Personalizable ICT-based Service Provision: The SocialRobot Solution

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Abstract. ICT-Service providing robots are usually developed to mitigate the impact of the volatile nature of elderly needs. Typically, these platforms focus on providing services that meet generic needs like agendas or passive monitoring. In the SocialRobot project, we propose an ICT-based service providing robot, whose architecture allows for a flexible and adaptable service provision that meets elderly requirements as they change. It promotes the creation of new and innovative services as well as improving existing ones. The key component of our architecture is SoCoNet, a virtual care collaboration tool that contains information about the elderly, personal data and their preferences. This information is integrated with services via a novel work-flow engine, such that it can be explored to provide unique services to each elderly person. Initial practical tests show this flexibility and demonstrate that the robot is ready for pilot-trial evaluation with real users.

Keywords: ICT-based Services, Social Robots, Elderly Care.

1 Introduction

Robots are programmed under the assumption that most information is known beforehand. This means that developers attempt to establish a set of needs for end-users at the beginning of the development stage and that these remain static. However, elderly needs are constantly changing [6], which is motivating research intensification in context aware services [9] in the later years. The truth is that service providing platforms are still at an early Technology Readiness Level (TRL) in what elderly care is concerned. Elderly care systems have their services mostly restricted to the following categories: monitoring, social connectedness, reminders, entertainment. These services are provided in a passive way, which means they mostly wait for the user to interact with them or they simply forward information to other responsible people. There are numerous approaches developed within large projects in the AAL domain. Next we describe three examples that we believe to be representative of the current state of the art.

The Companionable [2] possesses diary management, aide monitoring services or video conference support, which are managed through a touch screen interface which the user has to actively navigate. It also has the ability to detect falls and forward such event to carers so they can take necessary measures. The platform is preprogrammed in advance, therefore limited to the provided services. Also, apart from the personal daily management, there are no services that take into consideration user preferences or their disabilities. The Echord Astromobile [5] is a robot that interacts with the user using natural language. It has a unique ability to directly assist user mobility and navigation on demand using voice commands. Like the Companionable, it has reminders for medicine and a compartment to carry objects to the elderly and supports telepresence. It is a reactive platform, which is also preprogrammed and acts when called. Exception made for the reminding services. The GIRAFF Plus [3] project improved the Giraff platform to monitor the elderly activity, health signals. It has a skype like interface that allows virtual socialization of the elderly and monitoring. The system is said to be customized to the elderly needs, but this is done prior to deployment. It does not have the ability to be customizable after deployment and new service installation demands the robot to be reprogrammed. Despite their success, their are built to meet general needs and do not provide a level of personalization that will allow to enhance service provision, where most relevant information is requested directly from the users.

In SocialRobot we explore a user-driven paradigm, were services are highly adaptable to dynamic parameters and benefit from the knowledge of the end-users preferences and personal information provided by a system component, Social Care Community Network (SoCoNet)[7, 11]. The proposed architecture is highly modular, which combines different functions of the platform to provide different services. 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. SoCoNet enables the effective administration and coordination of independent user profiles and virtual care teams (VCTs) around the elderly person. It ensures a unique personalized profile of disabilities and abilities, special needs and preferences that are constantly updated during the life of the elderly and are used to promote personalized care provision.

2 SocialRobot Architecture and Robotic Platform

The proposed architecture for the SocialRobot is specified [11] following Service Oriented Architecture approach (SOA) parametrized into different abstraction levels, detailed in the following paragraphs (see also Figure 1 for reference).

- **Hardware**: Refers to the physical input/output components installed in the robotic platform. These include a Touch Screen/Display, VoIP, Sound Speakers, Microphones and Video Cameras for perception and interaction, complemented with a Laser Range Finder for autonomous navigation.

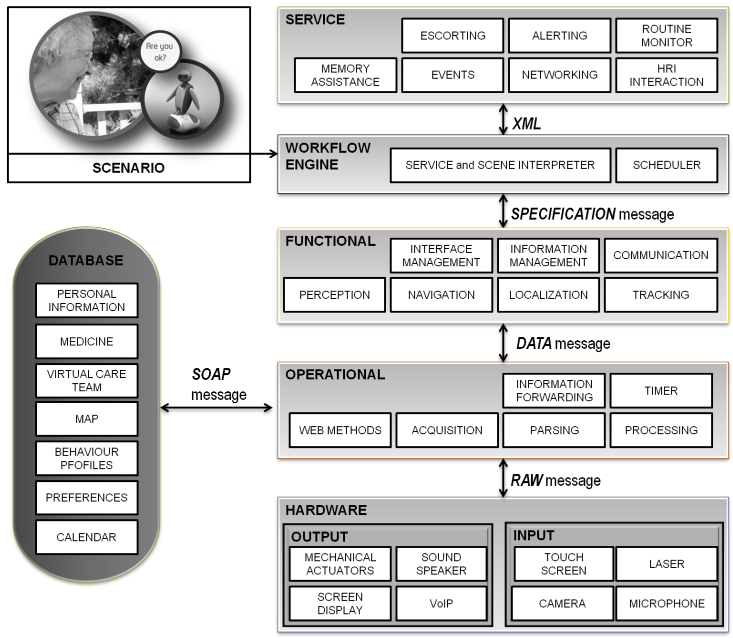

Fig. 1. SocialRobot architecture and information flow.

