Supporting the Design of AAL through a SW Integration Framework: The D4All Project

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Abstract. Contemporary design is characterized by the paradigm shift from a one-size-fits-all, oriented to the standard man, to an holistic and inclusive one-size-fits-one, that takes into account the full range of human diversity. Following the new paradigm, the "Design for All" Italian research project aims at realizing an effective demonstrator of a framework that promotes a design of an AAL oriented to the real individual, considering everybody in his peculiarities. On the one hand, the framework handles the knowledge about the home environment, also through innovative approaches aimed at modeling specific scenarios representing the relevant states of the individuals (situation and context awareness). On the other hand, it allows various software tools supporting the entire home's life cycle to exchange the knowledge in a smart manner. Mainly focused on interoperability aspects, the paper describes the motivations behind the "Design for All" project concepts, together with the goals and the first findings. Finally, it presents a demonstration scenario that aims at testing and validating the framework.

Keywords: Design For All, Ambient Assisted Living, Interoperability, Semantic Data Model.

1 Introduction

Traditional design is focused on the standard man, which is an abstraction of the real man. However, this approach neglects the real object of study: users with their variety of skills, knowledge, wishes and ambitions. To overcome this limitation it is emerging a new inclusive and holistic paradigm, the Universal Design [1], also known as Design for All, which takes into account a broad spectrum of human diversity. It proposes an adaptable design that offers basic universal features which can be easily adjusted to the needs of a specific user. The new approach has been deepened in different areas of research also through the involvement of modern information technologies. For example, in the context of the Design for All for eInclusion European Coordination Action, a detailed study has been conducted under the responsibility of the IFAC-CNR [2].

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The principles of Universal Design can also be applied in the field of the design of Ambient Assisted Living (AAL); in this case, it is necessary to face the crucial challenge of handling the continuously growing complexity resulting from the applied paradigm shift. The development and the administration of a home automation environment based on the new approach requires, indeed, the use of various heterogeneous tools supporting the entire home's life cycle (e.g. design, utilization, control and monitoring), in this way extending their applicability traditionally limited to the design process. Moreover, it is necessary to represent the articulated scenario in which the real user acts and to have a strong awareness of specific user activities (e.g. doors that open as people walk towards them). This leads to deal with several ubiquitous devices [3], such as sensors, actuators and controllers. The latter are often managed by different software which generate large amount of data (also in the form of Big Data) in a proprietary format, thus difficult to integrate.

In such a complex scenario, one of the AAL research topics that needs to be addressed is the enhancement of the semantic interoperability of the involved heterogeneous SW systems. Thus it's necessary to improve their capability to join distributed data sources, represented in various formats, into a view that facilitates the exchange of information and the use of the information to exchange [4]. Since the number of devices related and software applications increases, as well as the number of technology suppliers, it is fundamental to make software tools interoperable in order to fully exploit their functionalities. For this reason, in the last decade, many vendors have started to propose suites, in order to supply integrated alternatives to the customer. Despite this, the semantic interoperability problem has become relevant since no company is able to produce a full optional service, capable to satisfy all the customers' needs.

This paper introduces a new interoperability framework for an inclusive and sustainable home automation design, which integrates and harmonizes the knowledge related to the domestic environments, thus satisfying the holistic requirements for the next generation of AAL. The research represents the first finding of an Italian research project founded by the Ministry of University and Research called: "Design for All - SW integration and advanced Human Machine Interfaces in design for Ambient Assisted Living". The main project goal is the development of the previous mentioned software architecture that will support mainly the design phase (but not just this) of the future home automation environment addressing any type of users (Design for All … "users") and making application able to adapt to the context and to react. Moreover the platform will represent a unique integration point (Design for All …"applications").

Several recent studies have demonstrated that a valid solution to achieve interoperability is the approach based on the Semantic Web technology; e.g. in the context of Virtual Factory Framework (VFF) project [5], a semantic technologies-based framework for the interoperability was already designed, implemented and validated within the manufacturing domain for supporting the whole factory's life cycle. Thus, it can be considered a valid starting point for the Design for All project, but applying it to a new domain: the home automation.

The paper is structured as follows. Section 2 presents the outcomes of main studies carried out by others in the area of home automation systems interoperability. Section 3 introduces the architecture of the proposed interoperability framework. Section 4 defines the demonstration scenario that aims at testing and validating the framework. Finally Section 5 draws the conclusions summarizing the major findings.

