Lucia: a Cognitive Robot in an Intelligent Environment

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I. Introduction

Lucia is a context-aware domestic robot developed by two partners of the RoboCare project[1]: PST (coordinated by Amedeo Cesta of ISTC-CNR) and SPQR (coordinated by Daniele Nardi of DIS-Uniroma1). The robot is aimed at demonstrating the feasibility of a "robotically rich" environment for supporting elderly people. Specifically, Lucia is part of a multi-agent system composed of sensors and software agents whose overall purpose is to: (1) predicting/preventing possibly hazardous behavior, (2) monitoring the adherence to behavioral constraints defined by a caregiver, and (3) providing basic services for user interaction.

II. Lucia the Robotic Mediator

The mobile robotic platform, called Lucia, was built to explore the added value of an "embodied" companion in an intelligent home. The robot's mobility also provides the basis for developing added-value services which require physical presence. The robot hardware has been built on top of a Pioneer platform, by adding additoinal sensors: a laser range finder, a stereo camera, an omni-directional camera; as well as computational resources: 2 laptops, one for sensor processing and navigation, one for human-robot interaction. In the following of these section we first describes the basic functionalities of the robots: specifically, navigation, path planning, mapping ang localization; then the component for human-robot interaction, i.e. speech recognition and speech synthesis.

Navigation. Navigation of the robot is based on two components that are integrated togheter: a topological path planning and a reactive obstacle avoidance module

Mapping and localization. In our project we assume that the robot acting in the domestic environment can map the environment before operating in it and that only a few changes in the environment occur during time (e.g., pieces of furniture can be moved). Therefore, our approach to mapoping and localization is divided in two phases: in the first one, the robot is guided in the environment in order to build a map of it (this is usually done only once when the robot should operate in a new environment); in the second phase, the robot localizes itself using the previously acquired map. Mapping and localization services make use of a laser range finder that provides for accurante range measures. Mapping is implemented with a scan matching approach (since domestic environments are usually small enough to not require more sophisticated SLAM approaches) and localization with a particle filter based approach.

Fig. 1. Lucia the Robotic Mediator.

Speech recognition and synthesis. Lucia is also endowed with verbal user interaction skills: speech recognition is achieved with the Sonic speech recognition system (University of Colorado)[2], while speech synthesis occurs through the Lucia talking head [1] developed at ISTC-CNR-Padua[3] (Lucia the robotic mediator takes her name from the talking head).

III. Environmental Sensor for People Tracking

A major objective of the RoboCare project was the integration of different intelligent components, that are deployed not only on board of a mobile robot, but also as "intelligent" sensors in the environment.

In particular, we have developed a People Localization and Tracking service[4] (PLT) based on a stereo vision sensor, which provides the means to locate the assisted person and other people in the environment. This environmental sensor was deployed at RoboCup 2006 in Bremen in the form of an "intelligent coat-hanger", demonstrating easy setup and general applicability of vision-based systems for in-door applications. The system is scalable as multiple cameras can be used to improve area coverage and precision. Multiple people tracking is obtained by an adaptive background modelling and background subtraction [2]; moreover, stereo vision allows for integrating plan-view and appearance based tracking for robust tracking in presence of multiple people. Furthermore, color-based person model keeps track of different people and distinguishes people from (moving) objects, e.g., the domestic robot. In addition, vision-based Posture Recognition (PR) can be cascaded to the PLT computation in order to provide further information on what the assisted person is doing.

[1] robocare.istc.cnr.it

[2] cslr.colorado.edu/beginweb/speech_recognition/sonic.html

[3] www.pd.istc.cnr.it/LUCIA/

[4] www.dis.uniroma1.it/∼iocchi/PLT

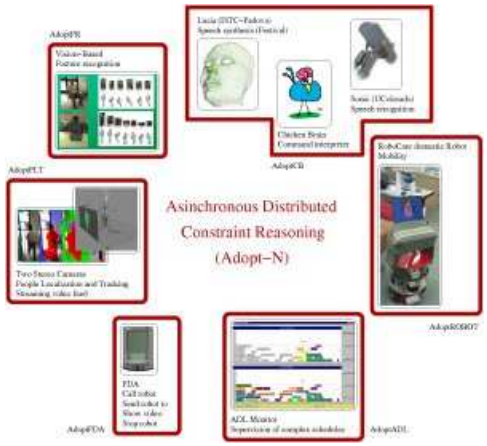

Fig. 2. The intelligent system developed for the ROBOCARE Domestic Environment (RDE) is devised as a multiplicity of hardware and software agents.

