Maggie: A Robotic Platform for Human-Robot Social Interaction

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Abstract—**Human-robot social interaction plays an important role in spreading the use of the robot in human daily life. Through effective social interaction, robots will be able to perform many tasks in the human society. These tasks may include, but not limited to, handling various house duties, providing medical care for elderly people, assisting people with motor or cognitive disabilities, educational entertainment (edutainment), personal assistance, giving directions at information points in public places, etc. These applications need to develop social robots that are able to behave with humans as partners if not peers. This paper presents Maggie, a robotic platform developed at RoboticsLab for research on human-robot social interaction. The different developed interaction modules are also described.**

Keywords—**Personal robots, social robots, human-robot interaction.**

I. Introduction

Most of the new robotic trends are in their nature designed to interact more with the human being, whether for the purpose of entertainment or transmission of information for the benefit of performing given tasks or services. This new reality entails the opening of a new field of work to deal with issues concerned with the human-robot social interaction. In recent years, this field has attracted considerable attention by the academic and the research communities. The human-robot social interaction is an interdisciplinary field, which integrates synergically robotics, artificial intelligence, cognitive science, psychology and other fields like linguistics and ergonomics, in order to improve the naturalness of human-robot interaction.

Many robotic platforms have been built with different design considerations and capabilities to study human-robot social interaction. Kismet is an expressive anthropomorphic robot head developed at MIT with perceptual and motor modalities tailored to natural human communication channels [1]. This robot has been designed to assist research into social interactions between robots and humans. Like Kismet, Sparky is social robot that uses both facial expression and movement to interact with humans [2]. RUBI is another anthropomorphic robot with a head and arms designed for research on real-time social interaction between robots and humans [3]. A Robota is a sophisticated educational toy robot designed to build human-robot social interactions with children with motor and cognitive disabilities [4]. In the Lino project, a robot head with a nice, cute appearance and emotional feedback can be configured in such a way that the human user enjoys the interaction and will more easily accept possible misunderstandings [5]. Maggie is a social robot developed at RoboticsLab and is described in the present paper (Figure 1).

Fig. 1 RoboticsLab's Maggie

Instead of using mechanical actuation, other social robot projects rely on computer graphics and animation techniques. Vikia, for example, has a 3D rendered face of a woman, which permits many degrees of freedom for generating expressions [6]. Valerie Roboceptionist [7], GRACE (Graduate Robot Attending a ConferencE) and George [8] are another examples for computer graphic-based social robots, which have expressive faces on panning platforms as well as large array of sensors. Valerie Roboceptionist has been developed to investigate long-term human-robot relationships. This robot is able to continually attract and engage many visitors on a daily basis over a long period [7].

All these projects pretend to develop robots that function more naturally and can be considered as partners for the human not just as mere tools. These robots need to interact with human (and perhaps with each other) through similar ways by which humans interact with each other. To achieve this goal, many novel interfaces have been currently developed in order to allow humans to move seamlessly between different modes of interaction, from visual to voice to touch, according to changes in context or user preference.

The paper describes a robotic platform (Figure 1) developed at RoboticsLab of Carlos III University of Madrid and is being currently used to investigate human-robot social interaction. The different design considerations and decisions around which Maggie was designed are presented. The paper also introduces the different modules developed for Maggie, the software tools used to integrate them, and the preliminary results we have obtained so far.

The remainder of the paper is structured as follows: in section 2, the concept of human-robot social interaction is discussed. Section 3 addresses the design considerations and decisions conducted through the development of Maggie. The hardware and software architecture are presented in section 4 and 5 respectively. Early evaluation of the platform is introduced in section 6. Finally conclusions and future work are summarized in section 7.

II. HUMAN-ROBOT SOCIAL INTERACTION

The human interaction and the robot's autonomy are key functions that can spread the use of the social robots in human daily life. Nowadays most of the available robots can interact only with their creators or with a small group of specially trained individuals. The long term goal of the most of robotic research is to develop a social robot that can interact with humans and participates in human society. In this case, the human roles during the interaction process will be evolved from being operator or supervisor to being a peer in form of bystander or teammate. Such type of robot must have effective and natural interfaces with high level of robot's autonomy by which the robot will be able to survive in different situations.

Human-robot interaction is defined as the study of humans, robots, and the ways they influence each other [9]. This interaction can be social if the robots are able to interact with human as partners if not peers. In this case, there is a need to provide humans and robots with models of each other. Sheridan argues that the ideal would be analogous to two people who know each other well and who can pick up subtle cues from one another (e.g., musician playing a duet) [10].

