Proceedings of the Sixth IASTED International Conference
Visualization, Imaging, and Image Processing
August 28–30, 2006, Palma de Mallorca, Spain
ISBN Hardcopy: 0-88986-598-1 / CD: 0-88986-600-7

PERCEPTUAL AND INTELLIGENT DOMOTICS SYSTEM FOR DISABLED PEOPLE

Carolina Muñoz, Diana Arellano, Dr. Francisco J. Perales, Dr. Gabriel Fontanet
Unitat de Gràfics i Visió per Ordinador
Departament de Matemátiques i Informàtica
Universitat de les Illes Balears
07122 Palma de Mallorca, Spain
[carolina.munoz | diana.arellano | paco.perales | gfontanet]@uib.es

ABSTRACT
The advance of technology provides new mechanisms to facilitate domestic tasks, which can be used to give assistance to disabled people. The objective of this project is to create a virtual house with a domotics system useful for people with limitations, attended by a virtual butler. This will be achieved through the unification of artificial intelligence techniques, virtual reality, multimodal interfaces, and digital networks, with domotics devices which are available in the market.

KEY WORDS
Visual Information System, Human-Computer Interaction, Virtual Reality, Perceptual & Intelligent Interfaces, Visualization, Manipulation of Virtual Objects. Advanced Computer Vision tracking systems.

1. Introduction

This paper describes the work we are carrying out in the first phase of the project INEVAI^{3D} (Integration of Virtual Environments with Intelligent Agents 3D). This project is based on distributed object technology, digital networks, its quality of service (QoS), 3D virtual worlds, and user communities related with them, interactive television, rendering and advanced computer graphics, and finally the perceptual and domotics devices for user interfaces used in immersive environments.

The objective, from a conceptual point of view, is to define the mechanisms and software that guarantee the exchange of information among virtual worlds in a unified and transparent way for the user. To achieve this, tools for prototyping and flexible development of virtual environments are going to be used. Some of these tools are DIVE [1] and Lightning [2], which has been employed in past projects (HUMODAN2001-32202). At this moment we are developing a generic application of a virtual domotics house, simulating its devices, to integrate real and virtual users. All that, through multimodal interaction based on gestures, text to speech, and haptic systems, in a distributed environment adapted to several requirements which are explained further in section 2.4.

The main purpose of the application is to offer assistance to a disabled person. Multimodal interfaces, autonomous intelligent agents and virtual reality are considered to be used to complete the objective.

The graphic representation of a virtual assistant, in this case a virtual butler, looks for credibility and confidence on the user side.

In order to accomplish these tasks, it is required the creation of parameterized animations that allows to obtain different animations by adjusting values of some parameters. That is why low count and high quality polygonal meshes are being modelled, and groups of Feature Points (FPs), animated by Facial Animation Parameters (FAPs) defined in the MPEG-4 standard, are being specified. Instead of animate each FAP, we can animate groups of FAPs corresponding to sections of the body.

We are studying the possibility of having various autonomous agents working independently one from the other, where the virtual butler is just an interface between the user and the system. Another possibility is having various autonomous agents managed by the butler. In any case, the reactions of the agents have to be coherent with received perceptions, reason why an event and activities log has to be maintained by them, so they can provide help to the disabled person spontaneously.

2. Project Scheme

The general scheme of this work consists in creating a domotics house that goes a step forward the current systems with domotics, because it introduces a novel element as main part of the system: a virtual character (the Butler) who accomplishes all the tasks of a butler.

This character has an advanced geometry model and an intelligent behaviour.

Currently we are working in the simulation of a real house with domotics. The users are disabled people and their caretakers (family). The butler interacts with the house and with the users, receiving perceptions and taking actions. Figure 1 shows a general scheme of the system.

