UNIVERSITI PUTRA MALAYSIA

SEAMLESS SEMANTIC SERVICE PROVISIONING MECHANISM FOR AMBIENT ASSISTED LIVING

WAN MOHD NUR MUZAALIFF BIN WAN MUSA

SEAMLESS SEMANTIC SERVICE PROVISIONING MECHANISM FOR AMBIENT ASSISTED LIVING

By

WAN MOHD NUR MUZAALIFF BIN WAN MUSA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the requirement for the Degree of Doctor of Philosophy

June 2013

COPYRIGHT

for

my mother Zainun Saruji

my father Wan Musa Jusoh

my wife Azareena Abdullah

my son Wan Harith Fahmi

my daughter Wan Nur Hanania

ABSTRACT

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

SEAMLESS SEMANTIC SERVICE PROVISIONING MECHANISM FOR AMBIENT ASSISTED LIVING

By

WAN MOHD NUR MUZAALIFF BIN WAN MUSA

June 2013

Chairman: **Borhanuddin Mohd Ali, PhD**

Faculty: **Engineering**

Parallel with the evolution of current technology and usage trends in Ambient Assisted Living (AAL); variety of new services are being introduced to assist dependent people to live independently, particularly elderly and people with mild dementia. Assistive services help them to carry out Activities of Daily Living (ADL) smoothly. Users are seamlessly delivered with relevant services as they roam into a new and sometimes unknown domain. To achieve this, a service discovery and provisioning mechanism beyond the current capabilities of any service platforms is required. This thesis proposes a mechanism for seamless semantic service provisioning using semantic web that is able to manage user and device mobility through semantic reasoning. The ultimate goal is to seamlessly provide users with relevant services at a specific location and time with a set of dynamic context.

ABSTRAK

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MEKANISME PEMBEKALAN PERKHIDMATAN SECARA SEMANTIK YANG BERTERUSAN UNTUK KEHIDUPAN TERBANTU AMBIEN

Oleh

WAN MOHD NUR MUZAALIFF B WAN MUSA

Jun 2013

Pengerusi: Borhanuddin Mohd Ali, PhD

Fakulti: Kejuruteraan

Sejajar dengan perkembangan teknologi terkini dan trend penggunaan dalam kehidupan terbantu ambien (AAL), banyak perkhidmatan baru diperkenalkan bagi membantu golongan yang memerlukan sokongan, terutamanya warga emas dan pesakit demensia tahap sederhana, supaya mereka dapat hidup berdikari. Perkhidmatan ini membantu mereka untuk menjalani aktiviti kehidupan harian (ADL) dengan lancar. Perkhidmatan yang berkaitan disampaikan kepada pengguna secara berterusan melalui berbagai peranti. Apabila pengguna bergerak, peranti juga mungkin berganjak memasuki domain yang baru dan adakalanya ke dalam domain yang tidak diketahui. Ia membawa kepada keperluan penzahiran dan pembekalan perkhidmatan yang menjangkaui kemampuan semasa platform-platform perkhidmatan yang sedia ada. Justeru, mekanisme pembekalan perkhidmatan secara semantik yang berterusan menggunakan jaringan semantik akan dibincangkan selanjutnya di dalam tesis ini. Cabarannya adalah bagi menghasilkan platform yang

Bukan sahaja menyokong pembekalan perkhidmatan secara semantik yang

berterusan, malah mampu mengendalikan pengguna dan mobiliti peranti melalui penalaran semantik. Tujuan sistem ini adalah memastikan pengguna berupaya menggunakan perkhidmatan yang berkaitan pada masa dan lokasi yang khusus berdasarkan set konteks yang dinamik.

ACKNOWLEDGEMENTS

I would like to express my sincerest appreciation to my supervisor, Professor Dr Borhanudin Mohd Ali, for his encouragement, sound advice and never-ending support that tremendously helped in bringing this work to completion. I am very lucky to have the opportunity to work under his guidance. Thank you to my internal co-supervisors, Associate Professor Dr Abd Rahman Ramli and Dr Dzhaharuddin Mansor, for their support in bringing the momentum to my work. My utmost gratitude for Professor Dr Mounir Mokhtari for his continuous support, endless encouragement and patience in assisting me completing this research, without whom, I can't achieve what I have accomplished.

