Virtual Agents in Next Generation Interactive Homes

Rafael Del-Hoyo, Luis Sanagustín, Carolina Benito, Isabelle Hupont, and David Abadía

Abstract. Today's houses are slowly turning into a complex electronic net of devices. The increasing complexity of systems and the need for these systems to remain simple, accessible and transparent for the user, makes it necessary to research technologies that enable intelligent and autonomous computing and new ways of interacting with future home. Autonomic computing systems are those which can manage themselves given high level objectives. If we integrate autonomic computing and new interactive user mechanisms like virtual agents, we obtain the future smart homes.

Keywords: Autonomic Computing, HCI, Virtual Agents, Smart Homes.

1 Introduction

Nowadays, huge R&D efforts are running on the re-invention of the Internet so that it is able to cope with future challenges, like the viral growth of the number of connected users, devices, services and user-generated contents. Today's houses are slowly turning into a complex electronic net of devices. Multimedia TVs based in DLNA (Digital Living Network Alliance), sensors, automation controls and energy consumption meters are connected to the Internet via residential gateways, using a variety of home communication networks (fiber, WiFI, Power Line). As a resultof this people is going to beimmersed in the Internet of things paradigm or the Internet of objects connected inside of each home. The increasing complexity of systems and the need for these systems to remain simple, accessible and transparent for the user, makes it necessary to research technologies that enable intelligent and autonomous computing and new ways of interacting with future

Rafael Del-Hoyo · Luis Sanagustín · Carolina Benito · Isabelle Hupont · David Abadía
Instituto Tecnológico de Aragón, P.T. Walqa Ctra. Zaragoza, N-330a, Km 566,
Cuarte (Huesca), Spain
e-mail: {rdelhoyo,lsanagustin,cbenito,ihupont,dabadia}@ita.es

J.M.C. Rodríguez et al. (Eds.): Trends in PAAMS, AISC 157, pp. 9–17.
springerlink.com

home. Autonomic computing systems are those which can manage themselves given high level objectives. These systems include environments that are able to evolve without the need for human interaction. These environments are capable of installing, configuring, maintaining and healing themselves, and their own components. This paper presents an Autonomic Interactive Fusion engine platform developed in the GENIO[1] project. The main element of the architecture is the Intelligent Autonomous System in charge of the information fusion process. This also controls a virtual agent that allows increases the interactivity from user perspective. This paper is structured in the following way; the first section is a brief statement about autonomic computing and virtual agent in smart homes. The second section describes current projects in smart homes and GENIO project and the following section describes the intelligent framework used for smart homes. The fourth section explains how the information is joined inside the fusion information engine. Finally, several conclusions are set forth.

1.1 Autonomic Computing

The essence of autonomic computing systems is self-management, or, the ability to reduce human interaction in administration tasks to the minimum. As it is explained in previous research [1], these systems should provide self-configuration, self-optimization, self-healing, self-protection. The system should incorporate itself seamlessly, and the other components present in the system must adapt to its presence by learning new configurations or topologies. An automatic system should continually seek ways to tweak parameters, and, at the same time, should be able to find and apply the lastest updates for each system component. Autonomic systems should detect, trace, diagnose and repair bugs and failures. Autonomic systems should defend themselves from large scale problems arising from malicious attacks or big failures.

1.2 Human Interaction through Virtual Agents

Virtual agents have proved to be a useful way of HCI (Human Computer Interaction). For humans, it is easier to communicate with a computer through a conversation with a virtual agent as opposed to just a keyboard and mouse. To make a virtual agent interact in a consistent, emotionally empathic and intelligent way with the user, a strategy must be defined for recognizing, integrating and interpreting user information coming from different modalities (video, audio, etc.). Secondly, it is important to realize how the human mind works to correctly "model" the virtual agent's reasoning mechanisms. The human brain is characterized by its capacity to handle and store uncertain and confusing perceptions. People usually face problems with great uncertainty and partial, context-dependent, and contradictory information. SoftComputing techniques, in special Fuzzy Logic, make it possible to model these types of problems and to find solutions similar to the ones taken by human beings. In doing so, it is possible to develop a more "cognitive" computation that tackles effectively the interaction among persons and virtual agents, how they communicate and act through words