2 Related Works

In order to enable an enhanced interoperability among the different software tools supporting the home automation system's life cycle, it is necessary to bridge the "knowledge gap" existing among them. A simple way to get interoperable two devices is to create a one-to-one bridge, but this solution cannot always be practically applicable because the number of the required bridges grows up too fast with the number of devices to be connected and the functionalities provided. Moreover, the framework deals with the information and knowledge produced by the software application themselves (from design to control, monitoring and automation). Thus, it is necessary to overcome this limit and search for a sufficiently scalable solution able to integrate data but also to capture the knowledge. The Korean Electronics and Telecommunications Research Institute proposes an Universal Home Network Middleware (UHNM) [6] to guarantee a seamless interoperability of appliances and services characterized by heterogeneous communication protocols. However this solution is far from an ideal interoperability based on open-standard technologies such as Web Services [7] or XML-based formats [8] and Internet protocols. In this regard an interesting approach has been provided by the Open Building Information Exchange group (oBIX) [9] that is working to create a standard XML and Web Services guideline to facilitate the exchange of information in the building automation field. Another important solution comes from Device Profile for Web Services [10]: a Service Oriented Architecture (SOA) [11] that allows devices to automatically discover each other and abstract the interface that they expose from the implementation, thus enabling an enhancement of the interoperability [12].

A mostly used approach to face the interoperability challenge is the adoption of the XML Schema Definition (XSD) technology [13]. This allows applications to share a common language to communicate each other. In this regard Sacco et al. [14] conceived the VFF data model as a set of XSD files defining the structure of the XML files that implement the schema. This solution offers relevant advantages in terms of syntactic validation of the XML files according to the defined XSD schemas; also, it provides a rich expressiveness, since several default data types can be further extended and complex constraints and properties can be modelled. However, XSD technology alone is not suitable for knowledge representation since it lacks an explicit characterization of the data at a semantic level. Moreover, since interoperable software applications can consume and publish data in a distributed way, different data repositories can be accessed by various software at the same time. For this reason consistency of the data plays a key role in making an effective collaboration among tools in such a scenario. Although XSD technology supports the references within the document, inter-document references, e.g. cross-references, are modeled so poorly to put at risk the consistency of the model.

The presented considerations led to evaluate and finally adopt a semantic model-based solution, represented via an ontology. This is a specification of a conceptualization [15], that is a formal description of the concepts and their semantic links within a knowledge domain. A valid approach to describe an ontology is based on Semantic Web first-order logic-based languages such as RDF [17] and OWL [18]. Thanks to their expressiveness, it is possible to represent a formal semantics for the knowledge in the domestic environment in a much more significant manner compared with the above mentioned XSD schemas.

The ontology model provides a systematic approach to classify and integrate the knowledge of the home automation environment; it represents an holistic view of the home as a whole, both considering its physical dimensions, its actors with their needs and its evolution over time. Furthermore, standardized models, based on a consistent description language, allow many existing tools to automatically infer and reason over the data model, bringing out new derived knowledge about the concepts and their relationships, in addition to those initially asserted. Finally, the ontology model is expected to support a new and more flexible design methodology, based on virtual reality technologies, aimed at a smarter evaluation of human-environment interactions scenarios. For this reason the application of semantic technologies can be considered the critical success factor of "Design for all" project.

3 The Virtual Home Framework – VHF

This section presents the Virtual Home Framework (VHF), an integrated platform whose main objectives are to handle the knowledge about the home environment and, on the other hand, to allow various software tools to exchange the knowledge in a smart manner, supporting the entire home automation system's life cycle.

VHF is based on four key Pillars (Fig. 1): (I) Semantic Shared Data-Model, (II) Virtual Home (VH) Manager, (III) Decoupled modules and (IV) the "Real Home". All the functionalities required by the Real Home are provided by different decoupled modules (Pillar III) that work on a consistent reference model (Pillar I) for the domestic environment domain. This can be realized thanks to the VH Manager (Pillar II) that plays an integrating role by interfacing all the modules. An interoperability framework can be effective only if all the applications coupled to it share a common language. This is achieved through the "Data Model" (DM) which represents the first pillar of the framework.

3.1 Pillar I – Semantic Shared Data Model

The Semantic Shared Data Model provides a common, standard and consistent representation of the knowledge related to the domestic environment. Moreover it has to be extensible and guarantee the proper granularity, providing at the same time the enablers for data consistency, data safety and proprietary data management. Taking advantage of its flexibility and expressiveness, it is possible to formally describe some concepts related to the home environment and their semantic links, such as resources, appliances, facilities, building components and also users who have an active role in the home environment. The Data Model can be conceived as a common meta-language that provides all applications a shared knowledge definition within the framework.