I am very grateful to all my colleagues at the National Centre of Excellence for Sensor Technology and Department of Computer and Communication Systems Engineering, Faculty of Engineering, UPM. Thank you Assoc. Prof. Dr Fadlee, Azman, Azizi, Sahrizan and many more, all of these would have been very difficult without their support. I would also like to acknowledge the support from Image and Pervasive Access Lab, I2R Singapore and Handicom Lab at Telecom SudParis, France, where I did my research attachments. Mahmoud, Mossaab, Abdallah, Stephane and Thibaut, there are just too many to mention, all of them have a very significant impact on my research.

I would also like to extend deepest gratefulness to my dear wife Azareena and my children Harith and Hanania. Without their encouragement and compromises, I would not have a chance at completing this research. Finally, my mother and father whom have been my shining star during the darkest nights.

APPROVAL

I certify that an Examination Committee met on 18 June 2013 to conduct the final examination of Wan Mohd Nur Muzaaliff bin Wan Musa on his thesis entitled "Seamless Semantic Service Provisioning Mechanism for Ambient Assisted Living" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Salasiah binti Hitam, PhD
Associate Professor
Department of Computer and Communication Systems Engineering,
Faculty of Engineering,
Universiti Putra Malaysia.
(Chairman)

Wan Azizun binti Wan Adnan, PhD
Department of Computer and Communication Systems Engineering,
Faculty of Engineering,
Universiti Putra Malaysia.
(Internal Examiner)

Khairulmizam bin Samsudin, PhD
Department of Computer and Communication Systems Engineering,
Faculty of Engineering,
Universiti Putra Malaysia.
(Internal Examiner)

Jacques Demongeot, PhD
Professor
Université Joseph Fourier, Grenoble
France
(External Examiner)

Noritah Omar, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 16 August 2013

The thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of Supervisory Committee were as follows:

Borhanuddin Mohd Ali, PhD
Professor
Faculty of Engineering,
Universiti Putra Malaysia.
(Chairman)

Abd. Rahman Ramli, PhD
Associate Professor
Faculty of Engineering,
Universiti Putra Malaysia.
(Member)

Dzaharuddin Mansor, PhD
Microsoft
Malaysia.
(Member)

Mounir Mokhtari, PhD
Professor
Institut Telecom SudParis,
France
(Member)

_____

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

_____

WAN MOHD NUR MUZAALIFF B WAN MUSA

Date: 18 June 2013

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLES

LIST OF ABBREVIATIONS

AAL	Ambient Assisted Living
ADL	Activities of Daily Living
AmI	Ambient Intelligence
AP	Access Point
ASM	Abstract Service Model
AT	Assistive Technology
CC/PP	Composite Capabilities/Preference Profile
DAML	Distributed Agent Markup Language
DARPA	US Defense Advanced Research Projects Agency
DL	Description Logics
DQ	Demanded Quality
FIPA	Foundation for Intelligent Physical Agent
FOL	First Order Logic
GPS	Global Positioning System
GUI	Graphical User Interface
GW	Gateway
HEI	Human-Environment Interaction
HoQ	House of Quality
IP	Internet Protocol Address
IQR	Interquartile Range
LQI	Link Quality Indicator
MAC	Media Access Control
MOM	Message-Oriented Middleware

MUM	Mobile Agent-Based Ubiquitous Middleware Management
NSE	Network Selection Engine
OIL	Ontology Inference Layer
OSGi	Open Services Gateway Intiative
OWL	Web Ontology Language
Q1	First Quartile
Q3	Third Quartile
QC	Quality Characteristics
QFD	Quality Function Deployment
QoS	Quality of Service
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
RFID	Radio Frequency Identification Device
RS	Relationship Strength
RSSI	Received Signal Strength Indication
SAE	Smart Assistive Environment
SD	Standard Deviation
SI	Service Interface
SLC	Service Logic Code
SP	Service Profile
SSE	Service Selection Engine
SSID	Service Set Identifier
TCP/IP	Transmission Control Protocol / Internet Protocol
UP	User Profile

