

ON THE DEVELOPMENT OF A SERVICE ROBOT FOR SOCIAL INTERACTION WITH THE ELDERLY

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Abstract

In this paper, we address the development of an innovative service mobile robot for social interaction and home care. Specifically, we focus on the integration of a set of intelligent services in the robot towards natural human-robot interaction, and targeting the 65+ age group. We describe the navigation, perception, interaction, data collection and interfacing capabilities developed using the Robot Operating System (ROS) framework to provide personalized care and socialization to the elderly. We discuss the main challenges involved and open optimistic prospects for the final end-users validation of the system.

1 Introduction

This work targets the development of a social robotic system to provide companionship, care and socialization services via Information and Communications Technology (ICT) to support the elderly, while motivating them to remain active and independent so as to improve their well-being. In recent years, there has been a noticeable growth in the attention given to assistive technologies for helping older individuals to stay active and live independently for longer in their preferred environment. This is backed up by the shortage of staff and qualified health care personnel in western countries and the fact that ageing people often prefer to live in their own homes as long as possible instead of being institutionalized in care centres [1].

Robotic systems are among the initiatives that can offer functionality related to the support of independent living, monitoring and maintaining safety or enhancement of health and psychological well-being of elders by providing companionship. Despite the fast growth of the ICT and Robotics market for ageing well, which is expected to reach €13 billion in the EU by 2016 [2], it is still in a premature phase and does not yet fully ensure the availability of the necessary solutions. Existing solutions are either not quite ready for commercial service or represent a high cost. A common property of assistive service robots is that they are pre-programmed with specific services and knowledge at the manufacturing stage, and as a consequence they often fail to properly cope with the constantly

changing needs of elderly people [3]. In this paper, we describe a service model for personalized care provision, which is adaptable throughout the platform's presence in the elderly life.

In the remaining of this paper, we describe related work on social and service robotics for assisted living. Afterwards, we provide a brief overview of the mobile robotic platform in Section 3, and in section 4 the developed services and functionalities are presented. We then discuss the main challenges involved based on preliminary results and end with conclusions.

2 Related Work

Designing robots for social purposes has been a trendy topic for the last decades. The literature in this area is vast and has yielded several interesting designs [4, 5]. In this section we provide a brief description of recent ICT projects on this issue.

The CompanionAble initiative¹ provides the synergy of robotics and ambient intelligence technologies, and their semantic integration for assistive home care. The project supports the cognitive stimulation and therapy management of the care-recipient, mediated by a robotic companion working collaboratively with a smart home environment. CompanionAble addresses the issues of social inclusion and home care of persons suffering from chronic cognitive disabilities prevalent among the older European population [6].

The GiraffPlus project² provides a telepresence robot, which allows relatives or caregivers to virtually visit an elderly person at home. The project places special emphasis in empathetic user interaction to address the needs and capabilities of the users. GiraffPlus benefits from a network of sensors to monitor the activities in the home environment, placed in and around the home, as well as on the body of the elderly to extract high level activities from sensor data [7].

In the Accompany project³, a robotic companion is proposed as part of an intelligent environment, providing services to elderly users in a motivating and socially acceptable manner to facilitate independent living at home. The Accompany system provides physical, cognitive and social assistance in everyday home tasks, and contributes to the re-ablement of the

¹<http://www.companionable.net>

²<http://www.giraffplus.eu>

³<http://accompanyproject.eu>



Figure 1: Robotic platforms developed in the mentioned projects. From left to right: CompanionAble, GiraffPlus, Ac-company, Robot-Era, Mobiserv and Hobbit.

user, *i.e.* assist the user in being able to carry out certain tasks on his/her own [8].

Similarly, the Robot-Era project⁴ focuses on implementing and integrating advanced robotic systems and intelligent environments in real scenarios for the ageing population. Besides demonstrating the general feasibility and effectiveness of the system, the consortium addresses social/legal plausibility and acceptability by end-users. To that end, the system is employed in real conditions to cooperate with real people so as to favour independent living, improve the quality of life and the efficiency of care for elderly people [9].

