The RoboCare Project
Cognitive Systems for the Care of the Elderly

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The RoboCare project focuses on the development of distributed systems in which software and robotic agents contribute to the common goal of generating active services in environments in which humans may need assistance and guidance, such as health care facilities.

Thanks to recent technological advances, there are now many potential applications for robotics including multi-agent systems. The aim of the RoboCare Project[1] is to study issues and challenges involved in the design of systems for the care of the elderly that adopt both fixed and mobile heterogeneous agents. These agents can be robots, intelligent sensors or possibly even humans. RoboCare shares some aspects with other projects for the assistance of elderly people, such as Pearle, the mobile robotic assistant for the elderly [9] and the Assisted Cognition Project [3], but addresses the particular goal of creating a heterogeneous multi-agent environment for generating user services.

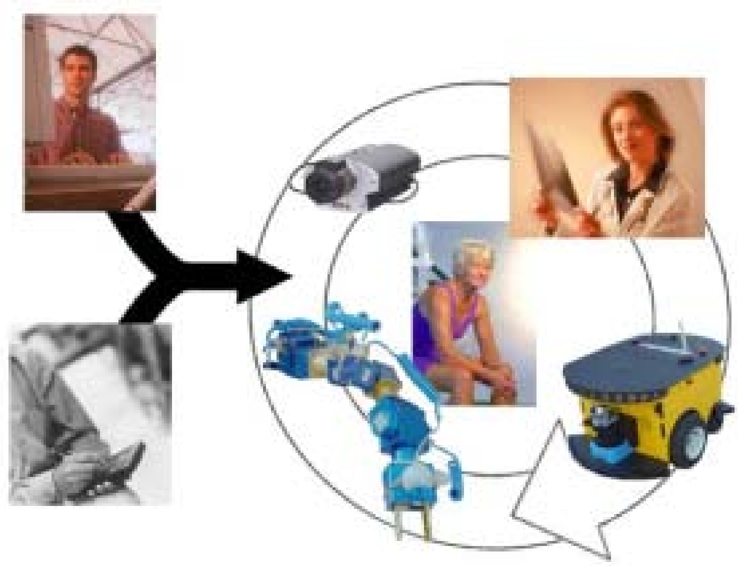

Figure 1. Overall system structure: operator level system control and distributed environment.

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The ambitious goal of providing support for the elderly with the use of intelligent systems is not merely aimed at automating certain tasks. The philosophy underlying this application of cognitive technology is to enhance the quality of care for the elderly, by employing an infrastructure of expert systems which cooperate in order to provide services. This requires, on one hand, the design of intelligent agents endowed with advanced learning capabilities, capable of complex symbolic reasoning tasks and high levels of interaction with humans. But in a world in which pervasive computing is the name of the game, the integration of intelligent capabilities in aiding tools is no longer enough. Tomorrow's health-care institution will be equipped with intelligent systems which are capable of interacting with humans; RoboCare addresses the issue of enabling these systems to work together.

The implementation of collaborative behaviors for intelligent systems is motivated by the necessity of providing constant care and support for people with disabilities. When it comes to caring for the elderly, intelligent systems aim at supporting them in all aspects of daily life, providing decision making, reminding and warning functionality. Such complex tasks necessarily involve teams of agents (be they robots, intelligent sensors or physicians). For instance, Alzheimer patients would benefit from a system which reminds them about certain sequences of actions to be performed (such as switching off the gas after turning off the stove and wearing glasses before wandering out of the bedroom). In its simplest form, such a system would be made up of a series of agents, like a gas monitor and a mobile robot capable of advising the assisted person. All the actors in the system would clearly be capable of carrying out individual reasoning, but would also need to collectively reason about the situations which can occur.

Creating such tightly coupled intelligent systems presents an important challenge for the AI and robotics communities. On one hand, researchers have been successful in creating teams of robots which are capable of cooperating in tasks such as foraging, unknown environment exploration and simplified forms of soccer playing. On the other hand, the AI community has advanced in the study of planning and scheduling, and has developed mature technology for automated problem solving. The realization of a complete system for the aid of the elderly to be employed in a complex, real world environment such as a health-care institution or a home requires a tight integration of these technologies. The system must provide more than a loose coordination between components, in other words, it must enable a synergetic cooperation among the agents. Thus, a supervision framework which maintains a global view of the system and provides control functionalities for human operators must be provided. On the other hand, in order to ensure robustness and reliability, the autonomous agents must be endowed with well-defined cooperative behaviors.