A social robot has attitudes or behaviours that take the interests, intentions or needs of the humans into account. Bartneck and Forlizzi define a social robot as "*an autonomous or semiautonomous robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact*" [11]. The term sociable robot has been coined by Breazeal [1] in order to distinguish an anthropomorphic style of human-robot interaction from insect-inspired interaction behaviors. In this context, sociable robots can be considered as a distinct subclass of social robots. She defines sociable robots as socially participative creatures with their own internal goals and motivations.

To develop a social robot or a sociable robot, many considerations must be taken into account. The required key features can be summarized in the following points:

A. Multimodality

Multimodality allows humans to move seamlessly between different modes of interaction, from visual to voice to touch, according to changes in context or user preference. A social robot must provide multimodal interfaces, which try to integrate speech, written text, body language, gestures, eye or lip movements and other forms of communication in order to better understand the human and to communicate more effectively and naturally [12].

B. Personality

Social robots used to exhibit distinctive personality. Personality is a form of conceptual model, for it channels behavior, beliefs, and intentions into a cohesive, consistent setoff behavior [13]. By deliberately providing a robot with a personality, it helps people to get good understanding of the robot's behavior and to set their expectations about the robot's capabilities. For example, the MIT's Kismet is given the personality of a child, one again making errors and misunderstandings appear natural [13].

C. Adaptivity

An important dimension of difference between animate and inanimate things is the ability to adapt [14]. A social robot must provide adaptive interaction to solve the problem of rigidity of traditional human-interaction techniques such as direct manipulation-based interfaces using artificial intelligence techniques. These techniques are used to make the interface adaptive by performing reasoning and learning, user modeling and plan recognition. The interaction process complexity may be also adapted according to user familiarity with robotics from very sophisticated low-level interaction (in case of robotics engineers and experts) to very intuitive and attractive natural interaction (novices and children).

D. Autonomy

Social robots must possess a high level of autonomy to survive in different situations. In some situations, a social robot should be able to act autonomously for example to volunteer information in order to correct user misconceptions or reject user's request, which may cause inconsistency or in order to preserve the system in case of error detection. Traditional robots are based in a master-slave paradigm, where the robot acts as a tool. However, for some applications of personal robots, this paradigm is not the best. Some applications, like robotic pets, require that the robot be perceived alive, instead of being perceived as a machine. An essential characteristic of live creatures, which should be replicated in some robots, is autonomy based on self motivation mechanisms. This kind of robots should be autonomous to choose by themselves their actions and goals, instead of obeying blindly all the orders of a human operator

E. Learning Ability

Learning is a crucial feature of a social robot. The robot must have the ability to learn from experience gathered from previous interaction sessions. Learning can help a social robot learn new tasks or automating repetitive ones. In human-robot interaction, Klingspor et al classified interaction agent learning into learning for communication (i.e., to learn how to communicate with the human user) and learning from communication (which includes, for example, learning by observation) [15]. In [16], Breazeal et al listed a number of core challenges in creating a robot that can learn from human guidance. These challenges include knowing what matters, knowing what action to try, knowing how to recognize success and correct failure and knowing how to explore.

F. Cooperativeness

A social robot can cooperate with other robots in order to achieve individual or common goals. These goals might or might not be known to the robot explicitly, depending on whether or not the cooperating robots are goal-based.

G.Reactivity

Reactivity is another important feature of a social robot. A reactive robot can perceive its environment and respond in a timely fashion to changes that occur in it. For example, a social robot must be able to realize the cases in which human's knowledge, desires, and intention conflicts with robot's knowledge, capabilities and functionalities.

H.Proactiveness

A social robot should also be proactive. It does not only react in response to external events but it also exhibits a goal-directed behavior and, where appropriate, are able to take initiative (i.e, perform unexpected actions) in order to correct the human, volunteer information, or suggest alternative courses of actions. The robot's behavior is determined by reasonable plans and goals.

III. DESIGN CONSIDERATIONS

The driving force behind the development of Maggie (Figure 1) at RoboticsLab was to have a human-friendly robotic platform for social interaction research. We wanted a platform that the human always enjoys interacting with and at the same time new features and functions can be added without great effort. These are some of the concepts around which Maggie was designed:

A. Attractiveness

Physical attractiveness can have a significant effect on how people are welling to interact with the robot. This fact has been taken into account in the developed platform. Maggie has an artistic design of a girl-like doll, which can easily attract humans to interact with. The robot has facial symmetry, large and widely spaced eyes and contrasting colors.