In the Mobiserv initiative⁵, a robot was developed to support the daily living of seniors focusing on health, nutrition, well-being and safety, including the capability to monitor vital signs or detecting falls. The Mobiserv system consists of an interplay between a social companion robot, wearable smart clothes and a smart home environment [10].

Finally, in the Hobbit project⁶, a socially assistive robot was developed to help seniors and old people at home by picking up objects from the floor, bring objects and provide entertainment functions. The main goal was to make older people feel safe at home via a mutual care concept, reducing the risk of falling and aiming at increased acceptability. The robot was designed to detect emergency situations and trigger an appropriate alarm. Furthermore, it provided tools to keep seniors socially connected, active and motivated to exercise [11].

In this paper we present the ongoing development of several robotic services for a social robot platform designed in the scope of SocialRobot⁷ and GrowMeUp⁸ European projects. Differently from most of the previously referred projects, our solution does not involve changing the environment or deploying intrusive sensors around the house or on the elderly person, being specially focused on natural social interaction and personalized care.

3 Overview

In the proposed solution, we explore a user-driven paradigm, where services are adaptable to dynamic parameters and benefit

⁴<http://www.robot-era.eu>

⁵<http://www.mobiserv.info>

⁶<http://hobbit.acin.tuwien.ac.at>

⁷<http://mrl.isr.uc.pt/projects/socialrobot>

⁸<http://growmeup.deec.uc.pt>

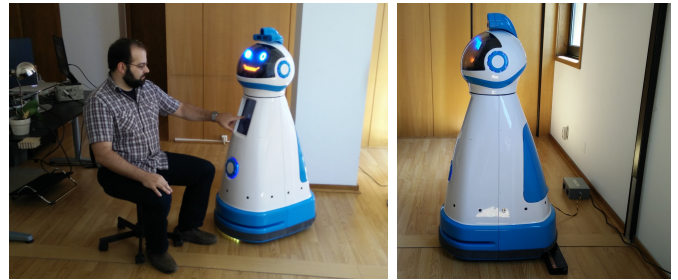


Figure 2: The service robot platform developed: a) Human-Robot Interaction; b) Docking Station.

from the knowledge of the end-users preferences and personal information. The system architecture is highly modular, combining different functions of the platform to provide different services. Therefore, it is an easily scalable solution and it has the ability to explore user preferences, abilities and habits to provide a high level service personalization. In previous works, the robot hardware [12] and the functional architecture for integration of the different modules of the system [13] have been described in detail. Therein, we described our method for service orchestration via XML description files. In this paper, we address specifically the diverse services and functionalities developed from the robot software perspective.

Our service robot, illustrated in Fig. 2, is fully integrated in the ROS framework [14], and the software has been fully developed in the C++ programming language. ROS provides drivers for integrating commonly used sensors without needing hardware expertise, such as the Hokuyo URG-04LX-UG01 laser range finder or the Asus Xtion PRO Live RGBD camera, which reduced the overall time spent in development. Such drivers place virtually all complexity in libraries, only creating small executables, exposing library functionalities.

4 Services and Features

In this section, we describe the developed services that are embedded in the robotic platform for elderly care and socialization. Given that the whole system is the result of an integration of several different modules, when the robot is under operation, it checks which components are plugged in and run their respective driver, which then become responsible for publishing sensor data. The services described below not only consider sensor data, but also use user information and environment knowledge to trigger different robot behaviours and functionalities.