The functioning of the system can be seen as a cyclic process where the Butler System receives a vector of perceptions coming from the domotics sensors of the house, as well as requests and/or answers from the users, especially the disabled person. Using this vector, the butler can have knowledge about the house and the tasks that have to be done (agenda), then he evaluates the state of the house and the users. From this evaluation, a vector with a set of actions is obtained, and the butler is able to update the state of the house and the users. Actions can be divided in two groups: those that are accomplished by the house changing its state, and those accomplished on the user, which are essential for the communication between them and the butler.

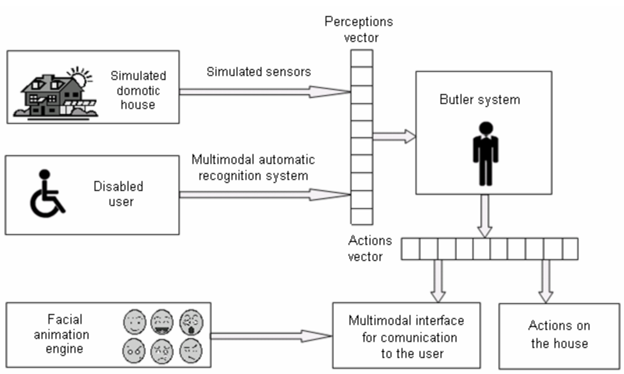

Figure 1: General Scheme

The communication is established by receiving messages from the system of Automatic Multimodal Recognition (AMR), and responding to them using a Multimodal Interface. With this interface the butler can interact with the user, because it implements a facial animation engine for the communication of expressions and emotions.

Once actions have been taken, the cycle starts all over again, maintaining a constant attention over the state of the house and the users.

2.1 Simulation of Intelligent Agents

Intelligent agents allow the interaction among persons and virtual elements (behavioural and geometrical models) in an immersive environment. Some wished characteristics of these agents we are working on are:

- Having mechanisms for the exchange of virtual elements (avatars, information, passive objects, etc.) among the virtual scenarios of the universe.
- Guarantee the quality of interaction between remote characters so implementation of requirements can be scalable, consistent, and failure assessment.
- Simulate the behaviour of avatars.

For those purposes, new person-machine communications systems, especially oriented to disabled people, are being investigated. These systems have to have the ability to solve functional limitations using advanced domotics systems and specific intelligent interfaces.

The idea is to get a quality level of virtual presence that resembles the natural presence, face to face. Facial animation, gestures and poses of the avatars are less than mandatory, so the final user can perceive this quality as a combination of technology, atmosphere, and psychology. Tools and software used are adapted to current standards, and their characteristics allow maximum portability and capability. Requirements specifications, process analysis and process design is being made using the Unified Modeling Language (UML) methodology [3], because it is useful for long term projects where lots of physical and logical resources are used.

Development of techniques for modelling of behaviour can be applied to other fields as robotics, animation, virtual reality, among others. The goal is to obtain a synthetic, autonomous, and adaptive creature: a humanoid. Normally these are equipped with sensors, actuators, and a model of behaviours. All these allow them to relate perceptions and resultant actions, facilitating their survival in an artificial world.

On the other hand, the concept of cooperative work is also ratifying the importance of these distributed and autonomous agents. That is the reason for the designing of an application that can work through different independent modules, which cooperate with each other, and gives as a result a multi-agent platform with collective behaviours.

For the modelling of this platform, two schemes are being studied: one centralized and other distributed. The distributed approach has the disadvantage of requiring that all agents have capabilities of auto-diagnosis. That is, they should be able to recognize a situation that does not correspond to the patterns of normal behaviour [4].

The centralized approach has to deal with incomplete models of the behaviour of agents. In this approach the agent has partial observations of the system because it can only trust in the information provided by sensors and/or agents [4].

In any case, communication between agents is a very important goal because inconsistencies may arise which eventually could lead to system failures, especially if it is distributed. In this approach each agent manages a module of the domotics house, so conflicts caused by taken decisions must be solved.

