, which are semantic relations between lexical units. Usually they contain a small number of concepts with relationships and inference rules, which are defined in detail for solution of particular independent task.

The choice of an appropriate semantic model to represent ontology depends on the purpose for which the ontology is build and the underlying assumptions for achieving these goals.

As an ontology a symbolic system $\{C, T, P, F, A\}$ is considered, where

C is the set of concepts,

T - a thesaurus, or partial order on the set C, the hierarchy of relationships, "subclass" and "super-class";

P - the set of predicates (properties);

F - a function that assigns to each element of P an element from the set of C (considering them in T);

A -is a set of axioms of the ontology.

A hierarchy of concepts is represented as a graph $G = (N, E)$, N - the set of nodes, E - the set of branches, $N=\{n_1, n_2,\dots n_n\}$, $E=\{e_1,e_2,\dots e_m\}$.

The graph can be described using XML Schema Datatype (XSD).

At development time ontologies are used to provide ontology–driven development (for example, to describe a domain) or ontology–enabled development (to support developers with their activities).

At run time ontologies form ontology–based architectures (as part of the system architecture) or ontology–enabled architectures (to provide support to the users).

C. Process Ontology

Fundamental process ontologies are becoming more important in recent times [4], [6], [7]. For example, in [19] the idea is discussed that everything is a process and consists of the processes.

The basic postulates are:

- the world is represented as an interconnected system of large and small events;

- some of them are relatively stable;
- the events are always changing;
- the changes represent the actualization of certain features and disappearance of others.

The processes can be divided into:

- constant processes that are interpreted as *concepts*,
- processes which are interpreted as *events*, represent a finite set of four-dimensional space-time.

Thus, the world is built from events, i.e., ontologically, all consists of processes.

The consideration of processes includes:

- when a process should be initiated and finished;
- who participates in this process;
- how this process should be performed;
- which results must be examined, analyzed and taken into account.

The surrounding of a process in such a way consists of data, event, resources, goal and output as a result of a process (fig. 2).

The processes are divided in three main classes:

- *basic* processes;
- *composition* of basic processes and
- *external* processes.

Additionally, processes can be identified that determine the *trends* and directions of changing of basic processes, depending on the analysis and estimated data. The processes are available in the streams of data as implicit patterns. The data is contained in a multitude of sources R (data sensors, files, databases, external resources), $R = \{R_1, ..., R_q\}$.

Extracting knowledge from a specific domain can be considered as the construction of structural design pattern – that process ontology [19]. The objective is to identify processes that have brought to the particular event, and to predict future events based on the past experience.

The process ontology is the key for combining the device and system knowledge.

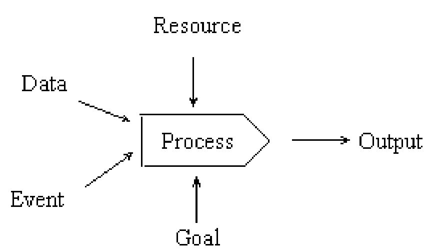

Fig. 2 Process surroundings

III. Proposed Trends and Solutions

The intelligent control methods in digital networked home aim to achieve three goals: semantic integration, providing interface to various devices and ensuring adaptation.

To supply resource control, interoperation and possibility for reconfiguration of digital systems we need to integrate the infrastructure with services.

The semantic and formal description of services and resources is relevant to digital home, where a large diversity of resources have to be described and managed in a highly dynamic way [14]. Services with different purposes can collaborate to offer new and more complex functionalities to the user transparently.

Buildings can be considered as a software problem. This problem addresses integration of information and resources, which are invisible in everyday life. One possible way is to develop operating system for buildings and drivers for every device enriched with semantics. Thus systems can be constructed that are connected to the Internet and are controlled automatically.

It is recognized that there are obstacles in extensive use of embedded devices with limited characteristics of mobility, computing resources and memory. Semantic description may be a way to overcome this large handicap.

Semantic description and modelling of services, together with constructing and using process ontologies provided to users is a key component to autonomic service management, service negotiation and configuration.

The full exploitation of semantics in user and device description has several benefits [21], [22]. The integration of knowledge representation features and reasoning techniques into standard home automation protocols can offer high-level services to users [7].

Current experiences suggest that trends from device-oriented to process-oriented control of home appliances can be seen.

Discovering process models from system event logs is definitely non-trivial. Within the analysis of event logs, process can be defined as the automated construction of structured process models. Each event is a part of the chain process.

The main goal is to suggest a model in which the decision support system provides solution on choosing the optimal set of services using the given network resources on the base of reasoning on process ontologies.

Decision support system (fig. 3) is a coordination unit that integrates heterogeneous data. It is on the top layer of the data processing and provides semantic reasoning. Middle layer realize control, monitoring and visualization functions by event processing, as each device is enhanced with metadata and it is associated with service. This allows discovering functionalities and request services from other devices. Services are discovered by semantic matching. It has to be developed a logic-based ranking of approximated matches allowing to choose resources/services best satisfying a request, also taking user preferences and context into account.

