A mobile robotic platform for elderly care

João Cunha, António J. R. Neves, José Luis Azevedo, Bernardo Cunha, Nuno Lau, Artur Pereira and António Teixeira

Transverse Activity on Intelligent Robotics, IEETA / DETI University of Aveiro,
3810-193 Aveiro, Portugal
{joao.cunha, an, jla, f552, nunolau, artur, ajst}@ua.pt

Abstract. This paper presents the proposal of a robotic platform for elderly care integrated in the Living Usability Lab for Next Generation Networks. The project aims at developing technologies and services tailored to enable the active aging and independent living of the elderly population. The proposed robotic platform is based on the CAMBADA robotic soccer platform, with the necessary modifications, both at hardware and software levels, while simultaneously applying the experiences achieved in the robotic soccer environment.

1 Introduction

Current societies in developed countries face a serious problem of aged population. The growing number of people with reduced health and capabilities, allied with the fact that elders are reluctant to leave their own homes to move to nursing homes, requires innovative solutions since continuous home care can be very expensive and dedicated 24/7 care can only be accomplished by more than one care-giver.

Technology directed to this section of the population can play a major role in improving their quality of life, enabling and fostering active aging without leaving their homes. In particular, information and communications technology can provide a variety of services to the elder population. With the large bandwidth available in Next Generation Networks (NGN) new services become available in areas such as Health and Ambient Assisted Living, like high definition video transmission from multiple cameras or monitoring of biologic signals from body sensors.

In the context of this scenario the introduction of a mobile robotic platform could be an asset, by complementing and enhancing the deployed infrastructure, as a robot can be a mobile monitoring agent, for instance by providing images from spots that are occluded from the house cameras, as well as helping to reduce the feeling of loneliness that often affects the elderly, when endowed by means of human interaction.

This paper presents a project to adapt a robotic soccer platform based on CAMBADA[1] platform to perform in a home environment. We discuss the main

[1] www.ieeta.pt/atri/cambada

goals by the robotic platform and we present some of the work already developed. The CAMBADA project started in 2003 in the Department of Electronic, Telecommunications and Informatics (DETI) and the Institute of Electronic and Telematics Engineering of Aveiro (IEETA), both of the University of Aveiro, with the goal of developing a team of soccer robots to compete in the RoboCup[2] Middle Size League (MSL).

The remaining of this paper is structured as follows: Section 2 presents the Living Usability Lab for Next Generation Networks project. Section 3 discusses an overview of the state of the art in service and elderly care robotics and some of the more relevant projects in the area. Section 4 discusses the proposed robotic platform Living Usability Lab for Next Generation Networks, the expected functions and goals, and a brief description of previous projects and experiences that serve as a basis for the project. Section 5 presents the conclusions.

2 The Living Usability Lab for Next Generation Networks

The aforementioned development of a robotic platform for elderly care is part of a broader project named Living Usability Lab for Next Generation Networks[3]. The project is a collaborative effort between the industry and the academy that aims to develop and test technologies and services that give elderly people a quality lifestyle in their own homes while remaining active and independent.

To enable active aging of the elder population, the different services provided make use of the NGN infrastructure that offers large bandwidth transport technologies suitable for services such as image and voice transmission. This feature allows a thorough analysis of the collected data to ultimately generate knowledge of the observed behaviors. This then allows a feedback on the developed services and technologies and provides an opportunity for improvement.

A Living Lab is not just a set of information services but a complex entity composed by physical spaces and infrastructures (information and communication systems and services, peripheral devices, development tools and methodologies for analysis, specification, evaluation, validation and dissemination of the results) and requires intense involvement of stakeholders (whether they are, for instance, end users, professionals, researchers or students) to allow the research and development, in continuum, of new technologies and services, as described in Fig. 1.