2.2 New multimodal interfaces for Intelligent Environments (Domotics)

An intelligent environment takes into consideration the entire set of sensors and applications that facilitates the interaction with the user in a natural way. We worked in the design and development of new multimodal interfaces so the user can react naturally. On this matter, we are working in a prototype where new multimodal interfaces (gestures, text, voice, and haptic devices) are integrated, and they are based in visual inputs (images).

2.3 Virtual Reality Models

A fundamental topic is the recognition and animation of a human face. Requirements of the system are:

- Achieve a realistic representation of the elements that are part of a visual environment.
- Simulate the behaviour of avatars and provide them with a realistic facial modelling and animation.
- Achieve an immersive environment for the virtual house.
- Analyze and synthesise avatars using non-invasive techniques.
- Obtain a portable product, highly compatible with other systems that can be adapted to current standards.

Our main task is to identify key animation points of the face automatically, and in some cases in real time. This feature points, or FPs, will be grouped in sections and then these sections will be animated. MPEG-4 is the standard used in the system [5].

Considering the fact that we are going to be working on a domotics application, a realistic facial modelling of the avatars is fundamental. Capturing the expression of users and an advanced facial representation of these agents who understand those expressions is a new frame of interaction in virtual environments.

Another important phase in the modelling of a face is the texture. In texturing we have to consider aspects which add realism to the model (movement of eyes, mouth, etc.). Every posture of the mouth must be allowed, because this is an element that contributes with the expression of emotions. Also it is the most important characteristic for the representation of the language.

The relevance in the study of the face and its animation, in the creation of a virtual humanoid resides in the different roles that a face expression has, as well as the emotion it can represent.

Facial expressions have been studied and currently six of them, corresponding to innate and universally considered emotions, are present in the MPEG-4 standard (happiness, sadness, anger, fear, rejection, and surprise). Once the detection of the facial expression is done, we can apply displacements over the points specified in a neutral face, and then transmit them on a polygonal mesh, expressions and emotions can be represented [5].

We have considered the use of Virtual Reality Modeling Language, VRML, with the purpose of achieve parameterized animations of the butler. The main idea is that from a model with defined control points, different and several animations can be obtained by changing values of some of these parameters. Using prototype programming in VRML we can group the FAPs defined in MPEG-4, and modify these groups instead of each point at a time [6].

Nevertheless, the lack of important characteristics in the modelling and animation using VRML, as well as the existence of these characteristics in other formats as X3D (considered successor of VRML), make this format a good candidate to be used. X3D is an Open Standard enabled-XML 3D file format, which allows the communication in real time of 3D data across applications and networks of applications. One of the main characteristics of X3D is that it is extensible and modular (uses a structure named Components), which makes programming an easy task. In order to have 3D models and animations of high quality, we are using the software Maya®, and then they could be exported to X3D format.

3. Definition of the Intelligent System

3.1 Butler System

There is an intelligent system in charge of supervising the state of the elements contained in the house, the state of the users and the tasks to be carried out in each time. The system is made of two basic parts as commented before:

- A system interface represented by a humanoid: the virtual butler. It interacts with the house and the users.
- The core of the application designed as a multi-agent system. Each agent manages a specific module of the application.

The cognitive state of these agents has clearly two differenced phases:

- The evaluation of the state of the environment from perceptions. With it the agent obtains knowledge about its state in its world.
- The reaction to adopt by the agent according with its situation.

The way to categorize the state in the world in terms of sensitive perceptions is being done through multi-evaluated object-attribute tables, also known as information systems. In these tables sets of concepts are modelled in terms of multi-evaluated characteristics.

Nowadays, these multi-evaluated tables are being studied very often as an analysis tool, because they bind behaviour of multi-evaluated variables (perceptions) with concepts or situations (world states).

Along these lines, multi-evaluated tables are used to select the reaction each agent has to have according with its situation [7].