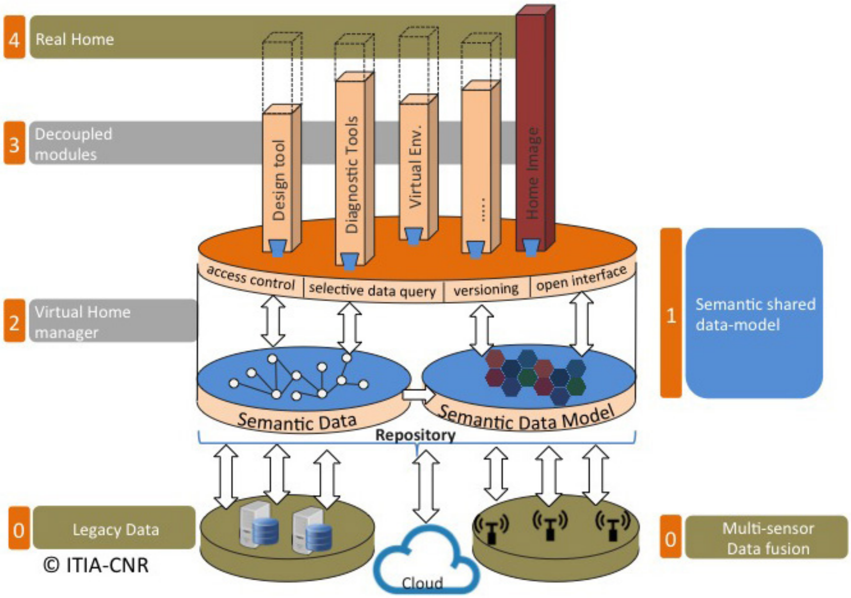

Fig. 1. Virtual Home Interoperability - VHF

While implementing a data model, an essential practice to follow is to refer to the state-of-the-art technical standards or other reference works available in different domains. One important reference comes from buildingSMART international organization [19] which has developed the ICF (Industry Foundation Classes) standard. This is a common data schema concerning the Building Information Modeling (BIM) aimed at representing physical and functional characteristics of buildings or facilities in order to exchange relevant data among different design software applications. Specifically regarding the domestic environment modeling, Konnex alliance [20] has proposed a model including objects grouped in four classes: measurement tools, house-hold appliances and systems, multimedia appliances and telecommunication tools. Another interesting work is DomoML [21], a markup language aimed at the definition of interoperability standard for domestic resources. It describes operational and functional aspects together with some preliminary architectural and positioning information. Furthermore in the context of ubiquitous computing, the SOUPA ontology [22] provides a modular modeling structure that includes vocabularies for representing intelligent agents, time, space, events, etc.

The home ontology is expected to facilitate the use of generic tools which can infer and reason about the ontology, thus giving a support that is not limited to the a priori asserted knowledge. In this regard, rule-based mechanisms and case-based reasoning techniques will be investigated.

3.2 Pillar II – Virtual Home Manager (VHM)

The "Manager" is the "core" of the entire framework. It coordinates all the modules connected to the framework and it is responsible for the data access control, versioning and data query management operations. A possible communication architecture could be based on "High Level Architecture" (HLA) [23], a standard that provides a common Application Program Interface (API) allowing all modules to invoke specific primitives to exchange data each other.

VHM is based on the "Virtual Factory Manager" (VFM) [24] that acts as a server supporting the I/O communications within the framework for the modules needing to access its data repository. Since VHM has to manage the real time communication between software applications in the domestic environment, it is necessary to investigate an extension to what is already implemented in the VFF.

The Data Repository is the backbone of the VHM and can be accessed by each module. Many solutions of repositories are available in literature, everyone works best under certain circumstances and may be more suitable in a case rather than in another, depending on the specific requirements of the scenario. For this reason, a survey among the most widespread of these solutions should be carried out to find the appropriate one that can host and expose the data related to domestic environment. Due to the specific characteristics of this scenario, main criteria used to apply this evaluation are the capability to manage live streaming data, to keep track of the multiple versions and to host large amount of data; also the scalability and performance of these systems under workloads with various characteristics will be taken into account.

3.3 Pillar III – Decoupled Modules

The Virtual Home modules are the decoupled functional tools used to support the whole home automation system's life cycle, following an approach based on the Design for All principles. They include both commercial or non-commercial applications; diagnostic and monitoring tools, design tools, human-machine interfaces and also virtual environment applications are some examples. All tools have their specific features and are addressed to a specific purpose, but, if they can share the same data model of the domestic environment, they result more coupled each other, and so more useful and powerful in the design phase as well for the user. For example, the output of a one tool can be easily given as input to another tool without the need for an ad hoc adaptation. They are able to understand each other. If the module cannot directly access the VH Manager in order to query the data repository, it is necessary to develop a module adapter to enable the communication between them. The module with the adapter is referred to as coupled module.