4.1 Navigation and Perception

The robot is capable of navigating autonomously by following the approach presented in [15]. We are using a 2D occupancy grid map, derived from the output of a Rao-Blackwellized Particle Filter (RBPF) SLAM implementation software [16]. This map is used both for motion planning and localization. This way, given any physically reachable goal, the robot should be able to autonomously navigate to that goal, avoiding collisions

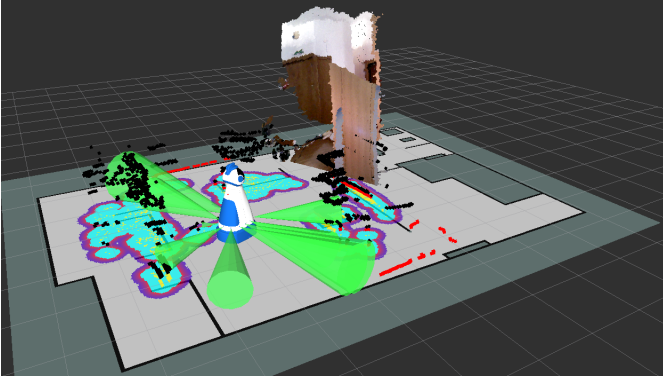


Figure 3: Robot navigating in an indoor scenario. Green cones correspond to sonar readings, red dots to laser range readings, black points to 3D voxels, and the depth image of the Asus RGBD sensor can also be seen in front of the robot. The projected obstacles (in purple/blue/yellow) correspond to the local obstacle costmap around the robot.

with obstacles on the way by following a series of steps.

Being commonly initialized with a grid map of the environment, the robot is aware of any unexpected obstacle by perceiving them with its range sensors, namely: a 12-sonar array, a forward-facing laser range finder and the Asus RGBD camera. The depth information acquired with the Asus Xtion PRO Live sensor, enables us to also consider obstacles in 3D, in the form of voxels, as illustrated in Fig. 3. Therefore, the robot is not limited to the scanning plane of the laser and the low-resolution ranging of sonars. These complementary sensors allow for robust navigation of the mobile robot platform in an indoor environment.

The navigation algorithm includes several interesting features. For instance, Random Sample Consensus (RANSAC) is applied to filter out Light Detection And Ranging (LIDAR) readings that are invalid due to hardware limitations, such as false positives generated by veiling effects. Also, the voxel costmap, which is initialized with the static map (if available), is used to represent obstacle data at different heights and the most recent sensor data, in order to maintain an updated view of the robot's local and global environment. Inflation is performed in 2D to propagate costs from obstacles out to a specified radius in order to conservatively avoid collisions.

The global planner uses an A* algorithm that plans in configuration space computed during obstacle inflation in the costmap, not taking into account the dynamics or the kinematics of the robot, which are considered instead by the local planner, which generates velocity commands for the robot, safely moving it towards a goal. The planner cost function combines distance to obstacles, distance to the path produced by the global planner, and the speed at which the robot travels. While moving, as more information about the world is acquired, the robot may re-plan in order to avoid collisions with obstacles.

Regarding the local motion planner, the robot uses the Dynamic Window approach [17], as tests shown its superior performance considering the platform kinematics, steering system

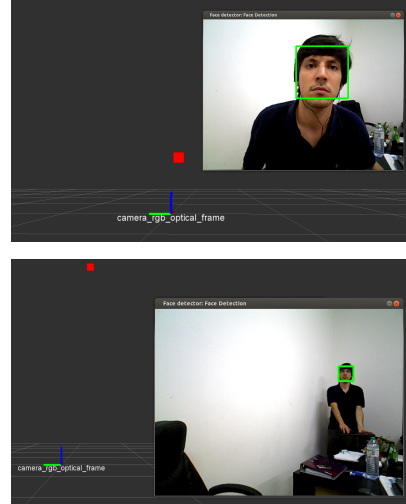


Figure 4: Detection of a generic person's face, and extraction of the coordinates of the person's head in 3D space. This is crucial for the robot to navigate and safely approach a person.

and configuration over the Trajectory Rollout approach [18]. The planner includes a few recovery behaviours that can be performed, *e.g.* due to entrapment. The robot will perform increasingly aggressive behaviours to clear out space around it and check if the goal is feasible, eventually giving up in case the goal is not feasible without colliding with obstacles. For localization, we make use of the Adaptive Monte Carlo Localization (AMCL) implementation, which is a probabilistic localization system that uses a particle filter to track the pose of a robot against a known map [19].