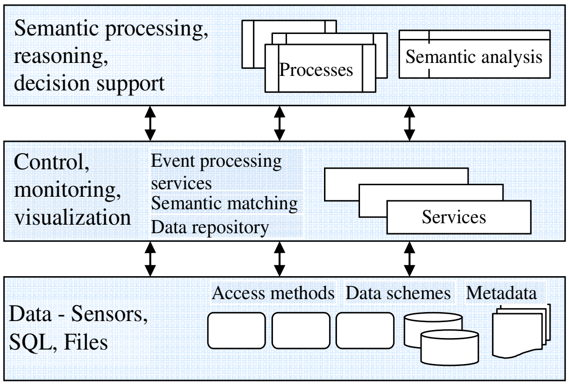

Fig. 3 Layers of data processing

In this framework ontologies are used twofold: for data integration from several sources and for intelligent systems operations.

The system evaluates and classifies records by the use of the process ontology. The ontology of processes will determine what information to extract and how to accelerate the semantic search.

The process-ontology will provide an appropriate philosophical foundation to integration problems. They will give a common conceptual framework for the researches as well as for the practice; it gives a possibility to compare different process-models and concepts and to interpret the dependencies between different models.

IV. Related Work

The development of ontologies in centralized settings is well studied and there are established methodologies. However, current experiences suggest, that ontology engineering should be subject to continuous improvement rather than a onetime effort and that ontologies promise the most benefits in decentralized rather than centralized systems [7].

Using ontologies for telecommunication is proposed by recently [1]-[3], [5]. The approach proposed in [1] discusses using ontologies to capture networking information as well as the domain and expert knowledge needed for network configuration tasks. By semantic description and the use of formal ontologies it is shown how task complexity can be reduced.

Collaborative mechanisms between services are a crucial aspect in the development of pervasive computing systems based on the paradigm of service-oriented architecture [15]. The current network can only provide syntax-layer services and not provide semantic-layer services [5].

The investigation in [20] describes a model of services composition based on a directed acyclic graph used in a service middleware for home-automation, in which loosely coupled services-oriented systems is suggested over the peer-to-peer technology.

The use of semantics (including the integration of ontologies with rule-based systems) has been proposed in early works on context-awareness in the home environment [23]-[26].

The presented in [8] approach proposes use of semantic description that can potentially make the digital networked home more adaptable, agile, sustainable, and dependable given the requirements of changing environment.

The development of multi-service model is discussed in [15] and it is concluded that is still at an early phase.

V. Conclusion

The upward trend in ubiquity and heterogeneity of networked home services and resources demands for a formal and systematic approach to home management tasks.

Current solutions of automated control systems in digital networked homes poorly support dynamic scenarios and context-awareness. Ongoing research covers sensors and how to include the description of these sensors in the control system for smart living environment [9].

In this work it is shown that:

- The primary aim to use of ontologies is to integrate different applications;
- Ontology is proposed to model the relations between events and to manage process configurations.

The rapid development and emerging demands for process automation and interoperability requires systematic modelling methodology and increased semantic information.

The work outlined some solutions for the hard problems during integration of heterogeneous data and processes and shows trends to overcome the lack of standard methods for integration of the information resources and processes that hampers the supply and the efficient use of the information by the users. Process ontologies are a base for providing the whole functionality of the digital networked home in a coordinated and controllable manner.

The future living environment will need to be more intelligent and adaptive, optimizing continuously the use of its resources without any impact on the demanding services.

An effective way to acquire knowledge and share it internally and with outside strategic sources is needed. It is still a challenge to provide a robust and acceptable solution for knowledge capture from different sources.

Methods that ensure integration between the various subsystems automatically and in real time have to be designed. It is hoped that the proposed model will invite further work on integrated framework and shall become reality in the near future.

References

[1] D. Cleary, B. Danev, D. O' Donoghue, “Using ontologies to simplify wireless network configuration”, in *Formal Ontologies Meet Industry*, Verona, Italy, June 9-10, 2005.

[2] X. Qiao, X. Li and J. Chen, “Telecommunications service domain ontology: semantic interoperation foundation of intelligent integrated

services", in *"Telecommunications Networks – Current Status and Future Trends",* J. Ortiz (Ed.), InTech, 2012, pp. 183-210.

[3] D. Cao, X. Li; X. Qiao; L. Meng, "Ontology-based modelling method for semantic telecommunication services", in *Proc. 5th Int. Conf. on Fuzzy Systems and Knowledge Discovery FSKD '08,* 2008, vol. 4, pp. 449 – 453.

[4] T. Liu, H. Wang, L. Liu, "Extended ontology-based process management architecture" in *Cooperative Design, Visualization, and Engineering,* LNCS, vol. 6874, 2011, pp 114-120.

[5] Z. Shangguan, Z. Gao, K. Zhu, "Ontology-based process modeling using eTOM and ITIL" in *Proc. IFIP Int. Conf. on Research and Practical Issues of Enterprise Information Systems,* 2008, vol. 2, pp. 1001-1010.