3.4 Pillar IV – The Real Home

The last pillar of the VHF is the “Real Home”. It is an abstraction representing an effective and efficient solution for an AAL that takes into account the above mentioned Design for All approach. Real Home can be meant as an holistic concept used to described the full range of services that the “Home for All” is expected to satisfy. It must be able to respond to the different situations in which real individuals are involved also considering variables coming from different contexts. For example, wake up scenario can require some alarm clock adjustment depending on weather or traffic and can trigger some operations such as the ignition of the heater in the bath or the start to prepare coffee in the kitchen.

The Real Home is also an adaptive system able to modify its characteristics in accordance with the user actions and the environment, also anticipating the user's behavior.

D4All project is part of the Italian cluster “technology for the living environment” in which a second project called “SHELL” (“Shared interoperable Home Ecosystems for a green, comfortable and safe Living”) is specifically dealing with the real house and it will provide input for the presented framework.

4 Validation

The main purpose of the VHF is to support the various software tools used in the entire home's life cycle. New methodologies and technologies for design, validation and market analysis of the domestic environment has been taken into consideration (e.g. 3D visualization, haptic interfaces, Virtual and Augmented Reality, etc.). These technologies allow designers to evaluate, in a flexible manner, the human-machine interactions in the home automation environment, also by adopting virtual prototyping in order to carry out a real home simulation and analysis.

In order to test and validate the introduced framework, a demonstration scenario has been identified. This scenario is thought to represent activities and habits that occur on a regular basis in a domestic environment, whose main operating context is represented by the home, the residential aggregates and the AAL, connected to the outside in different ways, depending on the specific needs. For example, one scenario focuses on the man while he sleeps (Fig. 2); in this situation, the idea is to check information related to physiological parameters of the user (e.g. heart rate, blood pressure, sweating, etc.) and subsequently identify the user's status (e.g. health status, posture, etc.).

Moreover, it is required to monitor specific user behavior, based on specific identified behavioral patterns (e.g. recognize when the user has not taken the prescribed drug before sleeping; recognize when, during the night, the user has woken up and has wandered, since there may be a greater chance of a fall, due to poor light conditions).

This can be realized implementing a new user-environment interaction system performing various tasks:

- collect and gather data and information related to the user's physiologic parameters coming from wireless technology based smart objects, also exploiting the potential of the emerging multi-sensor data fusion technology;
- derive the user health shape, the posture, emotional being and so forth;
- call different available services using data coming from several sensors within the environment related to the context of interaction between the user and the environment (e.g. activating an alarm, fading lights, activate a phone call);
- adoption of new user interfaces to interact with the domestic environment, exploiting also the most innovative and latest technologies of Virtual Reality.

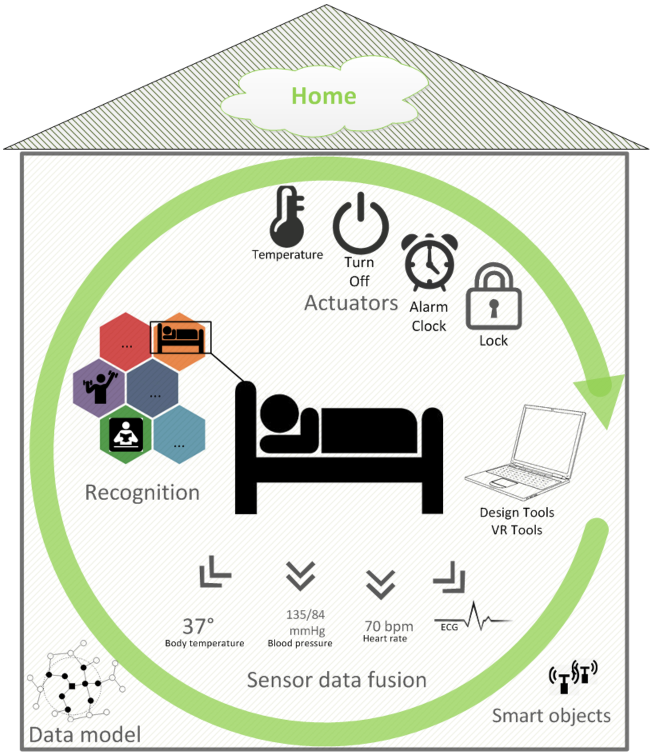

Fig. 2. Sleeping man scenario

Moreover, since the final goal of the Design For All project is to improve the effectiveness of an AAL based on the Universal Design principles, it is necessary to verify the impact of the new proposed approach. This need asks for the cooperation of industrial partners to provide their structures and labs for ambient assisted living. Thus, the validation of the obtained results and the developed prototypes will be performed by mean of experimental campaigns brought within the AUXOLOGICO structures in collaboration with industrial partners such as ABMEDICA, CALEARO, TEOREMA, EUROTECH, LAB IDEA and LOGICAL SYSTEM, and external interested companies like BTICINO, WHIRPOOL, ELECTROLUX, some already part of the

Cluster. Also, the industrial partners will evaluate possible collaborations and future developments for industrialization and commercialization of the proposed platform.