and perceptions [2]. Finally, the virtual agent must be believable: it has to move properly, paying special attention to its facial expressions [3], and have the capacity to talk in natural language [4]. Emotions have been proved to play an essential role in decision making, perception, learning and more [5]. Consequently, besides its external appearance, the virtual agent must possess some affectivity, an innate characteristic in humans, for which it is necessary to carefully manage the emotional display of the virtual agent. Human Computer Interaction (HCI) gets more natural when using a virtual agent as computer side communication entity.

1.3 Smart Autonomous Media Homes State of the Art

One of the most important fields to apply Autonomic Computing and Human Computer Interaction technologies is houses, thus making them intelligent or smart houses. These houses would detect the people inside, self-configure by personalizing the services for each users and detecting and configuring new devices plugged into the house; would self-optimize by disconnecting lights or closing doors if people aren't present; would self-heal by controlling sensors and preventing problems related to physical and software elements; and would self-protect by identifying the current users at home, and preventing external attacks. There are several research efforts to introduce major autonomic capabilities in smart houses, like self-configuration using adaptation models [6], petri-nets [7] or variability models [8] which determine a set of policies to know how the system should be modified against changes at home; or self-protection. The University of Valencia has developed a Model-Based Reconfiguration Engine (MoRE) [8,9]. Finally, the University of Mondragon, the University of Ulster and Washington State University present their project CASAS. It is an adaptive smart home autonomous system that utilizes machine learning and data mining [10] techniques to discover patterns in resident's daily and repetitive activities [11] and to generate automation polices that mimic these patterns. The autonomous system can be guided by resident providing explicit feedback or it can be left to the system to automatically discover and adapt to changes in pattern of activities.

1.4 The Smart Home in GENIO Project

The research presented in this paper is part of the European GENIO project. The GENIO project aims to define the home network of the future, developing an advanced self-management of the home network, facing the problem of heterogeneity and transparency of the devices and their interactions, and looking to maximize automation and to respond intelligently to events and alarms. The project intends also to solve other challenges like ubiquitous access to the home network contents and personalization of the services. A diagram of GENIO smart home can be seen in figure 1.

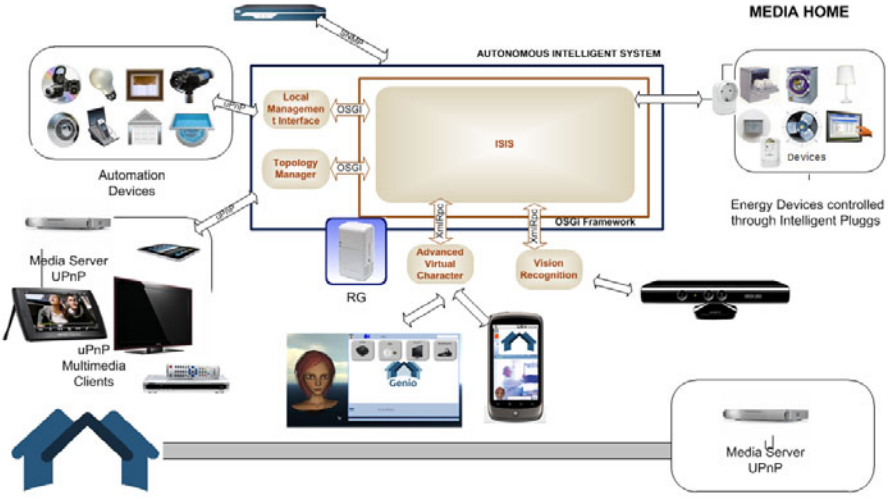

Fig. 1 Diagram of the system working as Autonomous System inside Smart Home.