However, the task of providing monitoring support is but a small aspect of the functionalities that such a system must implement. Caring for elderly people is often all about routine, such as scheduling walks and daily social events. As a consequence, the system should be capable of planning and scheduling for such needs as well as interpreting them.

A great deal of resources are being invested in the investigation of user acceptance of the technology, in terms of the psychological impact of robotic agents providing services for the care of the elderly. Since the level of social interaction which can be obtained between robotic agents and human beings is related to familiarity, we are also investigating the use of Aibo™ robots for monitoring tasks.

RoboCare is made possible by the cooperation of a number of participating units, which include leading Italian universities and various departments of the National Research Council (CNR). Thanks to the numerous units involved, the RoboCare project can count on experts from many fields of cognitive science and technology. The rest of this article is dedicated to detailing some of the work which is being carried out by our research units, which includes communication, knowledge representation, human-machine interaction, learning and collective and individual symbolic reasoning.

The Centralized Deductive Infrastructure

The primary aim of RoboCare is to develop a distributed system in which software, robotic and human agents cooperate in order to generate services for human assistance. Our research focuses mainly on two scenarios, the first being a domestic environment in which domotic technology, robotic components and care-givers contribute to the common goal of assisting an elderly person in his or her daily life. The second scenario is a health-care institution, an environment in which these actors cooperate in order to enact a predefined workflow of activities for the care of the elderly. Both these settings provide a rich set of challenges for the problem solving technology which is the scope of our team's research, motivating also the development of new solving tools which address the particular issues connected to improving the level of autonomy for older adults.

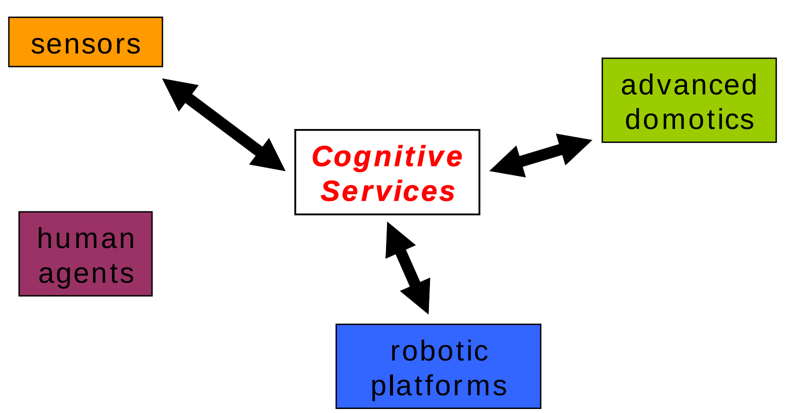

Figure 2. The Active Supervision Framework enforces the synergetic behavior of the systems components.

With respect to the two scenarios mentioned above, one aspect of our research is to develop a centralized infrastructure, called *Active Supervision Framework* [8], which is capable of supervising and providing proactive support for elderly people in their daily routine. It does so by providing *cognitive services* which regulate the behavior of the system's components by enforcing a synergetic cooperation among the tasks they carry out. In particular, the domestic scenario calls for capabilities that extend beyond the technological boundary of current domotic technology. Actively monitoring an elderly person at home implies that the system must be able to predict potentially hazardous or unwanted behavior: for instance, forgetting to wear glasses before wandering around the house, or dangerously leaving a cumbersome obstacle near the staircase might be prevented by the cooperative behaviors of environmental cameras, which constantly survey the environment, a deductive procedure, which recognizes the dangerous situation, and mobile robots, which would reach the assisted person in order to ensure his or her safety. On the other hand, the big workflow problems which are generated in the context of a health-care institution (in which each guest has particular medication, diet, therapeutic requirements) require problem solving tools which are capable of compiling an efficient schedule of tasks to be carried out. The objective of our research is to develop an Active Supervision Framework for these two scenarios, which would be in charge of centrally controlling and monitoring the situation, adapting to all contingencies thanks to its powerful reasoning capabilities.

The diverse needs of older adults, both in the domestic and in the health-care institution context, require for deductive systems which are capable of reasoning both in terms of causal constraints (for the predicting functionality) and in terms of time and resource constraints (for workflow management). The scenarios we have mentioned require both types of reasoning, but in different proportions.