UWB	Ultra Wide band
W3C	World Wide Web Consortium
WDS	Wireless Distribution System
WIMNET	Wireless Internet-access Mesh Network
WLAN	Wireless Local Area Network
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol

CHAPTER 1
INTRODUCTION

1.1 Background and Motivation

Ambient assisted living (AAL) is aimed at the dependant population, mainly elderly and disabled to maintain their independence for a longer time in an environment supported by Information and Communication Technology [1]. AAL includes methods, concepts, systems, devices as well as services that provide unobtrusive support for daily life, based on the context and situation of the assisted persons. The goal is to provide them with assistance anywhere; usually the assistance comes in the form of services in the form of software applications.

At home, a user is familiar with his environment and his terminal is pre-configured with existing local services and network infrastructure. However, when a user moves outside the home environment, he enters an unknown environment where his end terminal does not have information on what services is available or offered.

To allow the user to discover unknown services, the services in unknown environments must, at least, follow a predefined pattern or model, referred to as a service model. By using suitable software and protocols, a user can discover the said services, even if he or his device does not know it.

The systems architecture design and technology selection is very important in determining seamless delivery of relevant and targeted services to a specific user with specific needs and context. These are the enabling factors that influence the efficiency and usability of the services. User needs, services requirements, device capabilities, environment states and network parameters are compiled as global contextual information as depicted in **Figure 1-1** below.

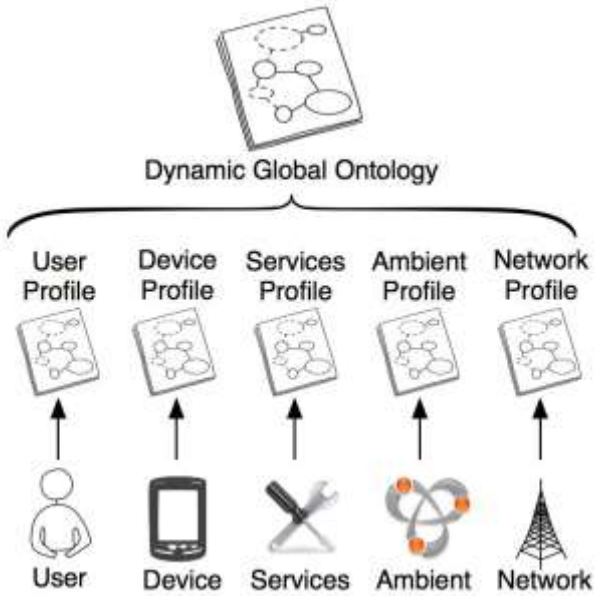

Figure 1-1: Global Contextual Information

At the same time, great care and effort must be considered for human-machine interaction level, because each user has special needs and their physical and/or cognitive capabilities may be different. Abstraction and generalization at the service level is required to accommodate this specification at the user's level. Subsequently, this will be beneficial during the adaptation and personalization step. Those aspects have to be respected while developing services for targeted groups. An Abstract Service Model (ASM) [2] is required to take these aspects into account and observed while developing services for the targeted group.

In this thesis, the target users are mainly dependant people; we define them as the people with physical and/or cognitive limitation due to a deficiency or to their age (people with disabilities and ageing people).

1.2 Ambient Intelligence

Ambient Intelligence (AmI) is made up of seamless and transparent infrastructure that is able to monitor response to the people living in it. It is a great extension of the concept known as ubiquitous and pervasive computing. Current technology forces user to adapt to the capabilities and limitations of the hardware or software.

AmI circumvents this problem by providing the platform where all the hardware and software adapts to the individual needs and requirements. However, such platform is still in infancy or at the conceptual level. This platform is very crucial for the design and development of assistive services, which includes all the relevant hardware and software that may be deployed in many different domains.