[6] St. Aitken, J. Curtis, "A process ontology", in *Knowledge Engineering and Knowledge Management: Ontologies and the Semantic Web,* LNCS, vol. 2473, 2002, pp 108-113.

[7] Ch. Tempich, H. S. Pinto, Y. Sure, and St. Staab, "An argumentation ontology for DIstributed, Loosely-controlled and evolvInG Engineering processes of oNTologies (DILIGENT)", In A. Gómez-Pérez, J. Euzenat (eds.) *"The Semantic Web: Research and Applications", Proc. Second European Semantic Web conference,* ESWC'2005, LNCS 3532, 2005, pp. 241-256.

[8] M. J. Kofler, C. Reinisch, W. Kastner, "A semantic representation of energy-related information in future smart homes", *Energy and Buildings,* April 2012, pp. 169-179.

[9] M. Chan, D. Est`eve, C. Escriba, E. Campo, "A Review of Smart Homes – Present State and Future Challenges", *Computer Methods and Programs in Biomedicine,* Elsevier Ireland, 2008, pp. 55-81.

[10] V. Monov, "Energy consumption and efficiency in industrial processes", *Proc. Int. Conference "Robotics, Automation and Mechatronics'12",* 2012, pp. a9-a12.

[11] T. D. Tashev, H.R. Hristov, "Modelling and synthesis of information interactions", *Problems of Technical Cybernetics and Robotics,* No 52, 2001, pp. 75-80.

[12] Mc. Dysan D., N. Björkman, "Multiservice networking using a component-based switch and router architecture", *in IEEE 2000 Multi-Service Forum, Technical Library,* http://www.msforum.org/techinfo/library.shtml

[13] F. Colace, M. De Santo, "A network management system based on ontology and slow intelligence system", *Int. Journal of Smart Home,* vol. 5, No. 3, July, 2011, pp. 25-38.

[14] C. Rodrigues, S. R. Lima, L. M. Sabucedo, P. Carvalho, "An ontology for managing network services quality" *Expert Systems with Applications,* vol. 39, Issue 9, 2012, pp. 7938-7946.

[15] A. Vilkman, R. Hautala, E. Pilli-Sihvola, "Multi-service model for mobility and logistics", *VTT Symposium on Service Innovation;* Issue 271, 2011, pp. 105-11.

[16] K. S. Munasinghe, F. Javadi, A. Jamalipour, "Resource competition at the NGN core network: An ecologically inspired analysis", *Proc. 18th Int. Conf. on Telecommunications, ICT 2011,* pp. 72-77.

[17] M. Charalambides, G. Pavlou, P. Flegkas, N. Wang, D. Tuncer, "Managing the future internet through intelligent in-network substrates", *IEEE Network,* vol. 25, 2011, pp. 34-40.

[18] J. Guillory, F. Richard, Ph. Guignard, A. Pizzinat, S. Meyer, B. Charbonnier, L. Guillo, C. Algani, H.W. Li, E. Tanguy, "Towards a multiservice & multiformat optical home area network" in *Proc. 14th ITG Conf. on Electronic Media Technology,* CEMT 2011.

[19] J. Palomäki and H. Keto, "A formal presentation of the process-ontological model", in *Information Modelling and Knowledge Bases XXII,* A. Heimburger et al. (Eds.) IOS Press, 2011, pp. 194-205.

[20] J. Holgado-Terriza, S. Rodriguez-Valenzuela, "Services composition model for home-automation peer-to-peer pervasive computing" in *Proc. of the Federated Conference on Computer Science and Information Systems, International Symposium on Services Science,* 2011, pp. 529–536.

[21] T. Atanasova, "Digital networked houses: problems, challenges and trends" in *Proc. 20th Telecommunication forum TELFOR 2012,* Belgrad, Serbia, November 20-22, 2012, pp. 1417-1420.

[22] M. Fathalipour, A. Selamat, and J. J. Jung, "Ontology-based, process-oriented, and society-independent agent system for cloud computing", *International Journal of Distributed Sensor Networks,* 2014, article ID 689650, 17 pages.

[23] H. Hu, D. Yang, L. Fu, H. Xiang, C. Fu, J. Sang, C. Ye, R. Li, "Semantic Web-based policy interaction detection method with rules in smart home for detecting interactions among user policies", *IET Communications,* 2011, vol. 5, No. 17.

[24] Y. Zhiwen, Z. Xingshe, Z. Daqing, C. Chung-Yau, W. Xiaohang, and M. Ji, "Supporting Context-Aware Media Recommendations for Smart Phones," *IEEE Pervasive Computing,* 2006, vol. 5, pp. 68-75.

[25] S. De, K. Moessner, "A framework for mobile, context-aware applications", Marrakech, Morocco, *Proc. IEEE 16th International Conference on Telecommunications (ICT),* 2009, pp. 232-237.

[26] V. Ricquebourg, D. Durand, D. Menga, B. Marhic, L. Delahoche, C. Loge, and A.-M. Jolly-Desodt, "Context inferring in the smart home: an SWRL approach," *Proc. 21st International Conference on Advanced Information Networking and Applications Workshops,* (AINAW'07), 2007.