In the domestic environment, we envisage a proactive support for the elderly person, thanks to which he or she can count on a set of tools (robotic assistants, intelligent sensors and so on) which provide a cognitive (as well as physical) support. These supporting functionalities range from “intelligent” reminding to automation of routine tasks. Nevertheless, they all require an interpretative step, in which the framework gathers information on the assisted person and the environment in order to understand the needs of the person and to devise a set of measures which satisfy these needs.

In the domain of a health-care institution, the capabilities of the problem solving technology we dispose of are useful for allocating resources (humans, robots and sensors alike) to tasks and finding efficient instantiations of these tasks in time which satisfy a set of predefined constraints. Current technology is capable of dealing with very big problems, in which there are hundreds of tasks to be allocated with very stringent constraints.

With respect to both scenarios, we are currently investigating the use and integration of an array of technological components, such as fixed and mobile heterogeneous robotic components, sensors, PDAs and various types of household and medical equipment. This functional integration is made possible by the centralized nature of the deductive framework, which constantly monitors the evolution of the assisted and the environment. Most importantly, though, the Active Supervision Framework interacts with human operators. These actors can be, for instance, a physician, who updates the medication requirements for the assisted, or the elderly person himself, who might want to summon a robot for a particular request, like bringing water. Indeed, the Active Supervision Framework enforces a synergy among the various components of the future home or health-care institution which results in a proactive support for the elderly.

Cognitive Robotics

Today, life expectancy is becoming longer and the problem of maintaining independence and active participation in society in later life is receiving growing attention. Several projects around the world focus on the care of the elderly. More in particular, the creation of robots for the care of the elderly is addressed by the Morpha [5] and Nursebot [7] Projects. In a similar context, the RoboCare Project studies how advanced technology and specifically cognitive robotics can be used in helping old or disabled people, with the additional idea of integrating many technological components and humans to form one integrated system. Thus, while previous projects where centered on the development of a single personal robot-assistant, our project is specifically focused on a multi-agent system (a multi-robot environment plus fixed devices).

In its explorative phase, the aim of the project is to establish what can be the concrete assistance that the system can provide. We focus on six achievable goals:

1. reminder (i.e. “it is time for your pill”);
2. entertainment (i.e. “let’s have a chess match” or “read me the news”);
3. transport (i.e. “get me a coffee from the coffee-machine”);

4. examination (i.e. “check the stove”);
5. search (i.e. “look for Mr. Smith”);
6. escort (i.e. “go for a walk with Mrs. Brown”).

To this end, several typical robotic issues must be addressed, such as image analysis, sensor integration, safe navigation, human body detection, people tracking, human-robot interaction and robot-coordination.

Figure 3. Some of the robotic platforms employed in the RoboCare Project.

The cognitive robotic system, which we have implemented on several robotic platforms, is based on a hybrid layered architecture [10], with two levels: the Operative Level, in which the information is handled numerically, and the Deliberative Level, which relies on a symbolic representation of the robot's knowledge. In particular, at the Deliberative Level, the environment is described by a knowledge base containing both axioms and static facts (i.e. background knowledge) provided by the designer, as well as dynamic facts (i.e. symbolic information) corresponding to the data acquired through the robot's sensor during its mission.

Computer Vision
All the robotic units have one or more cameras mounted on them. Analyzing the images that come from them to extract the information about the surrounding world is vital for every task assigned to the robot. Several techniques like color segmentation, edge detection, motion tracking and real-time algorithms are used to accomplish this task.

Human Body Detection
Human body detection is one of the most sophisticated and challenging aspects of object detection. There are two types of issues in human body detection which have to be considered: on one hand distinguishing the human body from other objects in an image frame or video stream and on the other hand presence detection and motion tracking.

Localization
Localization is the task of evaluating the robot’s position in the environment, given a sensor history and the knowledge of a map. In the RoboCare environment several efficient and reliable solutions can be studied and implemented, like the ones proposed in the projects mentioned above [3, 4]. Moreover, in some cases, the ability of structuring the environment allows for devising some external systems which automatically measure the precision of a localizing robot, granting the possibility to perform accurate experiments and evaluations of the developed localization algorithms.

Domain Representation, Plan Generation and Execution

Our planning and reasoning framework relies on an epistemic representation of the world, which explicitly takes into account the robot's knowledge, rather than the true world status. The domain description includes the specification of the basic actions the robot can perform, which are defined in terms of preconditions (conditions that must be verified for an action to be executed) and effects (conditions that are verified after the execution of the action). We have defined a logic formalism and developed a plan generator that generates plans for reaching specific goals. Such plans are executed by activating the basic actions according to the status of the environment.