A very promising application area that can definitely take full advantage of AmI is personalized and targeted assistance or health care, which will be the focus of study in this thesis. Personalized and targeted assistance can be achieved utilizing AmI where the intelligence exists ubiquitously in the living environment.

With the help of embedded sensors and inter-device communications, the ambient is aware of not only the presence and activities of the user, but also its contextual information. This contextual information includes:

i. User – Condition, activities, preference, disabilities, location, mood, habits, etc.

ii. Device – The current device used by the user, all available devices in the area, device state and condition, such as communication medium and protocol, battery level, screen resolution, sensors attached, etc.

iii. Services – Available services in the area and its features, capabilities, requirements etc.

iv. Network – Available network medium and its parameters, such as protocol, bandwidth, QoS, signal strength, cost, etc

v. Ambient – The ambient parameters included are temperature, weather, light intensity, sound, time, etc.

Another feature of AmI is that, it remembers and anticipates the state and activities of all the "agents" in the domain. These agents include the components listed above. AmI solution must be non-obtrusive, personalized, adaptive, able to anticipate and respond to users needs. This has brought researchers to a relatively new research domain known as Ambient Assisted Living (AAL), which will be discussed in the section below.

1.3 Ambient Assisted Living (AAL)

AAL environments provide assistance to the person living in it to accomplish a task that would otherwise be impossible or at least more difficult to manage [3]. It is evolving with the customized provisioning of assistive services in response to changes in users' condition [4]. The usage of hardware and software systems that provides the above-mentioned assistance is known as Assistive Technology (AT).

With the concept of AAL utilizing AT, we can create a Smart Assistive Environment (SAE) that is able to sense multiple user presence, their condition and activities. On top of that, SAE is a physical space that is able to handle multiple users joining and leaving the domain. SAE can provide users with relevant assistive services, which is seamlessly selected and pushed to the user's devices based on the global contextual information.

For the purpose of discussion in this thesis, the disabled are defined as people having a physical or mental conditions that limit movements, senses, or activities; for example having lost the ability to use the lower limbs to walk, or upper limbs to perform daily tasks such as eating, opening doors or accessing a computer. Today, they commonly rely on assistive technology devices such as electrical wheelchair, robot manipulator to move objects in their environment, interactive verbal prompting system as well as communication systems to allow them to communicate with others or obtain information through the use of a computer.

This assistance from AmI can be too complex for them to handle at times. This is due to the use of various heterogeneous systems, which provides multiple and complementary functionalities, which forms a completely complex environment described as a smart and assistive environment.

Realization of the AmI vision requires the extended home environment (or the AAL Environment) where the disabled are able to use the facilities intuitively through the enhanced in-home facilities, both inside the home as well as outside home environment. Various facilities have been discussed and conceptualized, however there are many that has yet to be devised. This thesis focuses on the development of such framework to cater for these demands.

Various types of electronic devices from different manufacturers are currently being used, whether a person is at home or mobile. These devices are loosely connected and most of the time not interoperable, thus services might only work on one device and not the other. As the user moves away from the smart home, he/she will get into unknown domain with plenty of unknown devices and services around. These unknown services and devices can provide a very significant assistance, especially for the disabled or elderly.

1.4 Problem Statement

This thesis focuses on service selection and user mobility, which are the two main issues under investigation in service provisioning mechanism. Although service selection and provisioning mechanism has been proposed by [5], it did not take into consideration network selection or handovers. This is a problem faced by users when they roam into new domain with multiple unknown networks. Furthermore, the problem of current solutions in network handover only considers network parameters as reported in [6] and [7].

Designing a service provisioning mechanism that considers contextual information imposes some very serious technical challenges. We need to create a mechanism to provide users with relevant service seamlessly while they roam from one unknown domain to another. These challenges are researched and a solution is proposed in this thesis. The major challenges are listed below:

i. Requires a standardized and comprehensive way to describe these contexts.
ii. A way to extract the explicit and implicit user requirements that will be used to formulate the selection rules.
iii. A simple but robust inference engine that is light-weight yet can handle the amount of knowledge in the context description file. It must be able to process the contextual information and select the best (most relevant) network when users roam into an unknown domain.