B. Expressiveness

Nonverbal emotional feedback by means of facial expressions and head/body motion plays a very important role in human interaction. Small motions of the head, the mouth, the eyes, or the eyebrows are often sufficient to indicate the state of the interaction process e.g. not interested, enjoying, understanding, etc. [5]. Maggie uses both facial expressions and body/arm/eyelids movements to interact with human.

C. Multimodality

As mentioned previously, a social robot must be able to naturally interact with human using multimodal interfaces. One of design consideration was to permit the integration of multimodal interaction using tactile, facial/body expressions and verbal communication.

D.Mobility

To support applications like handling various house duties, tour guiding and assisting elderly and disable people, the robot must have the ability to move. Mobility was one of design considerations for Maggie. A commercial mobile base has been used to provide this ability.

IV. HARDWARE ARCHITECTURE

As shown in Figure 2, Maggie has an artistic design of a 1.35 meters tall girl-like doll. Maggie's base is a Magellan Pro mobile robot produced by iRobot. This base is motorized by two differentially actuated wheels and a caster wheel on both sides. The base is also equipped with 12 bumpers, 12 infrared optical sensors and 12 ultrasound sensors. Above the base, a laser range finder (Sick LMS 200) has been added. The upper part of the robot incorporates the interaction modalities. On top of the platform, an anthropomorphic robot head with an attractive, well-groomed appearance has been added.

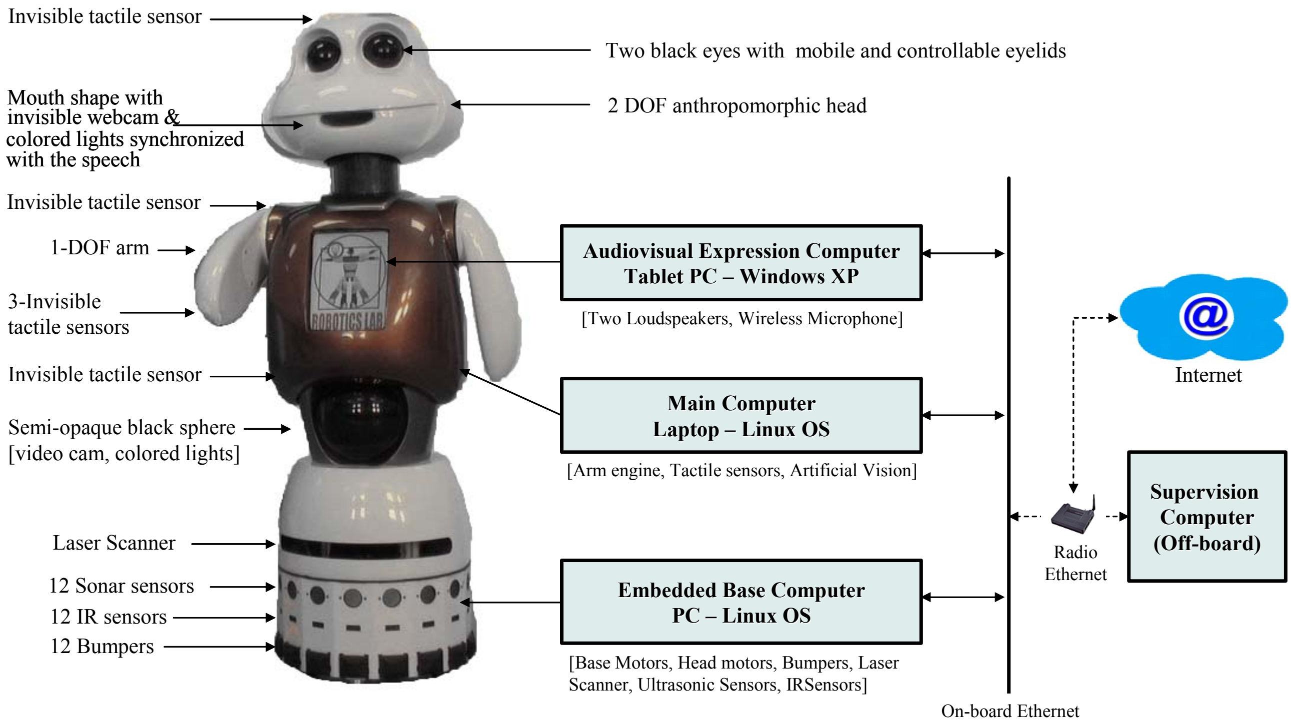

Fig. 2 Hardware Architecture

The head has two degrees of freedom (DOF) allowing for two basic movements: turning left/right and turning up/down. The head is equipped with two black eyes, mouth shape, invisible webcam and synchronized lights with the speech behind the mouth and two mobile and controllable eyelids. The position of the various parts is controlled by four servomotors. A microcontroller connected to robot base computer is used to control these four servos.