2 Framework Technology Overview

The aim of this section is to establish the Intelligent Autonomous System's technology overview. One of the possible technologies which is candidate for handling this type of smart home is algorithm based on soft-computing/computational intelligence techniques. These algorithms are able to work with a great number of data (even noisy and incomplete), and they also allow predicting the behavior of highly nonlinear systems, as is the case of Home Systems and in special communication systems. As we have showed in GENIO project, these properties allow us to analyze, predict the state of an IP network or to make decision about any problem inside of the home. In this project, the development of an intelligent decision support system (iDSS) is proposed, called Intelligent Autonomous System (IAS), based on some well-known artificial neural models. IAS will allow the entire home status management, dealing with high dimensionality information, through a new advanced interface personalized into a Virtual Agent. The objective of this virtual agent is to be the human-interface between the home user and the autonomous systems, informing the user about the status of the home and the predicted situations found. Also, through this interface the user can manage the home devices using several other interfaces, like SNMP or uPNP. The control logic in the IAS platform is implemented inside of the intelligent framework using natural language rules (fuzzy rules) and neural network for pattern recognition. This framework is also responsible of the behavior of the virtual agent. This IAS platform is able to evolve and adapt according to the actions obtained from the user. During the learning process, user patterns like the number of user repetitions, watching movies or managing home devices are learned by means of a neural network supervised learning process.

Due to the rules-based intelligent framework, the proposed platform is a powerful tool for general autonomous home systems. The main AI (Artificial intelligence) technologies uses in the decision autonomous system for GENIO are neural networks, Rule Engines and finally AIML(Artificial Intelligence Markup Language).

2.1 The Intelligent Support Interaction System (ISIS)

ISIS is the main element of the proposed system. It is the evolution of a SoftComputing-based intelligent system called PROPHET that enables real-time automatic fuzzy decision making and self-learning over any kind of incoming inputs (from sensors, video channels, audio channels, probes…)[12].ISIS is the engine in charge of the logic of the platform from IAS point of view. It is also the inference engine that makes the virtual Agent to react to different inputs coming to the platform. According to different inputs of the platform, ISIS extracts knowledge and thanks to the use of Neuro-Fuzzy techniques, the module has the capability of self-extracting and self-learning new fuzzy decision rules from historical data. ISIS consists of a set of modules for pre-processing, integrating and extracting information and making decisions in a flexible way under uncertain contexts. It is described in the following modules:

- **Hybrid rule inference engine:** it is the main sub-system of the Autonomous System. It is in charge of rule-based decision-making tasks..
- **Knowledge and data persistence module:** system that manages data and knowledge (rules) information.
- **Integration and transformation module:** module in charge of filtering, synchronizing and pre-processing the incoming inputs, in order to make them compatible with the hybrid rule inference engine input format.
- **Application control module:** state machine that controls the Autonomous Intelligent System behavior.
- **AIML module:** the AIML module computes an appropriate natural language answer, for a given user interaction context.
- **Communication interface with the GUI interface:** that manages communication between the Autonomous System and the GUI.
- **Communication interface with the Topology Managercomponent:** that informs the Autonomous System in real-time about the events that occur in the home network

2.2 Neural Network Algorithms Applied in Our Work

Learning from examples (or historical data) is one of the capabilities that make artificial neural networks and neuro-fuzzy systems a suitable approach for pattern recognition in home environments.We have applied neural networks and neuro-fuzzy to home management and pattern recognition, and we have compared results from both models and we obtain similar results due to the simplicity of the uses cases generated.