1.5 Objectives

The objective of this work is to design and develop a semantic based service provisioning mechanism with the capability of considering contextual information from user profile, services profile, device profile, ambient states and network parameters to select the most relevant network. Here, the most relevant network is defined as a network with the most relevant services to the user requirements.

This main objective can be achieved through the followings:

i. To conceptualize and compose global ontology based on user profile, services profile, device profile, ambient states and network parameters.
ii. To formulate inference rules based on explicit and implicit user preference and requirement.
iii. Design and develop network selection mechanism using inference engine, which considers contextual information in the global ontology.

1.6 Scope of Work

The scope of our research as presented in this thesis is on service provisioning mechanism, focusing on seamless semantic network (access point) selection. It focuses on semantic-based service provisioning mechanism, specifically through a smart network selection process.

The smart network selection mechanism uses a weighted scoring system to select the best access point. This is done by matching the explicit and implicit user requirements with what the services have to offer, considering the contextual information from current device, ambient and network state.

The work also includes the design and development of global ontology and inference rules to support a context aware network selection. The global ontology describes context information consisting service, user, device, ambient and network profiles. The context profiling design is out of scope of this thesis. It is based on the recommendations and works in [2,8,9]. Finally, an assessment and analysis of decision algorithm performance is done.

1.7 Thesis Organization

This thesis organized into five chapters, which consists of the introduction, literature review, methodology, results and discussions, and finally the conclusion and future work. This chapter introduces the scenario, problem statement, objectives and scope

of work of this thesis. The evolution of ambient assisted living and the supporting technologies are discussed briefly.

Chapter 2 discusses the currently available solutions and technologies in ambient assisted living. Some of the most relevant research publications are discussed including activity recognition, service selection mechanism, network handover, semantic web and reasoning theory. These are the topics and research areas that are relevant to the solution proposed in the thesis.

The methodology is discussed in Chapter 3. An ontology design for user profile, service profile, network profile, device profile and environment profile are presented. The service selection mechanism is also discussed in detail before arriving at the heart of the thesis, which is the semantic network selection and its reasoning engine. At the end of this chapter, the overall systems design is presented.

Chapter 4 presents the results obtained from the simulation and implementation of the proposed framework. Amongst the analysis done includes performance evaluation, accuracy evaluation and reliability considerations. The system's limitation and development challenges are presented at the end of the chapter.

Finally, Chapter 5 concludes the experiences acquired and lesson learnt from the design and development stages as well as the findings gathered from the implementation. Further works for future improvements are suggested for consideration.

REFERENCES

6. Antonio J. Jara, Miguel A. Zamora, and Antonio F. Skarmeta, "An Architecture for Ambient Assisted Living and Health Environments," in *the 10th International Work-Conference on Artificial Neural Networks: Part II: Distributed Computing, Artificial Intelligence, Bioinformatics, Soft Computing, and Ambient Assisted Living*, Salamanca, Spain, 2009.

7. Mahmoud Ghorbel, Rachid Kadouche, and Mokhtari Mounir, "User & service modelling in assistive environment to enhance accessibility of dependent people," in *International Conference on ICT & Accessibility (IICA)*, TUNISIA, 2007.

8. Molly Follette Story M.S., "Maximizing Usability: The Principles of Universal Design," *Assistive Technology: The Official Journal of RESNA* , vol. 10, no. 1, pp. 4-12, 1998.

9. Hamdi Aloulou, Mounir Mokhtari, Thibaut Tiberghien, Jit Biswas, and Lin Kenneth, "A Semantic Plug&Play Based Framework for Ambient Assisted Living," *Impact Analysis of Solutions for Chronic Disease Prevention and Management*, vol. 7251/2012, pp. 165-172, 2012.

10. M. Ghorbel, M. Mokhtari, and S. Renouard, "A Distributed Approach for Assistive Service Provision in Pervasive Environment," in *The 4th international Workshop on Wireless Mobile Applications and Services on WLAN Hotspots (WMASH '06)*, Los Angeles, 2006, pp. 91-100.