3 Domestic Robotic Assistants

Ever since the first robots were created, researchers have tried to integrate robots in our daily lives. In particular, domestic assistants have been a constant driving goal in the area, where robots are expected to perform dull daily chores in a

[2] www.robocup.org
[3] www.livinglab.pt

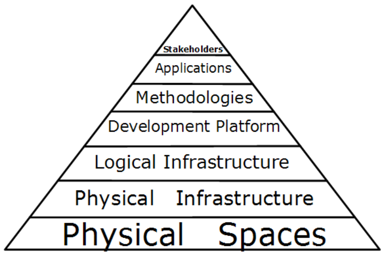

Fig. 1. The conceptual model of the LUL project

home environment. We can all certainly remember examples in the science-fiction universe, like the famous Jetsons robot maid, Rosie.

While some simpler forms of domestic robots, such as vacuum cleaner robots, are increasingly becoming part of our everyday life, robots designed for human care are far from commercialization. Meanwhile, a large number of this type of robots have been developed over decades by academies and research groups. The results and insights obtained through the conducted experiences will undoubtedly shape the care robots of tomorrow in fields such as Face Recognition, Speech Recognition, Sensor Fusion, Navigation, Manipulation, Artificial Intelligence and Human-Robot Interaction to name a few.

Among others, the following robots deserve a particular mention:

Asimo the famous robot from Honda, is arguably the most advanced humanoid like robot ever. Designed to be an all-purpose robot, it can perform care tasks such as deliver goods or carry objects by pushing a trolley in an indoor environment [1].

Care-O-Bot a highly advanced domestic care robot developed by the Fraunhoffer Institute. Equipped with a robotic arm the robot can perform manipulation tasks such as hand out beverages and open doors. The robot is being experimentally applied in elder-care facilities [2].

Flo and Pearl two robots developed in the Nursebot project [3][4]. The robots were designed with the specific purpose of providing assistance to elders both in the elder home or in a nursing home. Pearl, more recent than Flo, has the additional ability to provide reminders about daily activities.

PR2 a recent, very advanced wheeled robot, developed by Willow Garage. PR2 can produce a 3D mapping of the surrounding [5], which is very important given that objects such as tables or open drawers, that are common in a household environment, are often unnoticed using traditional 2D mapping. PR2 can also perform complex manipulation tasks such as opening a closed door, retrieve an item from the refrigerator or plug-in itself to electrical outlets to charge its batteries [6], achieving therefore a higher degree of autonomy.

RIBA a bear-like robot developed in Japan. RIBA is the first robot that can lift up or set down a real human from or to a bed or wheelchair [7].

Studies show [8] that in rehabilitation scenarios, robots are well received and have a positive impact in the patient willingness to perform prescribed exercises. Furthermore, a physically embodied robot produces a better response than simulation or tele-rehabilitation robots. However, robots designed for elderly care should follow careful design rules in order to be accepted by a section of the population that may not be receptive or accustomed to technology. Research shows that elderly people prefer light colored robots, medium sized (around 1.25 meters high) [9]. Interestingly, in the same study, elderly people preferred a wheeled robot over a legged robot. One may argue that elderly people are increasingly affected by the uncanny valley effect [10], and thus prefer a more machine-like appearance.

Although the physical shape can influence the robot acceptance, the robot interaction skills and social competence can outweigh the appearance factor [11]. On the other hand, it is not recommended to make the robot as socially advanced as possible. In general, a robot should match the human's expectations and the application requirements [12].

The fact that a large number of robotic assistants started being proposed two decades ago while no commercial application ever developed means the problem remains largely unsolved today.

4 Proposed Robotic Assistant

The DETI and IEETA have been developing, for many years, a significant activity in the context of mobile robotics. One of the most visible projects that has resulted from this activity is the robotic soccer team CAMBADA.

In this paper we propose the adaptation of robotic soccer robot to help and safely coexist with an elderly person in a home environment, using the experiences obtained in the CAMBADA project.

The CAMBADA project provided vast experience in areas such as Machine Vision, Perception, Navigation, Robot Software Architecture and Cooperation. This experience is reflected in the series of positive results achieved in recent years. The CAMBADA team won the last four editions of the Portuguese National Championship, placed second in the 2010 European Championship and placed third in 2009 and 2010 World Championship while winning the world title in 2008. The vast number of publications produced also reflects the quality of the CAMBADA project, to name a few [13][14][15][16].