These navigation capabilities enable the robot to perform autonomous monitoring within an indoor environment. This works similar to a patrolling behaviour [20], where the robot is given a set of way points to follow consecutively, while doing other tasks in parallel, such as detecting and approaching people or detecting anomalous situations. In addition, the robot constantly checks its battery status and, when reaching a minimum threshold, the robot is able to drive towards its charging station. In this process, the robot moves to a goal placed directly in front of it, and carefully drives backwards to dock into the charging station, while at the same time controlling its backwards distance with the rear-facing sonar. When the robot docks (see Fig. 2, right-hand side), it automatically acknowledges that it is charging via its low-level driver. This autonomous behaviour enables the robot to be in operation during long-term periods.

4.2 People Detection and Face Recognition

One of the paramount features within a social robot is to detect and recognize people. Detection consists in identifying the presence of generic people in the robot's field of vision, while recognition assumes higher intelligence, as the robot is supposed to acknowledge a specific person, thus being aware of this person profile during the interaction so as to provide a personalized service. In this subsection, we describe how the

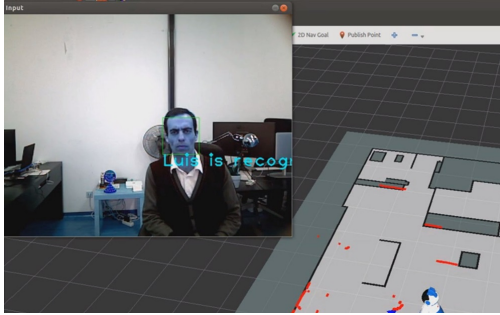


Figure 5: Recognition of a known person's face.

robot detects people and recognizes known faces.

For people detection, the robot actively looks for the eventual presence of people by visually detecting possible faces based on a cascade of Haar-like features [21] to obtain an initial set of detections. Afterwards, it prunes false positives using depth information from the RGBD camera. Namely, the depth information is used to predict the real-world size of the detected face, which is then preserved as a true face detection only if the size is realistic for a human face or if the detection contains sufficient depth information. This removes the majority of false positives given by the detector. The 3D position of the person's head in the depth sensor frame of reference can be extracted from the depth information provided by the RGBD camera, as illustrated in Fig. 4. The detection of a generic person and extraction of its coordinates in 3D space enables the robot to safely navigate closer to the unknown person to approach him/her and start an interaction, opening the possibility to perform several different types of interaction, as seen in subsection 4.3.

The process for face recognition has a few key differences from the one described for people detection. For identification of a specific person, we assume that a training dataset with the person's face has been created previously to generate an eigenfaces database that is stored internally by the software. These eigenfaces correspond to a set of eigenvectors that are derived from the covariance matrix of the probability distribution over the vector space of face images used for face recognition. These are generated by performing a principal component analysis (PCA) on a large set of images depicting different human faces. This way, using a Haar cascade classifier, consisting of a machine learning based approach where a cascade function is trained from several images, a person's face can be recognized in real-time due to its unique features (*cf.* Fig. 5). The ability to identify a person enables the system to trigger a vast possibility of personalized services, such as those addressed in subsection 4.4.

4.3 Interaction

After approaching the person, the robot is expected to start an interaction. In the current stage of development, this is done via audio interaction. The robot greets and inquires the identified person using the embedded stereo speakers, and then extracts emotion from the verbal reply via the microphones on

the Asus Xtion PRO Live sensor. Real-time emotion and affect recognition is possible using the Open-Source Emotion and Affect Recognition (openEAR) framework [23]. This is an efficient, multi-threaded, real-time framework providing an extensible, platform-independent feature extractor implemented in C++, with pre-trained models on six well-known emotion databases that are ready-to-use for online emotion and affect recognition, and supporting scripts for model building, evaluation, and visualization. Leveraging the efficient low-level audio feature extraction algorithms implemented in C++, it applies various statistical functionals and transformations to those features (*e.g.* extract signal energy, FFT-spectrum, Mel-Spectrum, pitch, voice quality, etc.) to classify emotions using Support-Vector Machines with polynomial kernel function of degree 1, resulting in emotions such as anger, fear, happiness, disgust, boredom, sadness and neutral.

