SMART AND INTERACTIVE FUTURE HOMES
Integration of Autonomic Computing and New HCI Methods

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Abstract: 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. 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. These houses would detect the people inside, and self-configure by personalizing the services for each user and detecting new devices plugged to the house: would self-optimize by disconnecting lights or closing doors if people aren't present: would self-heal by controlling sensors to prevent problems related to physical and software elements; and would self-protect by identifying the current users at home, and preventing external attacks.

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. In a close future people is going to be immersed in the Internet of things or the internet of objects connected to the cloud. 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. 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 project (http://projects.celtic-initiative.org/genio/). 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's explained in previous researches, these

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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. 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. The virtual agent can be a realistic 3D representation of a human being, but can also be a 3D cartoon or just a 2D animated agent. This depends on several factors such as the kind of application or the target user. Virtual agents have been used in very different contexts, such as marketing, education, shopper assistants, or personal trainers.

Firstly, natural human-human interaction is multimodal: we communicate through speech and use body language (posture, facial expressions, gaze) to express affect, mood, attitude and attention. Thus, when communicating with each other, human beings have to process and react in real-time to a broad spectrum of data coming from different channels: visual, auditory, tactil senses. 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.

Finally, the virtual agent must be believable: it has to move properly, paying special attention to its facial expressions and body gestures, and have the capacity to talk in natural language (Cowie, 2000). Emotions have been proved to play an essential role in decision making, perception, learning and more (Egges, 2004). 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. Thanks to both, verbal and non-verbal communication, the interaction between the user and the virtual agent becomes more credible.

1.3 SMART Interactive MEDIA HOMES

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.

The architecture is rapidly retargeted to a specific configuration. The engine can also self-heal, when a device or service is removed or fails, the system should adapt itself in order to offer its services in an alternative way to reduce the impact of the device loss. At last, the system can self-adapt, because users’ needs are different for each user at any given moment, the system should adjust its services in order to fulfil user preferences. The University of Colorado has introduced the adaptive house. They present the idea of adapt and reconfigure their autonomic system by observing the lifestyle and desires of the inhabitants, and learning to anticipate and accommodate their needs. The autonomic system monitors the environment, observing the actions taken by its occupants, and it uses neural network reinforcement learning and prediction techniques to infer patterns in the environment that predict these actions and perform them automatically. This system also introduces self-optimization by trying to conserve energy sources, where possible. For example, it can predict when the occupants will return home, and determine when to start heating the house, detect patterns of hot water usage to disconnect the water heater at times that is never used, control lighting patterns and intensities based on occupant activities, etc..

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 (Jang, 1997). These algorithms are able to work with a great number of data (even noisy and incomplete), and they also allow predicting the behaviour of highly nonlinear systems, as is the case of Home Systems and in special communication systems. As we have in GENIO project, these properties allow us to analyse, 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 (Haykin, 1999). IAS will permit us to manage entire home status, dealing with high dimensionality information, through a new advanced interface, a virtual Agent. The objective of this virtual agent is to be the human-interface between the home user and the autonomous systems, inform the user about the status of the home, and the predicted situations found. Also, thanks to 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 behaviour 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.

Thanks to the rules-based intelligent framework, the proposed platform is a powerful tool for general autonomous home systems. The platform can be adapted easily to any kind of device, network condition or content, and the exercises can be designed by any person even if he or she does not have programming knowledge, thanks to the natural language rules programming. The main AI technologies uses in the decision autonomous system for GENIO are neural networks, Rule Engines and finally AIML

2.1 The Intelligent Support Interaction System (ISIS)

ISIS is the main element of the proposed application. 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…). The system has already been successfully used in different domains such as logistics decision making systems (Martínez 2011). 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 (Lin and Lee, 1996).

ISIS consists of a set of modules for pre-processing, integrating and extracting information and making decisions in a flexible way under uncertain contexts. The system is based on a state machine: each module generates events that are treated asynchronously inside the state machine.
The high level Autonomous System design can be 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. 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.

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 Manager: component that both informs the Autonomous System in real-time about the events that occur in the home network and allows to send configuration commands to connected home devices on the basis of the decisions taken by the Autonomous System

3 MULTIMODAL FUSION ENGINE

Currently, the system integrates data 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 such as classification of non-linear patterns and the generation of an attribute that represents the output of this classifier.
- **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. In the inference engine are inserted the text converted, the value of accuracy of this text and the AIML engine response from this text.
- **Presence recognition and number of people counting**: the number of persons found in the scene.
- **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 Surft**.**
- **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 one 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.

These attributes are generated at each time *t* and they can be complemented with new attributes generated by crisp rules. This information is mapped into the working memory and based on this information are fired the rules in the RETE inference engine.

4 CONCLUSIONS

A novel platform for creating smart interactive homes has been presented. The platform can be seen as an prototype in GENIO project. From Autonomous Computing point of view, the possibility of creating a Self-configuration system capable of detect uPNP devices dynamically. Using fuzzy rules inside infrence engine is possible a Self-optimization and Self-healing of the Home. Finally the integration and information fusion and the pattern recoginiton feature allows the Self-protection and self-healing fore diagnosis.

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