The RoboCare Project: Intelligent Systems for Elder Care

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Abstract

This brief article describes the highlights of the first two years of activities of RoboCare, an Italian research project aimed at developing intelligent software and robotic agents which can enhance the quality of life of elderly people at home or in a health-care institution. Rather than describing in detail the specific techniques we have developed, for which we point the interested reader to related work, our aim is to focus on some specific issues which our results have given rise to in the context of AI applications in elder care.

Introduction

This brief article describes the highlights of the first two years of activities of RoboCare, an Italian research project aimed at developing and studying the applicability of AI techniques for the care of the elderly. 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. In particular, we are pursuing the idea of developing support technology which can play a role in allowing vulnerable elderly people to lead an independent lifestyle in their own homes.

Recent statistics show how the population in Europe is slowly getting older. Increasing attention has therefore been given to the issue of "independence" and "aging at home", and support tools have been developed to ensure that elderly and partially impaired people can continue to enjoy an independent lifestyle. For this reason, research in RoboCare focuses on two scenarios, namely the RoboCare Domestic Environment (RDE) and the Health-Care Institution (HCI) scenario.

The RDE is an experimental setup which recreates a three-room flat. It is intended as a testbed environment in which to test the ability of the domotic technology built by the various research units, such as non-intrusive monitoring, domestic robots and environmental supervision.

On the other hand, the HCI scenario focuses on analyzing the possible deployment of an array of software and robotic components to facilitate complex workflows which require the coordination of human personnel and artificial agents in the context of a large institution. The role of an intelligent supervisor in this scenario is to synthesize and monitor the current execution of complex plans which involve the use of heavy-duty robotic platforms, capable of moving in large spaces, walking or transporting people, as well as performing environmental supervisory tasks. Various research units operate in this scenario by means of simulations, while others contribute by developing large robots which are more suitable for this environment.

RoboCare mainly focuses on the following four fieds of research: *robotic platforms*, *sensory systems*, *activity supervision in complex environments*, and *human-technology interaction*. We dedicate the following paragraphs to (1) a brief overview of the main results obtained in these first two years of activities in these four fields of research, and (2) a discussion on some lessons learned and an outlook to future developments which have emerged in the process of our attempts to customize AI technology for elder care.

Main Research Tracks

The main objective of RoboCare is to investigate the integration of robotic, sensory and automated reasoning components into the domestic and health-care institution scenarios. In this sense, the target application does not consist primarily in the development of the single components, rather in a single service-providing support infrastructure for elder care in a domestic or health-care institution context. Also, RoboCare does not focus primarily on robotics. Nonetheless, robotics has an important role because of its contribution to two demos aimed at showcasing our results at the end of the third year (RDE and institution environments). This objective is being pursued in a bottom-up fashion: the first year of activities has focused on singling out and developing the basic functionalities of the single components, such as the people localization and tracking sensory system, the basic robotic capabilities and the symbolic reasoning modules for the supervisory agents. Starting from these basic functionalities, the second year of the project has focused on integration in the two scenarios. Research in RoboCare deals with two main aspects related to technology for elderly care: on one hand, the development of the enabling domotic components for deployment in the target scenarios (such as intelligent sensors and robotic platforms), and on the other the development of the service-providing software infrastructure which makes use of the functionalities provided by

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the domotic components (such as activity supervision and diagnostics). Clearly, the implementation of this technology within the specific applicative context of ROBOCARE has lead to extensive investigation in the areas of human-computer and human-robot interaction, with two distinct research units dealing exclusively with these topics. More in particular, the principal research areas and results are summarized below, along with references which the interested reader can follow for more in-depth analyses on specific topics.

Robotic platforms. One of the most fundamental abilities a mobile robot must have in order to carry out even the simplest task in the environment is that of being capable of deducing its current position in the environment. This problem is known in the literature as *localization*. A large body of research has been dedicated to this problem, as detailed in (Grisetti, Stachniss, & Burgard 2005; Mastrogiovanni, Sgorbissa, & Zaccaria 2005), in which various approaches are studied, such as SLAM (simultaneous localization and mapping) through laser-range finders and Kalman filters.

Along with localization, another important issue which is being addressed is *safe navigation*, which consists in the ability of a mobile robot (such as robotic wheelchairs) to plan trajectories which involve smooth curves and maximize the distance from obstacles (Farinelli, Iocchi, & Nardi 2003; Scalzo & Veruggio 2005).

Mobile robots have also been equipped with basic *people following* capabilities, as reported in (Gigliotta *et al.* 2005), as well as some *manipulatory* skills by means of a robotic arm which can be programmed by example (Aleotti, Caselli, & Maccherozzi 2005).