Besides emotion recognition, the robot is able to detect a limited set of simple words through speech. Ideally, the robot should incorporate an array of several non-colinear microphones for superior robust speech recognition. However, it is limited to the two colinear microphones incorporated in the Asus Xtion PRO Live sensor. In order to recognize speech, we make use of PocketSphinx, a lightweight speaker-independent speech recognition engine. It is an open-source framework featuring feasibility of continuous speech and large vocabulary recognition. It makes use of hidden Markov acoustic models (HMMs) with trained data to learn the best parameters, and an n-gram statistical language model. Additionally, to formulate verbal replies the robot uses predefined text-to-speech recordings to interact with the user. The above features were integrated in the robot via appropriate ROS wrappers.

In the short-term future, we intend to incorporate intelligent dialogue management in our robotic system based on the work described in [22], and enhance the emotion recognition system by also extracting vision features such as facial points or optical flow measures to be fused with audio features.

4.4 Data Retrieval and Personalization

One of the key modules of our system is the SoCoNet [13]. This is an elderly centred web-based collaborative social community network that enables the effective administration, management and coordination of the user profile and Virtual Care Teams (VCTs) around the elderly person. Additionally, it provides a knowledge repository containing organized personal information, including user preferences, events and medicine calendar. By connecting to the SoCoNet via web services, the robot is able to securely retrieve particular user information, and provide personalized care when it recognizes a specific person.

Examples of developed features include reminding the user to take his/her medicine during interaction or fulfilling household tasks; doing appropriate physical activity based on the individual's actual physical and psychological status; suggesting the user to carry out a preferred activity or ingesting a specific meal; and reminding the person to take a given accessory before carrying out an activity. Furthermore, the robot provides

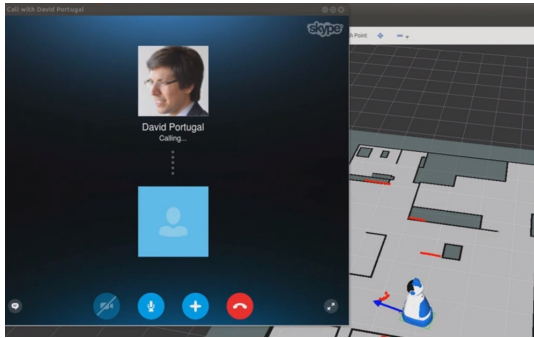


Figure 6: The robot is able to connect to Skype, providing telepresence and putting the elderly in touch with relatives.

a Skype interface (cf. Fig. 6). Skype is a telecommunications application software, enabling the robot to call the user’s relatives, emergency contacts or caregivers. As seen in section 2, telepresence is a highly required feature, since it alleviates the anxiety and worry that senior citizens often feel.

Since the elderly fragile condition leads to constantly changing needs, the proposed methodology fosters services adaptability. Having this in mind, SoCoNet provides an interface to add, remove and modify the user information. This allows the robot to adapt to the most recent changes.

4.5 Interfacing

The platform developed incorporates five capacitive sensors, which allows for the robot to perceive if a person is touching its back or torso area. This type of feedback results in affective interaction between the person and the robot. Moreover, a touchscreen has been embedded in the chest area of the robot for user interface. A simple QT-based GUI has been developed to confirm the answers provided by users to the robot and yield error-free interaction. The advantages of a user interface include overcoming social isolation by facilitating the access to phone and video conversation, daily shopping, social life, public services and easy access over the internet.

Currently, we are integrating Citard Active⁹ in the robot for a clearer and better interface for the elderly and caregivers. Citard Active is an ICT product supporting older people to carry out an active life, encouraging them to be socially and physically active for a longer period of time. This is done by stimulating and motivating them to participate in activities that take place in their living area (home, care centre). Anyone with a tablet or PC can easily download the software and participate in Citard Active.