To develop the system we designed one agent in charge of each module of the application. This application is divided in five modules; the last one is further divided in three sub modules. These are:

1. **Health care module**. Keep the medical history of the users. It manages doctor's prescriptions for user's treatments. It notifies the user to take the medication and its dose. It monitors the basic physiological parameters of the users, such as: temperature, heart rhythm, blood pressure and weight.
2. **Nourishing module.** It plans the daily menu of the users based on the suitable diet, food available and previous menus.
3. **Activities agenda and preferences module**. Users' personal agenda. It helps to plan the activities, hobbies preferences and makes the butler's schedule more flexible.
4. **Stock module.** It informs of all the goods available in the house at any time. It also informs of all the goods exhausted (food, medicine, domestic products). This module helps the butler to prepare a shopping list and send it over to the supermarket.
5. **Devices control module.** This module manages the house devices: sensors, electrical appliance, engines, etc. This module has 3 independent sub modules:
   - 5.1. **House accommodation module.** It manages the light level, temperature, blinds, windows, etc.
   - 5.2. **House security module.** It warns of electrical failure, water or gas leaks, fires, unexpected visitors, etc.
   - 5.3. **Electrical appliances management module.** It helps the butler to act on the electrical appliances.

Each agent receives a set of perceptions that helps evaluate the environment and provides a set of actions.

The perceptions can come from readings issued by the sensors laid out throughout the house, or by the users (as a result of a request or an answer during a conversation with the butler). The reading coming from the sensors in the house are taken at regular time intervals. The perceptions coming from the users could be issued at any time.

Both types of perceptions are grouped together in the perceptions vector which has fixed length. Each of the positions of the vector could come from the house or from the user and it refers to parameters used to evaluate the environment. The positions not needed for a specific action are null. The rest of the positions could have values related with multiple choice actions (for example: temperature change).

The figure 2 shows the perceptions vector received by the agent in charge of the accommodation module. The rest of the agents receive similar vectors with the parameters needed to manage their modules.

Agent in charge of the House accommodation module

	Pos.	Perception
Generals	1	Date
	2	Time
	3	Position, place in coordinates where the user stays in the current moment
Illumination	4	Interior light intensity
	5	Exterior light intensity
	6	The user feels comfortable/uncomfortable with the current illumination state (answer to a question from the butler)
	7	The user wants to change the illumination
	8	Switch on / Switch off the light
	9	More / Less
Temperature	10	Interior temperature
	11	Exterior temperature
	12	The user feels comfortable/uncomfortable with the current temperature state (answer to a question from the butler)
	13	The user wants to change the temperature
	14	Switch on / Switch off the air conditioner
	15	More / Less
Blinds	16	Current blinds opening stage.
	17	The user feels comfortable/uncomfortable with the current blinds state (answer to a question from the butler)
	18	The user wants to change the blinds state
	19	Open / Close
	20	More / Less

Windows	(house)	21	Current windows state (opened/closed)
	(user)	22	The user feels comfortable/uncomfortable with the current windows state (answer to a question from the butler)
		23	The user wants to change the windows state
		24	Open / Close
Doors	(house)	25	Current doors state (opened/closed)
	(user)	26	The user feels comfortable/uncomfortable with the current doors state (answer to a question from the butler)
		27	The user wants to change the doors state
		28	Open / Close

Figure 2: Perceptions Vector of an Agent

The perceptions in the vector are classified by the object they belong to, such as light level, temperature, blinds, etc. For example, when it comes to manage the light not only position 4 and 9 are taken into account but also general perception in positions 1, 2, and 3, and other parameters from other objects like the blind state (position 16).

These relationships among objects and perceptions, needed to make a decision regarding a parameter, are sketched in the Perception Roadmap for each of the agents and designated tasks. Figure 3 shows the roadmap for the agent in the previous example (accommodation module).

The agents evaluate the perceptions obtained and produce an actions vector based on the values in the vector, the knowledge of the house, activities and preferences of the users. The actions vectors for each agent work like the perceptions vectors. They have fixed length and each of the positions is an action to be carried out in the house or to communicate with the users. Likewise the position of the vectors could be null (not needed) or have a value (for multiple choices).