Overall, the robotic functionalities which have been implemented during the first year thus allow robust and safe robot navigation in domestic and health-care institution environments, and basically consist in the “go-to-position”, “follow-person” and “follow-robot” behaviors. These functionalities have been integrated on both small robots for domestic use (e.g., ActiveMedia Pioneer equipped with touch-screen and tray) and on a heavy-duty robot named Staffetta developed at the University of Genoa, which is used in the larger institution scenario.

Sensory systems. Sensors are a particularly important part of the development process, as they provide a bridge between the physical world of the target scenario and the high level reasoning capabilities of the supervision agents, which rely on a symbolic representation of the real world. Sensors must be intelligent in that they must interpret raw data and build from it this symbolic layer. Moreover, this process is subject to strong real-time constraints.

One of the first basic services to have been developed consists in *people/robot localization and tracking*. This sensor consists in a stereo-camera and a series of image processing algorithms aimed at singling out and tracking multiple persons (or robots) in 3D space (Bahadori *et al.* 2005). Along with these tracking capabilities, which provide *gesture/posture recognition* sensors (Dindo, Chella, & Infantino 2005) have been developed with the aim of providing a visual means of communication between the intelligent environment and an assisted elderly person. Thus, the vision-based environmental sensors implement functionalities such as “where-is-person/robot” queries, as well as basic human-robot/computer/intelligent environment communication by means of body posture and hand movement recognition.

Activity supervision in complex environments. Whether in the domestic care or health care institution scenario, one of the most important aspects of the prototypes we are trying to achieve is the ability to reconstruct the state of the environment and of the assisted person(s) through the symbolic representations provided by the sensors. To this end, our research has focused on three issues.

First, work by the University of Turin (Micalizio, Torasso, & Torta 2004) has developed a platform for *multi-agent system diagnostics* in the context of a health-care institution scenario. Given a complex schedule of activities to be performed by a multitude of robotic agents in a large institution, and given the fact that most of the agents' tasks are highly interdependent, the ability to diagnose the state of the system is fundamental for correct plan execution and contingency reaction. This task is carried out by the diagnostics module, which is capable of integrating the (partial) information on the state of the agents and of the tasks they are carrying out in order to quickly infer possible execution-time failures and their causes.

Alongside the diagnostics capabilities, the ISTC-CNR research unit is attempting to provide a proactive functionality, namely a complete *caregiver console for non-intrusive supervision*. The aim is twofold: first, to develop a software supervisor which is capable of monitoring the adherence of the daily activities of an assisted elderly person in the RDE to a set of predefined behavioral constraints (Cesta *et al.* 2005); second, to orchestrate the available domotic services (robots, intelligent household appliances, etc.) according to the requirements of the assisted person, a task which can be cast as a planning problem (Pecora & Cesta 2005). This real-time execution monitoring relies on a CSP representation of what we call a “behavioral pattern”, which represents a collection of complex time constraints on certain activities the assisted person may carry out during the day. These constraints in turn represent the inter-dependencies between daily tasks a caregiver may want to enforce; the violation of each constraint can be independently associated to a different reaction strategy, which can go from simple log registration or alarms which trigger the intervention of a human being, to the on-line generation of complex reaction schemes which involve the caregivers and the software/robotic agents.

In addition, a distinct research unit is investigating the issue of *safe planning* by means of QBF (quantified boolean formula) verification (De Luca *et al.* 2005), where the underlying idea is to cast a planning problem along with a set of safety constraints into a problem which can be solved by means of an efficient QBF solver.

Interaction between humans and technological artifacts. The numerous issued related to the acceptance of the technology developed by ROBOCARE are being addressed by two distinct research units. On one hand, some work has investigated and provided a taxonomy of different modalities of *human-robot interaction*, as reported in (Cappelli, Giovannetti, & Federico 2005), particularly focusing on human-robot communication.

As for technology acceptance, the ISTC's Environmental Psychology unit has begun an investigation into *laypeoples' attitudes towards technology* (Giuliani, Scopelliti, & Fornara 2005; Scopelliti & Giuliani 2004). The particular focus of this work is to explore the expectations of targeted groups of elderly people towards the potential benefits of robotics and domotics in general, such as safety, comfort, etc. An in-depth study was conducted on the dependency of their inclinations on age-group, education, and other influential factors. This analysis has revealed that a large category of elderly persons (particularly those below the age of 75) are rather favorable to embedding technological components into their homes.

AI Technology in Elder Care

Overall, ROBOCARE represents an effort to understand what sort of support tools can be obtained by integrating today's state-of-the-art AI technology in an off-the-shelf manner. The challenge is to assess the extent to which the above mentioned techniques can provide a cost-effective means for building these off-the-shelf components for assistive technology. The following paragraphs attempt to sketch an outlook based on the results obtained after the second year of activities.