There is no better proof of the successful application of soccer robots in home environments than the RoboCup@Home[4] league. This league was created in 2006 from the need to place more emphasis on real world problems, not addressed in robotic soccer [17]. This league is currently the largest league of the RoboCup initiativeand includes a vast number of teams that started as soccer teams and then evolved to this robotic paradigm.

Although a shift from the robotic soccer environment many of the problems address in the RoboCup@Home league can be, and have been, solved[19] by

[4] www.robocupathome.org

Fig. 2. The participating robots in the 2009 edition of the RoboCup@Home competition, adapted from [18].

teams coming the robotic soccer leagues, using the experience learned in that competition.

4.1 Architecture

The CAMBADA robots were designed and built at the University of Aveiro. The hardware is distributed in three layers which facilitate replacement and maintenance.

Fig. 3. The CAMBADA robot.

The top layer has the robots vision system. The CAMBADA robots have an omni-directional vision obtained by means of a CCD camera pointed upwards towards an hyperbolic mirror which enables a robot to see in 360 degrees[20][21].

The middle layer houses the processing unit, currently a 12" laptop, which collects the data from the sensors and computes the commands provided to the actuators. The laptop executes the vision software along with all high level and decision software and can be seen as the brain of the robot. Given the positional advantage, a ball retention device is placed on this layer.

Beneath the middle layer, a network of micro-controllers is placed to control the low-level sensing/actuation system, or the nervous system of the robot. In order to comply with real-time constraints the FTT-CAN[5] protocol is used[22]. The sensing and actuation system is highly distributed, meaning that each node in the network controls different functions of the robot, such as, motion, odometry, kick, compass and system monitor.

The lower layer is composed by the robot motion system and kicking device. The robots move with the aid of a set of three omni-wheels, disposed at the periphery of the robot at angles that differ 120 degrees from each other, powered by three 24 V / 150 W motors. On this layer there is also an electromagnetic kicking device. Also, for ball handling purposes, a barrier sensor is installed underneath the robots base, that signals the higher level that the ball is under control.

Following the CAMBADA hardware approach, the software is also distributed. Therefore, five different processes are executed concurrently. All the processes run at the robots processing unit using the Linux OS.

All processes communicate by means of an RTDB[6] which is physically implemented in shared memory. The RTDB is a data structure which contains the essential state variables to control the robot. The RTDB is divided in two regions, the local and shared regions.

The local section holds the data needed by the local processes and is not to be broadcasted to the other robots. The shared section holds the data of the state of the world as perceived by each running agentof the the team. Each sub-divided area is allocated to one robot where it stores the perceived state of the world. There is also one sub-divided area specific for the coach information. As the name implies the shared section is broadcasted through the team, as each agent transmits the owned sub-divided shared section, achieving information sharing between the team.

The RTDB implementation guarantees the temporal validity of the data, with small tolerances [23].

The processes composing the CAMBADA software are:

Vision which is responsible for acquiring the visual data from the cameras in the vision system, processing and transmitting the relevant info to the CAMBADA agent. The transmitted data is the position of the ball, the lines detected for localization purposes and obstacles positions. Given the well structured environment the robots play in, all this data is currently acquired by color segmentation [20][24][13].

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[5] Flexible Time-Triggered communication over CAN

[6] Real-Time DataBase

Agent is the process that integrates the sensor information and constructs the robot's worldstate. The agent then decides the command to be applied, based on the perception of the worldstate, accordingly to a pre-defined strategy [25].

Comm that handles the inter-robot communication, receiving the information shared by the team-mates and transmitting the data from the shared section of the RTDB to the team-mates [26][27].

HWcomm or hardware communication process is responsible for transmitting the data to and from the low-level sensing and actuation system.

Monitor that checks the state of the remaining processes relaunching them in case of abnormal termination.