Both, perceptions vectors and actions vectors are always consistent and never contradictory. In the event of contradictory perceptions or actions among various agents that cause a conflict, this is to be solved before the vector creation.

3.2 Appling structured methodologies

UML is a graphic language to visualize, specify and document each part of the software development life cycle. It provides functionality to model conceptual objects, such as processes, system functionality, as well as specific objects, such as writing code in any language, data base modelling, and reusable software components.

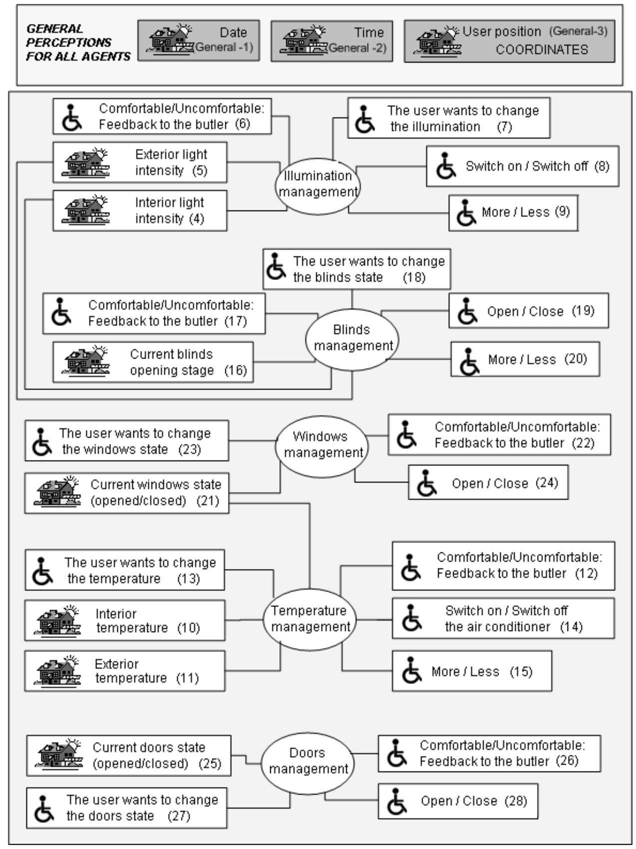

Figure 3: Roadmap of Perceptions

The use of conceptual modelling to develop domotics systems has several advantages. The process of development becomes more intuitive, since it uses primitives closer to the context problem. Furthermore, the adequate use of modelling languages can speed up the process of production because it makes possible to produce software to manage the system out of the model. In this way, development of the software is independent of the technology used to implement the system; it also allows an early validation of the requirements by means of prototypes or animated models. [8].

The use cases are not part of the design (how) but part of the analysis (what). Since they are part of the analysis they help to describe what the system has to do. The use cases describe what it has to do from a user view point, that is to say, describes the use of the system and how it has to interact with the user. The figure 4 shows one of the use cases carried out in the project (management of the system).

CU-2	**Gestión del sistema**		
Descripción	El sistema debe permitir que el administrador del sistema, usuarios reales y virtuales puedan realizar la gestión de la agenda del sistema, cada uno con unos privilegios concretos según se describe en el siguiente caso de uso.		
Precondiciones	El sistema está estable. Los actores se han validado correctamente.		
Postcondiciones en caso de éxito	El sistema está estable.		
Postcondiciones en caso de fracaso	El sistema está estable.		
Actores primarios secundarios	Usuarios reales y virtuales -		
Trigger	Acceder la gestión de la agenda del sistema.		
Secuencia normal	**Paso**	**Acción**	
	1	Aparece un menú con las opciones de menú disponbles dependiendo del actor.	
		1a	Gestión del módulo Salud
		1b	Gestión del módulo Dieta
		1c	Gestión del módulo Agenda de actividades y prerencias
		1d	Gestión del módulo Provisiones
		1e	Gestión del módulo Acomodación de la casa
		1f	Gestión del módulo Seguridad de la vivienda
		1g	Gestión del módulo Gestión de electrodomésticos
Frecuencia	Continuamente		
Importancia	Vital		
Súper casos de uso	La casa domótica		
Sub casos de uso	Gestión del módulo Salud Gestión del módulo Dieta Gestión del módulo Agenda de actividades y preferencias Gestión del módulo Provisiones Gestión del módulo Acomodación de la casa Gestión del módulo Seguridad de la vivienda Gestión del módulo Gestión de electrodomésticos		