11. Paolo Bellavista, Antonio Corradi, and Luca Foschini, "Context-aware handoff middleware for transparent service continuity in wireless networks," *Pervasive and Mobile Computing*, vol. 3, no. 4, pp. 439-466, August 2007.

12. Anthony J. Nicholson, Yatin Chawathe, Mike Y. Chen, Brian D. Noble, and David Wetherall, "Improved access point selection," in *The 4th international Conference on Mobile Systems, Applications and Services (MobiSys '06)*, Uppsala, Sweden, 2006, pp. 233-245.

13. FIPA Device Ontology Specification web site. [Online]. http://www.fipa.org/specs/fipa00091/PC00091A.html

14. W3C Composite Capability/Preference Profiles (CC/PP): Structure and Vocabularies. [Online]. http://www.w3.org/TR/CCPP-struct-vocab/

[20]. M. E. Pollack et al., "Autominder: an intelligent cognitive orthotic system for people with memory impairment," *Robotics and Autonomous Systems*, vol. 44, no. 3-4, pp. 273-282, September 2003, Best papers presented at IAS-7.

[21]. R. Want, A. Hopper, V. Falcao, and J. Gibbons, "The Active Badge Location System," *ACM Transactions on Information Systems*, vol. 40, no. 1, pp. 91-102, 1992.

[22]. Tao Gu, Zhanqing Wu, Liang Wang, Xianping Tao, and Jian Lu, "Mining Emerging Patterns for Recognizing Activities of Multiple Users in Pervasive Computing," in *6th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services (MobiQuitous '09)*, Toronto, 2009.

[23]. R. Bodor, B. Jackson, and N. Papanikolopoulos, "Vision-Based Human Tracking and Activity Recognition,".

[24]. P. M. Jorge, J. S. Marques, and A. J. Abrantes, "Online Tracking Groups of Pedestrians with Bayesian Networks," in *The IEEE International Workshop on Performance Evaluation of Tracking and Surveillance*, Prague, 2004, pp. 65-72.

[25]. Henrik Sørensen and Jesper Kjeldskov, "Immediate User Interface Adaptation in Multi-device Environments," in *The 11th International Working Conference on Advanced Visual Interfaces*, Capri Island, 2012.

[26]. Mossaab Hariz, Mahmoud Ghorbel, and Mounir Mokhtari, "Service abstraction model for dynamic user interface presentation," in *The 5th international conference on Smart homes and health telematics*, Nara, 2007, pp. 170-178.

[27]. Quoc-Thinh Nguyen-Vuong, Nazim Agoulmine, and Yacine Ghamri-Doudane, "A user-centric and context-aware solution to interface management and access network selection in heterogeneous wireless environments," *Computer Networks*, vol. 52, no. 18, pp. 3358-3372, December 2008.

[28]. Nobuo Funabiki et al., "A Smart Access-Point Selection Algorithm for Scalable Wireless Mesh Network," *IAENG International Journal of Computer Science*, vol. 38, no. 3, pp. 260-267, August 2011.

[29]. Ioannis Chamodrakas and Drakoulis Martakos, "A utility-based fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks," *Applied Soft Computing*, vol. 12, no. 7, pp. 1929-1938, July 2012.

5. Rajeev Agrawal and Amit Seghal, "Network Selection for Remote Healthcare Systems through Mapping between Clinical and Network Parameter," in *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, Karan Singh and Amit K. Awasthi, Eds. Greader Noida, India: Springer Berlin Heidelberg, 2013, vol. 115, pp. 31-41.

6. Tim Berners-Lee, James Hendler, and Ora Lassila, "The Semantic Web," *Scientific American*, May 2001.

7. W3C. (2004, February) World Wide Web Consortium. [Online]. http://www.w3.org/TR/owl-features/

8. D. Fensel et al., "Semantic Web Application Areas," in The 7th International Workshop on Applications of Natural Language to Information Systems, Stockholm, 2002.