Robotic platforms. The state-of-the-art in robotic platforms has allowed us to develop mobile robots with robust navigation capabilities. Through the use of different techniques, we have successfully deployed these platforms in both the domestic and the health-care institution scenarios. Yet one critical question still remains to be answered: what sort of meaningful support functionalities can mobile robots effectively provide for domestic use by an elderly person or in the context of a large health-care institution? Indeed, one of the principal aims of ROBOCARE is to provide an answer to this question.

So far, one interesting conclusion we can draw from our two-year experience is that we have ascertained that there is still a great deal of work do be done in order to effectively employ robots for elderly care. The first two years of this project have primarily focused on the development of robust localization, mapping and navigation techniques. While the results obtained are important and in line with the state-of-the-art in robotics research, they also mirror the large gap between state-of-the-art and application of robotic technology for elder care. The principal reason for this gap lies in the lack of off-the-shelf components providing functionalities which are advanced enough for deployment. While it is clearly possible to produce highly specialized robotic platforms for caretaking purposes, it is also clear that this sort of technology also comes at a very high price in terms of both hardware and software development. For the general-purpose robots we have employed in ROBOCARE, it is necessary to further invest in the high-end capabilities, by means for instance of specific projects aimed at developing manipulatory add-ons as well as other high level cognitive capabilities. This would certainly contribute to increasing the availability of complex and commercially-viable robotic platforms which could be applied more directly in the context of elder care.

Nonetheless, there are a number of very good reasons to invest in robots for the care of the elderly. One of them lies in the expectations elderly people have of robots. Recent surveys (e.g., (Giuliani, Scopelliti, & Fornara 2005)) have shown these to be very compelling arguments for having an assistive robot at home, yet quite out of reach for today's off-the-shelf robotic platform. Another compelling reason is related to embodiment. This is a characteristic in which elderly people are particularly interested in, expressing preferences such as "it should look like a child" or "it should not frighten the cat". Meeting these requirements while affording the functionalities elderly people would like in a robot is a big challenge for roboticists, and will certainly forebode interesting developments in the future.

Sensory capabilities. The ROBOCARE project has largely focused on artificial vision technology for people/robot localization and tracking, as well as person, posture and gesture recognition. High-performance CPUs and video processors, as well as relatively cheap medium-range cameras available today have allowed us to develop algorithms for achieving complex artificial vision functionalities. The step to bundling this software in self-contained and easily deployable "intelligent sensors" is well in reach. Currently available technology is capable of providing services such as people tracking and recognition, as well as interpreting gestures and diagnosing the state of a person based on posture.

Overall, we envisage that we will soon be able to count on a large amount of information from static artificial vision sensors deployed within the environment. This information can be used to provide services which may indeed be of use in an elderly person's home. For instance, a "lost and found" functionality could be set up relatively simply: a central supervisor maintains a database of all non-static objects within the field of view of the cameras, e.g., glasses, keys, hat, scarf, etc. Upon request, the system can be summoned to provide answers to queries such as "what have I done with my glasses?". Perhaps even more interestingly, the system may be programmed to start by providing only "hints" in order to point the assisted person to the lost object, a feature which is attractive for mildly-affected Alzheimer patients.

In conclusion, our two years of experience in ROBOCARE have allowed us to develop a series of specific artificial vision techniques which can be employed with commonly available hardware components in order to provide interesting services for the care of the elderly, and which are also relatively close to being readily deployable.

Non-intrusive supervision. Given the focus on integration, one of the primary aims of ROBOCARE is to develop a software infrastructure which can serve as an interface between human caregivers or the assisted elderly persons and the intelligent environment as a whole. This overall "controller" is composed of a variety of different planning, scheduling, and constraint reasoning algorithms, all of which provide the representation and reasoning capabilities for activity supervision, diagnosis, and execution monitoring. The integration effort has focused on making these many functionalities accessible in the form of a "caregiver console", a group of interfaces which subsume the technology-related aspects of the underlying representations and provide a highly customized control panel for supervising and configuring the overall behavior of the intelligent home.

One important issue we are beginning to address now is related to information integration. More precisely, the amount and complexity of the symbolic information we can obtain from the sensory subsystem (in order of difficulty: objects, people, complex situations, ... — see sensory capabilites above) is steadily increasing. We envisage that we will soon be able to count on a large amount of high-level information form the intelligent sensors. This forebodes the development of more elaborate reasoning capabilities, which in turn will allow to increase the effectiveness of the intelligent environment in real every-day situations. At this point of development we are capable of implementing a rather stable sensor-supervisor loop which allows to track some key behaviors of the assisted elderly person in his or her daily routines. Yet while the state of the art reasoners which are being employed are for now sufficiently powerful and well-suited for dealing with the combinatorial problems of the RDE, it is possible that as the sensors grow in complexity we will have to extend their capabilities in order to accommodate more elaborate forms of reasoning. In particular, the current solvers are direct relatives of research prototypes, and as such are not "tuned" for use in this particular applicative context. One of the main efforts which will have to be made will probably consist in enhancing the expressiveness of the automated reasoning tools in order to accommodate requirements which are more suitable for the elder care context.