2.3 Rule Engine

The embedded rule inference engine is in charge of rule-based decision making tasks in the home manage process. It is a hybrid rule inference engine since it can both deal with crisp rules (applied to exact inputs' values) and execute inference from rules that handle fuzzy concepts. Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is robust and approximate rather than brittle and exact. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions. The elements in the inference engine's Working Memory are not only the rules pre-defined by an expert, but also the set of automatically self-learned decision rules created by the knowledge extraction and classification obtained from neuro-fuzzy systems. Fuzzy set theory defines fuzzy operators on fuzzy sets. The problem in applying this is that the appropriate fuzzy operator may not be known. For this reason, fuzzy logic usually uses IF-THEN rules. Rules are usually expressed in the form:

```
IF variable IS property THEN action
```

In the case of GENIO project will have the following rules examples

```
IF temperature IS very cold THEN select movie about
winter (personalization rule)
IF QoS is low  THEN don't allow remote movies
IF QoS is high THEN select HD movies
```

There is no "ELSE" – all of the rules are evaluated, because the temperature might be "cold" and "normal" at the same time to different degrees.

3 Multimodal Fusion Engine

The main feature of the Autonomous System is its capability to integrate information coming from several sources, of very different natures and arriving with different timings. The system integrates data (every 500ms) from the following sources:

- **Pattern Recognition:** through the inclusion of different classification algorithms previously predefined. This preprocess module allows the generation of new attributes based on this data mining algorithm and the generation of an attribute that represents the output of this classifier (figure 2).
- **Virtual Agent Speech Recognition:** based on the recognition of the user's voice, it is converted into text and placed as an attribute of the text itself.
- **Presence recognition and number of people counting:** the number of persons found in the scene is introduced as a new attribute.
- **Gesture Recognition:** gesture recognition is performed by a gesture recognition algorithm within the platform Kinect.
- **Feature Image Classification Algorithm:** With a vision algorithm based on a feature detection algorithm called Surf**.** This information is entered into the system as a new nominal (object name recognized) attribute.

- **Information about UPnP devices / network existing inside the home:** when an uPnP device is detected, ISIS dynamically generates a number of attributes into the system corresponding to each of the properties associated to UPnP device.
- **SNMP information from network devices Home:** ISIS is able to monitor any home network device.
- **Energy consumption Information and home automation sensors:** home sensors are mapped to numeric attributes inside the inference engine.

3.1 Heterogeneous Output Information

The most important actions that can be generated in a given time *t*in the system are:

- **Gestural animation of the virtual actor's face:** with this types of consequences in the rules can be modified emotion the face of virtual agent.
- **VirtualAgentverbalinformation:** the inferenceenginecan control a Text to Speech virtual agent system.
- **UPnP/DLNA device control:** The enginecan operate asUPnP/DLNA controlpointand controlany deviceof this kind.
- **Control home automation devices and Energy:** The element of decision allows you to control alarms or interrupting powerto any electrical appliance.
- **Generate the training of a given data mining classifier:** Based on information from the historic the system launches a learning process for a particular pattern using one specific classifier such as a neural network.

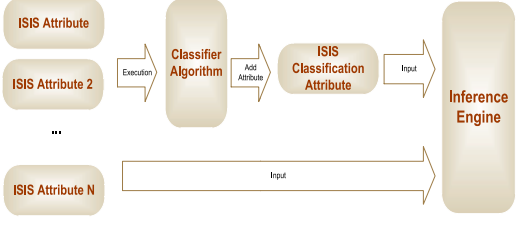

Fig. 2 Integration of the pattern recognition algorithms inside the inference engine

Fig. 3 Examples of Agent's Emotional expressions.

3.2 New User Home Interaction

The user interaction as previously discussed is performed by integrating information from heterogeneous data sources. The user can send audio (voice

commands) or visual information (detection people, generate hand gestures or detect objects that are recognized by the system). This information is processed and integrated with other types of information to generate verbal responses or emotions by the virtual agent to increase interaction between man and machine. Different use cases have been tested. From the generation of alarms by the virtual agent through the recognition of patterns in sensors deployed around the house or the management of uPnP devices such as movies or cameras via voice commands or through hand gestures. Others more complex cases can be when the user is watching a film on a TV in the lounge, the user shows a Tablet PC to the virtual agent and the film is moved to Tablet at the point where you were watching it and thus bring in your media information always with you and anywhere in the house. Moreover, the network is monitored all time, so you can validate that there is sufficient quality of service on the network before launching the film in the tablet itself. One of the most interesting system features is the ability to generate emotions in the virtual agent depending on the condition of your home. Using Fuzzy rules ISIS can generate a temporary emotional personality of the agent, using a similar method than in [13] therefore different emotional expressions (figure 3) are generated on the agent during user interaction.