Two 1-DOF arms without end-effectors are built in the central part of the platform to provide nonverbal expressive feedback through body movement. The positions of these arms are controlled by two encoder-motors connected to a local electronic driver in the laptop. In the chest, Maggie incorporates a tablet PC to provide audiovisual feedback. A Bluetooth enabled wireless microphone and two speakers are connected to this tablet PC. A high quality speech engine enables the robot to speak in Spanish language. This tablet PC is also in charge to render images as a respond for tactile screen events.

Near the abdomen, a semi-opaque black sphere is added. This sphere is equipped with a color camera for people tracking and also integrates colored lights for visual expression.

They have been also incorporated several invisible capacitive sensors to work as tactile sensors in the upper part of the robot. There is one sensor on each shoulder, one on the top of the head, two on the chest, two close to the abdomen, two on the upper part of torso's back and three on each arm. Each sensor has an extensive active zone (≈5 cm^2) and is activated by human touching (hand, cheek, arm, etc.) close to the active zone.

Inside Maggie, there are three computers connected through an on-board Ethernet.

- The embedded base computer is a PC with Linux OS. This computer hosts the drivers of the wheels, ultrasonic sensors, IR sensors, bumpers, laser range finder, head and eyelids.
- Audiovisual Expression Computer is a Tablet PC with Windows XP. It provides audiovisual feedback through verbal communication and images rendering.
- Main Computer is laptop with Linux OS for artificial vision processing, control of robot skills.

As shown in Figure 2, Maggie is self-contained; all of its components (computer, tablet PC, sensors, cameras, microphone, speaker, etc.) are inside its body structure. However the robot includes a 802.11g link that allows the external connection with an off-board supervision computer and permits access to/from Internet.

V. Software Architecture

The development of the interaction modes is being carried out by multiple developers. For this purpose, common software architecture is proposed and implemented to support the developers and to facilitate any future integration between the developed modules. The following subsections describe the control architecture and the implementation schemes of Maggie.

A. Control Architecture

The proposed software architecture relies on hybrid control architecture called AD (Automatic-Deliberative) [17]. As shown in Figure 3, the AD architecture is a two level architecture based on skills.

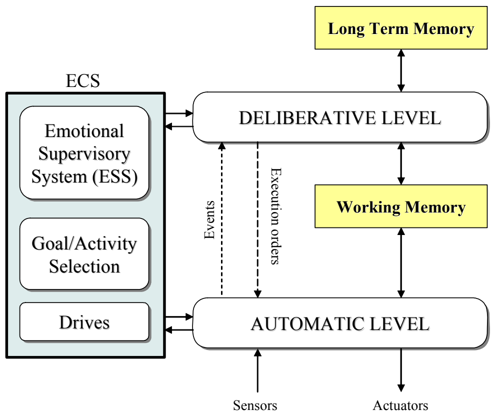

Fig. 3 Control Architecture

A skill represents the robot's ability to perform a particular task. They are all built-in robot action and perception capacities. In the deliberative level there are skills capable of carrying out high level tasks, while at the automatic level there are skills in charge of interacting with the environment. The path planner, the environment modeler and the task supervisor are some of the skills included in the deliberative level. The sensorimotor and the perceptive skills are found in the automatic level. The first are in charge of the robot motion. The second ones detect the events needed to produce the sequencer transitions which manage the task performed by the robot.

An emotional control system (ECS) [18] has been added to the AD architecture. Inside the ECS, there are three different modules: Drives, Activity Selection and Emotional Supervisory System (ESS). The Drives module is the one that controls the basic drives of the robot. The Activity Selection module on the other hand, determines goals and action tendencies of the robot. Finally, the ESS module generates the emotional state of the robot. The role of the ESS in the control architecture can be summarized in the following points [18]:

- To establish general goals such as wellbeing, which allow the architecture to develop behavior selection mechanisms and a global appraisal of the situation. This global evaluation can be used also as reinforcement in learning processes.
- Supervision: When the changes of the wellbeing signal (current or future) are greater than a certain threshold, one emotion will become active. These emotions include Happiness, Anger, Fear and Sadness. In this sense, the ESS will act as an alarm system where emotions are the alarm signals.