Figure 4: UML Use Cases

4. Conclusion and Future Work

We have presented a global system which integrates intelligent systems, virtual reality systems and multimodal interfaces in a house with domotics devices with non invasive and low cost systems. This system is intended for elderly and disabled people, and is a main research topic of the UE in VI research projects, section AAL.

So far, the house is being virtually designed and the domotics devices are only simulated. The system focuses on the facial expression to communicate with the users. It means that the natural multimodal interaction is the final goal of the project, and this is a challenging task at the moment. Our main contributions are perceptual user interfaces and, in this particular paper, the UML methodology applied in multidisciplinary and high heterogeneous applications with several multi-agents systems dealing with high perception input vector.

In the near future, during the last year of the actual project we will plan to implement a prototype system in a real house with conventional domotics hardware and low cost cameras and input devices for elderly people. Furthermore, we will study ways of user emotions recognition as a new way of communication.

Acknowledgements

This work has been subsidized by the national project MCYT TIN2004-07926 of the Spanish Government. Also we would like to give many thanks to Dr. G Fiol & Dr. M. Miro by their supervision in IA definitions and support.

References

[1] C. Carlsson, O. Hagsand, DIVE: A Multi User Virtual Reality System. *Proceedings of IEEE VRAIS 93*, 1993, 394-400.

[2] A High Flexible Virtual Reality System. *Future Generation Computer Systems, Special Issue on Virtual Environments,* Vol 14, n. 3-4, 1998, 167-168.

[3] P. Stevens, Rob Pooley, *Using UML: Software Engineering with Objects and Component* (Addison-Wesley Longman)

[4] R. Micalizio, P. Torasso, G. Torta, The Architecture of the Diagnostic Agent in the ROBOCARE Project: the long report. *Technical Report RC-TR-1203-2*.Department of Informatics, Universitá di Torino, Torino, 2003.

[5] D. Thalmann, F. Vexo, MPEG-4 Character Animation. Virtual Reality Laboratory, Swiss Federal Institute of technology. 2003.

[6] C. Babski, D. Thalmann, A Seamless Shape For HANIM Compliant Bodies. Swiss Federal Institute of Technology. 1999.

[7] M. Mirr.-Juli., G. Fiol-Roig. An Algebra for the Treatment of Multivalued Information Systems. *Lecture Notes in Computer Science 2652,* 2003, 556-563.

[8] J. Muñoz, J. Fons, V. Pelechano, O. Pastor, Hacia el modelado conceptual de sistemas domóticos. Dpto. De Sistemas Informáticos y Computación, Universidad Politécnica de Valencia, Valencia.

[9] INEVAI3D: Integración de Escenarios Virtuales con Agentes Inteligentes 3D (TIN2004-07926).

[10] (BLINDED FOR ANONYMOUS CONFERENCE SUBMISSION): Non-verbal communication by means of head tracking, *Ibero-American Symposium on Computer Graphics – SIACG,* 2006, 1–4.

[11] V. Remiro, D. Gutiérrez, F. J. Serón, Sistema Automatizado de obtención de sincronización labial en español para personajes virtuales. *XIII Congreso Español de Informática Gráfica (CEIG'03)*, Universidad de la Coruña, 2003.

[12] J. Muñoz, J. Fons, V. Pelechano, O. Pastor, Desarrollo de Sistemas Domóticos Guiado por Modelos. Dpto. De Sistemas Informáticos y Computación, Universidad Politécnica de Valencia, Valencia.