5 Conclusion

Low interoperability is the most important barrier slowing a wide spread of AAL systems based on a design oriented to the Universal Design principles.

To overcome such a limit, this paper, starting from the study of the state of the art, illustrated the structure of the Virtual Home Framework, its goals and how to reach them in order to realize the idea of the home as a holistic and inclusive environment, thus satisfying the requirements for the next generation of AAL.

Finally, as the impact of the new approach on the real home has to be evaluated, a demonstration scenario has been defined to allow the test and validation of the proposed framework.

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References

1. Mace, R.L., Hardie, G.J., Place, J.P.: Accessible Environments: Toward Universal Design (1991)
2. Emiliani, P.L., Burzagli, L., Billi, M., Gabbanini, F., Palchetti, E.: Report on the impact of technological developments on eAccessibility, DfA@eInclusion Project deliverables (2008), http://www.dfaei.org
3. Poslad, S.: Ubiquitous Computing. Smart Devices, Environments and Interactions (2009)
4. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries, 610, IEEE (1990)
5. Sacco, M., Pedrazzoli, P., Terkaj, W.: VFF: Virtual Factory Framework. In: Proceedings of 16th International Conference on Concurrent Enterprising, Lugano, Switzerland (2010)
6. Lee, C.E., Moon, K.D.: Design of a Universal Middleware Bridge for Device Interoperability in Heterogeneous Home Network Middleware. In: CCNC Conference (2005)
7. Richardson, L., Ruby, S.: RESTful Web Services. Web services for the real world. O'Reilly Media (2007)
8. Extensible Markup Language (XML) 1.0 (2008), http://www.w3.org/XML/
9. oBIX (Open Building Information Xchange), http://obix.org/
10. A Technical Introduction to the Devices Profile for Web Services, http://msdn.microsoft.com/en-us/library/ms996400.aspx
11. Understanding Service-Oriented Architecture, Microsoft Developer Network (2004), http://msdn.microsoft.com/en-us/library/aa480021.aspx
12. Jammes, F., Smit, H., Martinez Lastra, J.L., Delamer, I.M.: Service-Oriented Paradigms in Industrial Automation. IEEE Transactions on Industrial Informatics 1(1), 62–70 (2005)

13. W3C. XML Schema Part 1: Structures Second Edition (2004), http://www.w3.org/TR/xmlschema-1/
14. Terkaj, W., Pedrielli, G., Sacco, M.: Virtual Factory Data Model. In: Proceedings of 2nd OSEMA (Ontology and Semantic Web for Manufacturing) Workshop (2012)
15. Gruber, T.R.: What is an Ontology? Summary statement of Gruber's defintion of ontology as a specification of a conceptualization (1995), http://www-ksl.stanford.edu/kst/what-isan-ontology.html
16. Fisseha, F.: The Basics of Ontologies. Nordic Agricultural Ontology Service (AOS) Workshop Royal Veterinary and Agricultural University Copenhagen, Denmark (2003)
17. W3c RDF Primer, http://www.w3.org/TR/2004/REC-rdf-primer-20040210/
18. W3C.OWL 2 Web Ontology Language - Document Overview (2009), http://www.w3.org/TR/owl2-overview/
19. Industry Foundation Classes (IFC) data model, http://www.buildingsmart.org/standards/ifc
20. KNX international site, http://www.knx.org/
21. Miori, V., Tarrini, L., Manca, M.: An Open Standard Solution for Domotic Interoperability
22. Chen, H., Finin, T., Joshi, A.: The SOUPA Ontology for Pervasive Computing. In: Ontologies for Agents: Theory and Experiences, pp. 233–258. Birkhäuser, Basel (2005)
23. IEEE Standard for modeling and simulation high level architecture (HLA) - framework and rules. IEEE Std. 1516-2000, pp. i–22 (2000)
24. Ghielmini, G., Pedrazzoli, P., Rovere, D., Terkaj, W., Dal Maso, G., Milella, F., Sacco, M., Boer, C.R.: Virtual Factory Manager of Semantic Data. In: Proceedings of DET 2011 (2011)