4 Conclusions

A novel platform for creating smart interactive homes has been presented. The platform has been achieved as a result of the work developed in GENIO project. Moreover, fuzzy rules used inside the inference engine enable the Home self-optimization and self-healing. Finally the multimodal integration and information fusion and the pattern recognition features allow the Home self-protection and self-healing for diagnosis. The second outstanding feature of GENIO project is the great possibilities it offers to the user for interacting with the Home by means of the Virtual Agent. The agent is able to interact with physical elements of the home, such as sensors or multimedia DLNA devices.

Acknowledgments. This work has been co-funded by GENIO project (TSI-020400-2010-98), QUEEN project (IPT-2011-1235-430000).the Spanish Ministry of Industry, project FEDER ATIC.

References

1. Kephart, J.O., Chess, D.M.: The Vision of Autonomic Computing. Computer, 41–53 (January 2003)
2. Zadeh, L.A.: Computing with Words and Perceptions - A Paradigm. In: Proceedings of the 2003 International Conference on Machine Learning and Applications, pp. 3–5 (2003)
3. Pantic, M., Bartlett, M.S.: Machine Analysis of Facial Expressions. Face Recognition, 377–416 (2007)

4. Cowie, R., Douglas-Cowie, E., Schroeder, M.: Speech and Emotion. A conceptual framework for research. In: Proceedings of the ISCA Workshop, Belfast (2000)
5. Egges, A., Kshirsagar, S., Magnenat-Thalmann, N.: Generic Personality and Emotion Simulation for Conversational Agents. Computer Animation and Virtual Worlds 15, 1–13 (2004)
6. Morin, B., Fleurey, F., Bencomo, N., Jézéquel, J.-M., Solberg, A., Dehlen, V., Blair, G.S.: An Aspect-Oriented and Model-Driven Approach for Managing Dynamic Variability. In: Czarnecki, K., Ober, I., Bruel, J.-M., Uhl, A., Völter, M. (eds.) MODELS 2008. LNCS, vol. 5301, pp. 782–796. Springer, Heidelberg (2008)
7. Zhang, J., Cheng, B.H.C.: Model-Based Development of Dynamically Adaptive Software. In: Proc. 28th Int'l Conf. Software Eng. (ICSE 2006), pp. 371–380. ACM Press (2006)
8. Coplien, J., Hoffman, D., Weiss, D.: Commonality and Variability in Software Engineering. IEEE Software, 37–45 (1998)
9. Cetina, C., et al.: Autonomic Computing Through Reuse Of Variability Models At Runtime: The Case Of Smart Homes. Computer, 37–43 (2009)
10. Cook, D., Holder, L.: Sensor Selection to Support Practical Use of Health-Monitoring Smart Environments. Data Mining and Knowledge Discovery 1(4) (2011)
11. Rashidi, P., Cook, D.: Keeping the resident in the loop: Adapting the smart home to the user. IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans 39(5), 949–959 (2009)
12. Martínez, H., Del-Hoyo, R., Sanagustín, L., Hupont, I., Abadía, D., Sagüés, C.: Augmented Reality based Intelligent Interactive e-Learning Platform. In: ICAART (1), pp. 343–348 (2011)
13. Liu, Z.: A Personality Based Emotion Model for Intelligent Virtual Agents. In: 2008 Fourth International Conference on Natural Computation, Jinan, Shandong, China, pp. 13–16 (2008)