9. N. Guarino, "Formal Ontology in Information Systems," in *International Conference of Formal Ontology in Information Systems*, Trento, Italy, 1998, pp. 3-15.

10. A. Gomez-Perez and O. Corcho, "Ontology languages for the Semantic Web," *IEEE Intelligent Systems*, vol. 17, no. 1, pp. 54-60, February 2002.

11. Franz Baader, Ian Horrocks, and Ulrike Sattler, "Description Logics as Ontology Languages for the Semantic Web," in *Mechanizing Mathematical Reasoning*, Dieter Hutter and Werner Stephan, Eds.: Springer Berlin Heidelberg, 2005, vol. 2605, pp. 228-248.

12. Brian McBride, "Jena: A Semantic Web Toolkit," *Internet Computing*, vol. 6, no. 6, pp. 55-59, December 2002.

13. I. Horrocks, P. F. Patel-Schneider, and F. Van Harmelen, "Reviewing the design of DAML+ OIL: An ontology language for the semantic web," in *The National Conference on Artificial Intelligence*, Edmonton, Alberta, 2002, pp. 792-797.

14. Deborah L. McGuinness and Frank Van Harmelen, "OWL web ontology language overview," The World Wide Web Consortium (W3C), Recommendation 2004.

15. D. Nardi and R. J. Brachman, "An Introduction to Description Logics," in *Description Logic Handbook*, F.Baader et al., Eds.: Cambridge University Press, 2002, pp. 5-44.

- Choi J., Shin D., and Shin D., "Research and Implementation of the Context-aware middleware for controlling home appliances," *IEEE Trans. on Consumer Electronics*, vol. 51, no. 1, pp. 301-306, 2005.

- R.H. Ranganathan A. Campbell, "A Middleware for Context-Aware Agents in Ubiquitous Computing Environments," in *ACM/IFIP/Usenix International Middleware Conference*, 2003.

- Alexander Pretshner and Susan Gauch, "Ontology Based Personalized Search," in *11th IEEE International Conference on Tolls with Artificial Intelligence*, Chicago, 1999, pp. 391-398.

- JENA Semantic Web Framework. [Online]. http://jena.sourceforge.net/

- QFD Institute. QFD Institute Homepage. [Online]. http://www.qfdi.org/

- The Apache Software Foundation. [Online]. http://jena.apache.org

- Yoji Akao, "QFD: Past, Present, and Future," in *Third International Symposium on QFD*, Linköping, Sweden, 1997.

- Chan Lai-Kow and Wu Ming-Lu, "Quality function deployment: A literature review," *European Journal of Operational Research*, vol. 143, no. 3, pp. 463-497, December 2002.

- Kinnar K. Ghiya, A. Terry Bahill, and William L. Chapman, "QFD: Validating Robustness," *Quality Engineering*, vol. 11, no. 4, pp. 593-611, 1999.

- Glen H. Mazur, "QFD For Service Industries: From Voice of Customer to Task Deployment," in *Th Fifth Symposium on Quality Function Deployment*, Novi, Michigan, 1993.

- Giuseppe Amato and Umberto Straccia, "User Profile Modeling and Applications to Digital Libraries," in *3rd European Conference on Research and Advanced Technology for Digital Libraries (ECDL)*, 1999.

- Ivy Software bus. [Online]. http://www.tls.cena.fr/products/ivy/

- The XMPP Standards Foundation. [Online]. http://xmpp.org

vii. Thomas L. Saaty, "How to make a decision: the analytic hierarchy process," *European journal of operational research*, vol. 48, no. 1, pp. 9-26, 1990.

viii. Andrew Olewnik and Kemper Lewis, "Can a House Without a Foundation Support Design?," in *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*, Long Beach, California, 2005.

ix. Robins Matahai Kalapurackal and Shun Takai, "Sensitivity Analysis of Relative Worth in Empirical and Simulation-based QFD Matrices," in *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (IDETC/CIE2008)* , Brooklyn, New York, 2008, pp. 149-158.