B. Primitive Servers Implementation Scheme

Primitive servers include the basic servers of sensors and actuators incorporated in the platform of Maggie such as base actuator, head actuator, laser sensor, tactile sensors, etc.

It was necessary to replace the stock software (Mobility) of the base to maximize the flexibility of this platform for ongoing research. Sensor and actuator servers are implemented based on *Player* framework [19]. Source code availability minimizes software constraints when developing behaviors for social interaction. *Player* provides the drivers needed to the sonar sensors, laser range finder, odometry and wheels engines of Magellan Pro. Above these drivers, a local set of sensor and actuator functions have been implemented in C language. These functions include the base movement and sensory data acquisitions. Each device (sensor/actuator) has an associated server accessible for any of Maggie's computer based on client-server paradigm.

C. Skill Process Implementation Scheme

Three generic components have been developed to facilitate skill implementation and access to working memory: a distributed memory manager, a distributed event manger and a skill template. The distributed memory manger controls the access to central shared memory implemented in form of a blackboard to provide the sensory information and execution parameters to/from the running skill processes. The distributed event manager handles the generated events from the running skill processes. To keep the state of the running servers synchronized, a publisher-subscriber design pattern has been used to implement the distributed memory manager and the event manger. These managers are continuously notifying any number of subscribers about changes to their states. Skill template encapsulates the main skill attributes and methods such as name, activate, block, etc. Developers can easily use this skill template to define a simple skill or to generate complex skill by combining simple ones.

D. Communication Scheme

To achieve the communication between all robot's sensors and actuators with the internal architecture, the client-server pattern is used. For each robot device (sensor or actuator) a C++ client class has been implemented. This class encapsulates a set of properties and member functions (methods), which can be reached through remote RPC (Remote Procedure Call protocol) calls for an instance of this class. This instance serves a proxy for a local server of the device.

VI. CURRENT INTERACTION SCENARIOS

This section introduces some preliminary developments for the designed platform.

A. Partner Dance

During the CampusParty^{TM} 2005 [20], Maggie has demonstrated its ability for closely cooperative dancing with humans (Figure 4). In this interaction scenario, Maggie and her partner stay together for the duration of the dance. During this duration, Maggie changes its movements as respond for events detected by tactile sensors as results of partner touching.

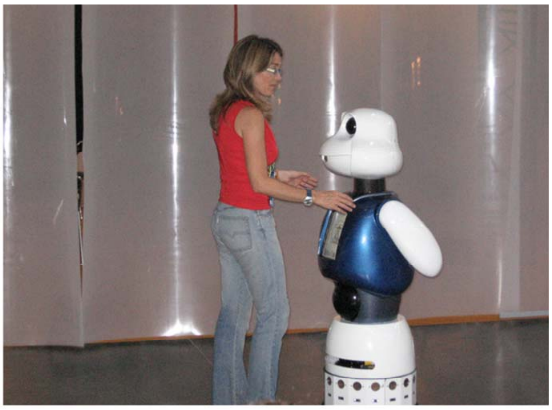

Fig. 4 Partner Dance at CampusParty^{TM} 2005

B. Verbal Interaction

A high quality speech engine enables the robot to recognize and speak in Spanish language. This engine contains a speech synthesizer, a speech recognizer and grammatical knowledge base. Dragon Naturally Speaking (DNS) Client SDK developed by Scansoft has been used as speech synthesizer and recognizer and VoiceXML serves to build the grammatical rules. DNS's synthesizer uses Windows Speech Application Programming Interfaces (SAPI) to convert text into speech (TTS). DNS' recognizer is a speaker-dependent tool, which needs a brief training process. The speech engine has been encapsulated in form of Automatic Speech Recognition and Speech Synthesis Skill.

VII. CONCLUSION AND FUTURE WORK

Most of social robot projects pretend to develop robots that function more naturally and can be considered as partners for the human not just as mere tools. Maggie represents an initial attempt to develop a robotic platform for social interaction research. This platform incorporates interaction multimodalities and has an attractive physical appearance social robot with which the human always enjoys interacting. The paper reported the different modules developed for Maggie, the software tools used to integrate them, and the preliminary results we have obtained so far.

Of interest, for future work, is the synchronization between the developed interaction modes and the implementation of the proposed emotion-based control.

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