Psychological aspects in RoboCare: Laypeople’s view of domestic robots

Given the technological advances in intelligent systems and robotics, the possibility of having robotic devices inside one’s house appears to be more and more realistic in the next future. Nonetheless, laypeople’s representations of robots are still deeply associated to science fiction. The general representation which comes from books, movies and similar sources is undoubtedly ambivalent, resulting both in a friendly idea of robots as helping/supporting assistants to human beings and in a more frightening image of potential competitors or, even worse, overwhelming agents. However, the possibility of successfully introducing this new technology inside a domestic setting has to deal with a stronger understanding of expectancies and affective response of the users. This issue is even more important for elderly people, who are less familiar with IT. Moreover, they often mistrust, and sometimes are afraid of technology.

The aim of our research is to explore laypeople’s attitudes towards robotic services at home, and their preferences with respect to the shape of robots and interaction modality. We focus our attention on older people’s view towards the possibility of obtaining help from a robot in different tasks and the attribution of anthropomorphic features and tendencies [2] to it.

A sample of adult and elderly Italian people was surveyed through a questionnaire including both open ended and multiple choice answers. The questionnaire, partially borrowed from [4], is aimed at collecting information about helping needs at home, the use of technology, different dimensions of the representation of domestic robotic devices, and environmental features of the house.

Preliminary results show that generational differences are relatively irrelevant compared to socio-cultural and individual differences, including familiarity with technology. Older people however seem more concerned about an harmonious integration of robots in the social and physical environment of the home, emphasizing requirements such as “the robot must behave in such a way to not frighten the pets” or “it should not be a cumbersome obstacle, especially for people with visual or motor impairment”. As for the evaluation of the different tasks robots can perform inside the house, the largest amount of respondents appeared to perform wishful thinking, rather than being fully aware of the actual possibilities afforded by modern technology. It is noteworthy, however, that people mistrust or negatively evaluate tasks which imply decision-making and reduce user’s control on the environment. The physical attributes of the robot are depicted by respondents in an array of different ways. They agree only on its size: it should be small enough to be able to move everywhere inside the house. As for other physical attributes, answers about the material it should be made of are quite diverse (metal, plastic substances, rubber, humanlike); answers about its color range from pure metal to more human or vivid colors. Answers about its appearance again range from a minimum to a maximum degree of anthropomorphism (from “cylinder or parallelepiped, with no reference to human beings” to “it should be like a child, so that I will not see it as a stranger”). People reported divergent preferences as to the communication modality towards the robot and to receive information from the robot: they definitely prefer to use direct speech to interact with the robot (usually through short and simple words “like when speaking to a foreigner” or “with my dog”). With respect to how the robot should communicate, preferences are far less shared: people indicate the use of both acoustic and visual modalities.

The representation of the robot as a machine is largely agreed upon: nevertheless, respondents often described the eventual interaction with the robot by referring to social dynamics which are typical of human beings [6] as shown in comments such as “I would like it to mind its own business” or “I would speak to it as if it were a person, I would never give it an order like a dictator would”.

Conclusions

The development of effective technology for aiding elderly persons is an important challenge for the scientific community. It is becoming clear that AI problem solving techniques are part of the answer to the diverse issues related to ensuring an independent lifestyle for elderly people. In particular, the delivery of cognitive support by humans, robots and other technological devices is made possible by their inclusion in a centralized supervision framework which enables them to cooperatively contribute to the well-being of the persons to be assisted.

Among the many issues which are being studied is the acceptability of the technology. In fact, the development of an Active Supervision Framework as described above requires singling out the aspects of their lifestyle the users are willing to receive cognitive support in. This is a rather delicate issue, which requires a great deal of study and testing. Nonetheless, the issue of user acceptance is a fundamental one, in that a successful deployment of such technology will ultimately determine the applicability of current AI technology in supporting independent lifestyles for older adults.

The psychological studies under way are showing the complexity of the representations that laypeople in general, and especially elderly people, have of the physical, functional, behavioral and psychological characteristics of modern domestic robots, mostly derived from science fiction. These results will be taken into account in order to implement domestic robotic devices which can be more acceptable and adequate to satisfy not only the functional but also the psychological needs of customers.

We have presented the contribution of three research units of the RoboCare Project. By the end of this first year we will have a virtual demo of all the functionalities of the entire system, a complete experimental environment with two robots on the run, a demonstration of system capabilities and an evaluation of the results.

Acknowledgements

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