Another interesting issue which is beginning to emerge and which has not been fully addressed yet is the acceptance of automated supervision. On one hand, an automated supervisor can be configured to share only a small part of the information with humans, extracting from the detailed logs of the assisted person's activities only the aggregated information which is meaningful from the point of view of the caregiver. Our hypothesis, which still needs to be validated by an in-depth analysis, is that 24/7 monitoring by means of fixed environmental sensors can be acceptable as long as the data is processed by computers and only a subset of previously agreed upon results are then submitted to human caregivers — notice that this hypothesis underlies the acceptance of targeted advertisement mechanisms, such as some email clients which automatically parse your email and provide advertisement links which are related to the parsed text. Obviously, only a detailed analysis can assess in which types of situations this approach is acceptable, yet we believe that it may be indeed feasible if this "habit-tracking" technology can contribute to a prolonged independent lifestyle.

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References

Aleotti, J.; Caselli, S.; and Maccherozzi, G. 2005. Trajectory reconstruction with nurbs curves for robot programming by demonstration. In *IEEE International Conference on Computational Intelligence in Robotics and Automation, CIRA*.

Bahadori, S.; Iocchi, L.; Leone, G.; Nardi, D.; and Scozzafava, L. 2005. Real-Time People Localization and Tracking throught Fized Stereo Vision. In *Proceedings of Industrial and Engineering Applications of Artificial Intelligence and Expert Systems (IEA/AIE)*.

Cappelli, A.; Giovannetti, E.; and Federico, M. 2005. The Role of Communication in Human-Robot Interaction. In *Proceedings of the Second Robocare Workshop, ISTC-CNR, Rome (Italy)*.

Cesta, A.; Cortellessa, G.; Pecora, F.; and Rasconi, R. 2005. Monitoring Domestic Activities with Scheduling Techniques. In *Proceedings of the Second Robocare Workshop, ISTC-CNR, Rome (Italy)*.

De Luca, M.; Giunchiglia, E.; Narizzano, M.; and Tacchella, A. 2005. "Safe Planning" as a QBF evaluation problem. In *Proceedings of the Second Robocare Workshop, ISTC-CNR, Rome (Italy)*.

Dindo, H.; Chella, A.; and Infantino, I. 2005. A System for simultaneous People Tracking and Posture Recognition in the context of Human-Robot Interaction. In *Proceedings of the Second Robocare Workshop, ISTC-CNR, Rome (Italy)*.

Farinelli, A.; Iocchi, L.; and Nardi, D. 2003. Path Planning in a Domestic Dynamic Environment. In *Proceedings of the First Robocare Workshop, ISTC-CNR, Rome (Italy)*.

Gigliotta, O.; Caretti, M.; Shokur, S.; and Nolfi, S. 2005. Toward a Person-Follower Robot. In *Proceedings of the Second Robocare Workshop, ISTC-CNR, Rome (Italy)*.

Giuliani, M.; Scopelliti, M.; and Fornara, F. 2005. Coping strategies and technology in later life. In *Proceedings of AISB 2005 - Symposium "Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction", Hatfield, UK*.

Grisetti, G.; Stachniss, C.; and Burgard, W. 2005. Improving grid-based SLAM with rao-blackwellized particle filters by adaptive proposals and selective resampling. In *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA'05)*.

Mastrogiovanni, F.; Sgorbissa, A.; and Zaccaria, R. 2005. On The Tips of One's Toes: Self-localization in a Dynamic Environment. In *IEEE International Conference on Computational Intelligence in Robotics and Automation, CIRA*.

Micalizio, R.; Torasso, P.; and Torta, G. 2004. On-Line Monitoring and Diagnosis of Multi-Agent Systems: a Model Based Approach. In *Proceedings of ECAI, Valencia, Spain,* 848–852.

Pecora, F., and Cesta, A. 2005. Evaluating Plans through Restrictiveness and Resource Strength. In *Proceedings of the 2nd Workshop on Integrating Planning into Scheduling (WIPIS) at AAAI-05, Pittsburgh, USA*.

Scalzo, A., and Veruggio, G. 2005. People following and guiding with a non-holonomic slow steering robot. In *Proceedings of the First RoboCare Workshop, ISTC-CNR, Rome (Italy)*.

Scopelliti, M., and Giuliani, M. 2004. If I had a robot at home... Peoples' representation of domestic robots. In Keates, S.; Clarkson, J.; Langdon, P.; and Robinson, P., eds., *Design for a more inclusive world*. Springer Verlag. 257–266.