Citard Active is successfully in use by residents in four care centres of Zuyderland institution, in the south of Netherlands, and participants testimonies state that it is easy to use and described it as a nice way to support their social lives. Within its features, caregivers and administrators have dedicated pages to control the system. Caregivers can add activities and manage the elderly, and administrators can control the different settings

⁹<http://citard-serv.com/products-cascn.php>

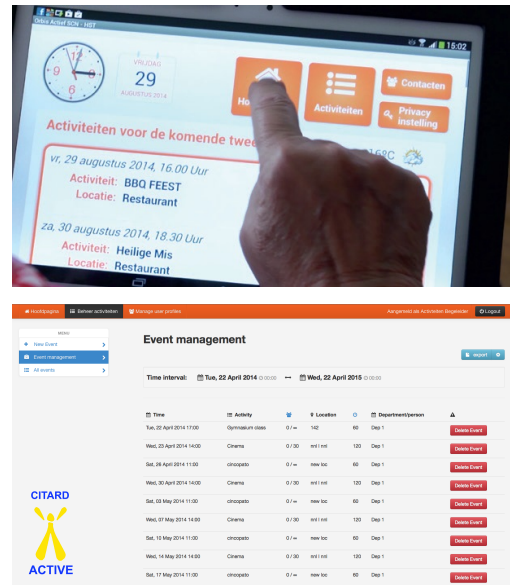


Figure 7: The Citard Active Interface.

and preferences of the system. Moreover, it provides the elderly options for sharing agendas with family or friends to see in which activities they will participate or have participated in the past. Additionally, the app encourages the elderly to take part in the activities taking into consideration their ageing related cognitive and physical behaviour changes. Furthermore, the system registers the normal behavioural pattern of the elderly and detects when changes occur and the person is more passive than usual. In that case the app stimulates the user to participate in activities.

5 Discussion and Conclusions

Older people are implicated but not usually present in the development of robots and their matters of concern are not usually identified in the design process. Instead in our work, end-user involvement has been a priority ever since the beginning, namely in the requirement specification stage, system design and prototype testing. Several preliminary trials with the system have already been conducted, yielding interesting results, challenges and valuable lessons. For instance, results have shown that the robot is able to properly navigate indoors, even in tight spaces using its range sensors. However, it can encounter problems in highly cluttered environments due to its size. Additionally, its drive system does not allow the robot to climb stairs. Preliminary results have also shown the reliability of the person detection software, since even in low lighting conditions the robot is able to approach a person thanks to the available depth information. The face recognition software only rarely returns false identifications. This is more likely when there are multiple trained faces. Also as expected, recognition yields superior results when the person looks directly at the robot.

A key aspect is that at any instance if the user feels uncomfortable with the robot, it may be stopped by simply pressing

the red button located at the platform's back. We plan to further evaluate to what extent the users feel that they are always in control of the operations. Also, unexpected collisions can be detected at hardware level (triggered by the robot's bumpers) and bypass all decisions levels to stop the robot safely. Moreover, the semi-controlled scenarios tested consist of limited sound sources, structured layouts and adequate lightning conditions. In the short-term future, we will verify whether the obtained success can be transferred to an uncontrolled real world environment by running an innovative 1-week-long pilot at the Zuyderland Hoogstaete care centre in Sittard (NL), where the robot is expected to interact with several different people.

The solution proposed in this paper seeks a balance between addressing the opportunities and challenges of an ageing society rather than seeing the increase in longevity as a burden and a threat. We focus on the ways in which lifestyle, attitude, and skills can be supported and changed to create a better quality of life for older people. We envisage to introduce the system early enough in the life of the elderly when the first signs of physical and cognitive disabilities appear, thus providing initially simple and essential personalized functionality covering daily care needs. This will ensure that the elderly will be given enough time to become acquainted and increase their acceptance for more complex robot care features introduced gradually to address further ageing capabilities degradation.

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