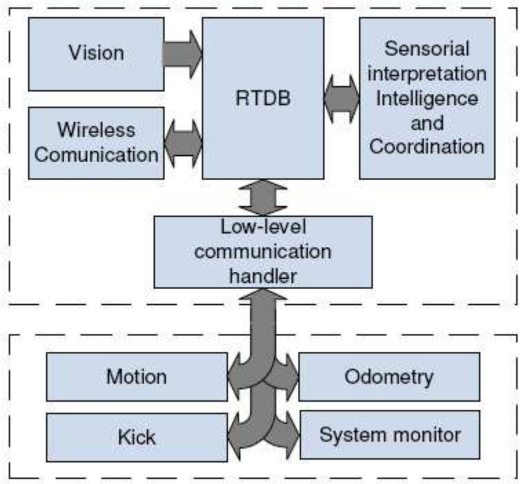

Fig. 4. The software architecture of the CAMBADA robots, adapted from [28].

Given the real-time constraints, all process scheduling is handled by a library specifically developed for the task, *pman*, process manager [13].

4.2 Objectives

As stated before, the goal of this project is to develop a mobile robot designed to help improve the quality of life of an elderly person in a household environment, ultimately postponing the departure to a nursing home.

In order to achieve this goal, and because there is a broad range of possible actions a robot can perform to improve the quality of life of an elderly person, some of the most important tasks were chosen to be addressed by this project.

Therefore during the project we expect to develop a platform that is able to:

- be safe for users and the environment,
- avoid dynamic and static obstacles,
- dispense or remind the elder to take medication,
- output audio and video,
- receive information from external sensors,
- dock in a charging station when batteries are low,
- execute external orders,
- follow a human and answer when called.

4.3 First Results

The developed work until now, focused on the following topics:

- integration of aditional hardware, namely a laser range finder which is the main source of sensorial information to produce environment maps used for localization and navigation, and stereo vision cameras to complement the omni-vision system of the CAMBADA robots;
- development of machine vision algorithms for recognition of objects present in a home environment;
- initial design of a medication dispenser suitable for both a mobile robotic application and elderly care,
- redesign of the robot control architecture to achieve an easy behaviour scalability, to transparently develop behaviours for different environments such as home applications or robotic soccer;
- design and implementation of algorithms for indoor localization, using internal and external cameras to the robot,
- development of new motor controllers electronic boards, allowing a broader variety motors used in the robot;
- implementation of software for hardware communications, to enable the interaction of the high-level software modules with the different hardware available in the robot, such as the laser-range finder information and the odometry;
- algorithms for worldstate-modelling based on sensor and information fusion, to produce a better estimation of the observed environment by the robot;
- design of the system architecture where the tasks with heavy computational weight are executed on processing units external to the robot. The external computer also serves as the interface with the Living Usability Lab, consuming and providing different services.

5 Conclusion

This paper presented the proposal of a robotic platform for elderly care. The development of the robot is part of the Living Usability Lab for Next Generation Networks. The paper discusses the motivations to increasingly apply robotic technology in home environments near humans, particularly elder citizens. A

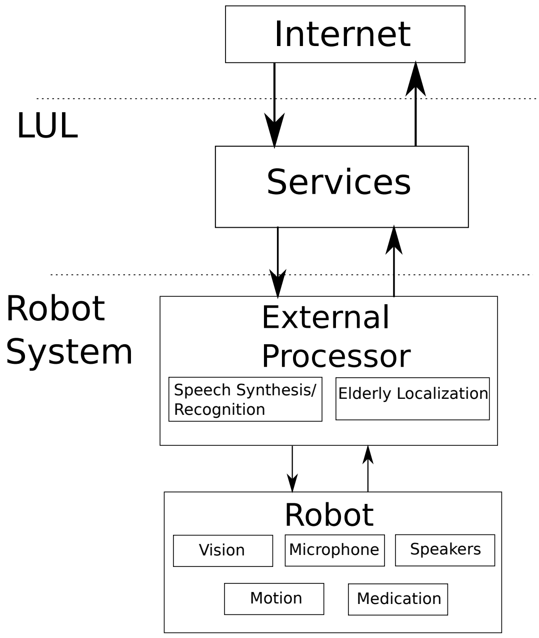

Fig. 5. The proposed system architecture.

brief overview of the state of the art research was discussed such as the most important robots developed to date in this field. Finally, the proposed platform objectives were presented along with the CAMBADA hardware and software architecture that serve as basis to the proposed platform architecture.

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