IV. MULTI-AGENT COORDINATION INFRASTRUCTURE

The ROBOCARE Domestic Environment (RDE) relies on the correct interleaving of the services provided by the various components: people tracking and posture recognition information must be merged in order to assess the activity that the assisted person may be carrying out; the ADL monitor must trigger suggestions and warnings through Lucia's user interface (speech synthesis); and the basic mobility services provided by the robot are to be summoned contextually (e.g., reach the assited person before issuing a warning). Therefore a fundamental issue related to the RDE is how the various services provided by the smart home work together, leading to a Multi-Agent Coordination (MAC) problem. One common approach to solve MAC problems is distributed constraint reasoning, whereby the MAC problem is cast as a distributed constraint satisfaction/optimization problem (DCOP).

More specifically, the overall functional cohesive of the RDE is provided by ADOPT-N [3], an asynchronous distributed constraint optimization algorithm which extends ADOPT to hanlde n-ary constraints and constraint posting.

The mechanism by which the overall behavior of the smart home is specified consists in iterative resolutions of the constraint optimization problem, where agents share information on their own choices in order to converge on a variable assignment that optimizes the global cost function that expresses the desired system behavior.

V. MONITORING ACTIVITIES OF DAILY LIVING

The goal we wish to achieve in this application is to develop an intelligent supervision agent for an elderly person to be deployed in his or her home, which is capable of interacting with the assisted person through the embodied agent Lucia. To this end, we employ CSP-based scheduling technology for schedule representation, manipulation and monitoring. The goal of this scheduling agent is to assess the adherence of the daily activities of an elderly person to a set of predefined behavioral constraints. The constraints represent behavioral requirements concerning habits such as diet, medicine taking, physical or recreational activities. These requirements are specified by a caregiver, who is responsible for specifying some aspects of the elderly person's daily routine which must be monitored. The scheduler agent is achieved through the instantiation of a general scheduling framework named T-REX, through which we obtain a complete "caregiver console" which allows the caregiver to specify, monitor, and diagnose the behavioral constraints to which an assisted person should comply.

Thanks to the information perceived by the ADL monitor on the current activity of the assisted person, T-REX provides basic services for monitoring the daily schedule of an assisted elderly person in his or her apartment [4]. By means of an internal representation of the assisted person's *nominal schedule*, this module is capable of recognizing inconsistencies in the actual execution of the activities as they are performed by the assisted person. These inconsistencies trigger (through the multi-agent coordination schema) actions in the environment, such as warnings and suggestions (which are verbalized by the robotic mediator).

VI. CONCLUSION

The system, which is deployed in a mock-up domestic environment at the RoboCare laboratory in Rome, was partially recreated in the RoboCup@Home domestic environment during the RoboCup 2006 competition in Bremen[5]. During the competition Lucia showed its basic capabilities of safe navigation and human following and it entertained people interacting in a natural way, playing music on request or making phone calls via Internet. To demonstrate the capabilities of our system, we have considered the following example scenario: an asssited peron is monitored through the environment, when s/he is sitting at the kitchen table, the system supposes that it is breakfast time; Lucia goes to her/him asking if s/he is having breakfast and on a positive answer it remembers her/him to take the proper pill before eating. The schedule of the activities keeps track of the answer. Later, after some minutes, the person falls down on the floor. The posture recognition service detects the abnormal situation and an alarm is set. Lucia goes to the position of the person and asks if everything is ok. When no answer is obtained, Lucia calls an emergency number (i.e., the phone number of a relative or a caregiver). This scenario has been the subject of the final trial in the RoboCup@Home 2006 competition, where the task was successfully fulfilled, allowing for the RoboCare team to place 3rd in the overall competition.

REFERENCES

[1] P. Cosi, A. Fusaro, and G. Tisato, "LUCIA a New Italian Talking-Head Based on a Modified Cohen-Massaros Labial Coarticulation Model," in *Proceedings of Eurospeech 2003, Geneva, Switzerland*, 2003.

[2] S. Bahadori, L. Iocchi, G. R. Leone, D. Nardi, and L. Scozzafava, "Real-time people localization and tracking through fixed stereo vision," in *Proc. of Industrial and Engineering Applications of Artificial Intelligence and Expert Systems (IEA/AIE)*, 2005.

[3] F. Pecora, P. Modi, and P. Scerri, "Reasoning About and Dynamically Posting n-ary Constraints in ADOPT," in *Proceedings of 7th Int. Workshop on Distributed Constraint Reasoning, at AAMAS'06*, 2006.

[4] S. Bahadori, A. Cesta, L. Iocchi, G. Leone, D. Nardi, F. Pecora, R. Rasconi, and L. Scozzafava, "Towards Ambient Intelligence for the Domestic Care of the Elderly," in *Ambient Intelligence: A Novel Paradigm*, P. Remagnino, G. Foresti, and T. Ellis, Eds. Springer, 2004.

[5] www.ai.rug.nl/robocupathome/