x. Mahmoud Ghorbel, "Abstract Service Model for Adaptive Provision in Ambient Assistive Living," RST, Institut National des Telecommunications, Evry, PhD Thesis 2008.

xi. V Barnet and T Lewis, *Outliers in Statistical Data*, 3rd ed.: John Wiley & Sons, September 1994.

xii. V.J. Hodge and J Austin, "A survey of outlier detection methodologies," *Artificial Intelligence Review*, vol. 22, no. 2, pp. 88-126, 2004.

xiii. Michiel Debruyne, Sanne Engelen, Mia Hubert, and Peter J. Rousseeuw, "Robustness and Outlier Detection in Chemometrics," *Critical Reviews in Analytical Chemistry*, vol. 36, no. 3-4, pp. 221-242, April 2006.

xiv. Tukey J.W., *Exploratory Data Analysis*. Reading, Massachusset, USA: Addison-Wesley, 1977.

xv. National Institute of Standards and Technology NIST. Standards.gov. [Online]. http://standards.gov/standards_gov/assistiveTechnology.cfm

xvi. A Pretschner and S Gauch, "Ontology Based Personalized Search," in *11th IEEE International Coference on Tools With Artificial Intelligence*, Chicago, 1999, pp. 391-398.

xvii. Ivan Herman. (2011, Feb.) World Wide Web Consortium. [Online]. http://www.w3.org/2001/sw/

4. Tanzeem Choudhury et al., "the mobile sensing platform: An embedded Activity Recognition system," *IEEE Pervasive Magazine - Special Issue on Activity-Based Computing*, April 2008.

5. Nishkam Ravi, Nikhil Dandekar, Preetham Mysore, and Michael Littman, "Activity Recognition from Accelerometer Data," in *Seventeenth Conference on Innovative Applications of Artificial Intelligence (IAAI/AAAI 2005)*, 2005.

6. Grigoris Antoniou and Frank van Harmelen, "Web Ontology Language: OWL," in *Handbook on Ontologies in Information Systems*, S. Staab and R. Studer, Ed.: Springer-Verlag, 2003, pp. 79-92, http://www.cs.vu.nl/~frankh/postscript/OntoHandbook03OWL.pdf.

7. Kejun Du, Daqing Zhang, Muzaaliff W. Musa, Mounir Mokhtari, and Xingshe Zhou, "Handling Activity Conflicts in Reminding System for Elders with Dementia," in *Second International Conference on Future Generation Communication and Networking*, vol. 2, 2008, pp. 416-421.

8. Xudong Wang, Ian F. Akyildiz, and Weilin Wang, "Wireless mesh networks: asurvey," *Computer Networks*, vol. 47, no. 4, pp. 445-487, March 2005.

9. Mounir Mokhtari, Mahmoud Ghorbel, Rachid Kadouche, and M. A. Feki, "From Smart Home to Smart Space in Independent Living: A Framework for Multiple Contexts Management," in *Third IEEE International Conference on Wireless and Mobile Computing, Networking and Communications*, New York, 2007, p. 74.

10. Muzaaliff W. Musa, Mounir Mokhtari, Borhanuddin M. Ali, M. F. A. Rasid, and Mahmoud Ghorbel, "Seamless semantic service provisioning mechanism for ambient assisted living," in *8th International Conference on Advances in Mobile Computing and Multimedia*, Paris, 2010, pp. 119-125.

11. Kinnar K. Ghiya, A. Terry Bahill, and William L. Chapman, "QFD: VALIDATING ROBUSTNESS ," *Quality Engineering*, vol. 11, no. 4, pp. 593-611, 1999.

12. I. Horrocks, P. F. Patel-Schneider, and F. Van Harmelen, "Reviewing the design of DAML+ OIL: An ontology language for the semantic web," in *The National Conference on Artificial Intelligence*, Edmonton, Alberta, 2002, pp. 792-797.

5. A. Gomez-Perez and O. Corcho, "Ontology languages for the Semantic Web," *IEEE Intelligent Systems*, vol. 17, no. 1, pp. 54-60, 2002.