– **Operational**: Methods which require low-level capability procedures to perform their objectives. Includes modules for basic data processing, querying data from sensors, forwarding data to output devices or parameter parsing.
– **Functional**: Includes algorithms for decision-making and cognitive reasoning (e.g. emotion recognition). Its main task is to assist the discovery of information needs, decision making and management of information.
– **Workflow Engine**: Responsible for the interpretation of a service, orchestration of the required sequence of functionalities that fulfil the associated expectation for that service. (It is designed to include a fail-safe module, which is responsible to determine alternative solutions in case of an error from the functional layer).
– **ICT-based Service**: Designed so as to allow non developers to be able to define new services themselves. It holds XML format descriptions of a service, which are defined as a sequence of functional modules adequate to assist an elderly in a given scenario. The main categories are: 1) Care & Wellness, 2) Guidance and 3) Mobility Monitoring.

The foundation of this architecture is the so called SoCoNet, a framework composed of two main components: a secure database containing elderly profiles and an operational level exposing web-methods that allow accessing and managing such information. Moreover, simple statistical analysis is made, providing a fair degree of autonomous information management, such as promoting highly frequented activities to the preferred categories. Hence, SoCoNet plays a key role in our Service provision paradigm, and is defined as:

- **SoCoNet**: The database is a key element in our framework. It is a knowledge repository containing organized personal information, including user preferences, events and medicine calendar, behaviour profiles and Virtual Care Teams (VCTs). The VCT is a list of associated family members, caregivers, friends or neighbours which form a social pool for contacting in case of emergency or socialization purposes.

The database has a unique Entity Relationship schema, designed to gather and strategically relate different types of information, which can be managed either by the system or by a member of the Social Virtual Care Team. The following two examples, illustrate the type of information that can be provided to and used by the robot or by the caregivers: **Disability**: Stores a list of all possible disabilities a Person may have (impaired hearing, sight issues, walking problems, etc.). **SocialCharacteristic**: Stores a list of all possible social characteristics that the Person may have. Such social characteristics are for example, does not like water activities, does not like outdoor activities, etc. These information types are associated with relation tables. For example, particular emotional states are associated to specific activities (e.g. activity "Card games" with friends make Mrs. Johnson "happy").

The architecture is supported by different frameworks. The **Robotic Operating System (ROS)** is the supporting framework located at the robotic platform. The SoCoNet uses a **Microsoft SQL Server** and a set of **Java Web-Methods** that are exposed via webservice. Communication between both frameworks is ensured by **SOAP-based messages** and standard web communication protocols.

2.1 The Platform

The design and development of the platform [4] has been guided upon close interaction with real end-users, satisfying thus their requirements. The SocialRobot platform is running over a two wheeled differential drive, complemented by two omnidirectional *mecanum* wheels in the back. The development and assembly of the remaining SocialRobot platform can be divided into two parts. The bottom part includes the platform base mechanics with the motors, batteries and low-level electronics, which can be easily adapted to serve different applications. The upper body specifically targets the SocialRobot use case scenarios, includes the installation of high-level devices mounted over an upper structure and the design of an outer shell. The outer shell is can be seen in Fig. 2. The set

Fig. 2. The SR Platform.

of different high level devices used to interact with the environment and specially the users includes a RGB-D camera (Asus Xtion Pro Live) for people detection and tracking and to sense visual user feedback for natural user interaction. It can also be used to detect changes in the surrounding environment, thus assisting the navigation process. An additional camera will be used for analysis of facial expressions and gestures. A microphone array will be used for word spotting and to detect different emotions from the elderly speech. A touch screen will be used to interact with the user, displaying and requesting relevant information. Other sensors are still being evaluated: RFID and UWB.

3 Service Personalization and Function Orchestration

All functionalities are implemented using the Robotics Operating System (ROS). They are exposed as ROS Services, which are constantly available if the system is running. Request and Response service messages contain different types of information which can be used as dynamic parameters in function logic. These functions, may request additional information from the SoCoNet, whose methods can be accessed using gSoap [12] library. The challenge in our system is to develop an orchestration engine, which could execute the necessary functions such way that the platform is able to perform a service to the user. The following sections will describe which functions are available on the robot, and what rules have been established to govern the work-flow engine. We end this section, discussing how our strategy allows for an adaptable, flexible and personalizable service provision.

3.1 Robot's Functional Capabilities

The functionalities implemented in the platform are exposed to the work-flow engine as ROS Services. They are categorized into perception, navigation, (data) communication and interaction. In Table 1 presents their descriptions.

A service emerge from a combination of different available functionalities, that accept dynamic parameters mainly coming from the perception and interaction categories. The following section will describe how does the robot executes each of this functionalities such way that they create a service.

3.2 Service Work-flow Engine Rules

Unlike other known service robots, our architecture offers an intuitive XML-based service orchestration, minimizing the need for expert developer intervention (c.f. Figure 3). To define a service, we only need to select some functions and specify their execution rules. During the first stage of a service interpretation, the work-flow engine is responsible to assess service integrity, which means it has to verify that the functional sequence meets input/output requirements and the defined rules. The following paragraphs introduces the parameters and how the work-flow engine interprets them while executing multiple services.

Table 1. SocialRobot platform functionalities.

Category	Function	Description
Perception	face_recognition	Captures an image from the available vision devices identifies the face of the person in front of the robot. Can detect multiple faces and is based on the ROS face_recognition package.
	emotion_recognition	Records audio and identifies a set of different emotions. It is based on the opensource OpenEar software [8].
	object_recognition	Capability of recognizing objects. Experimental phase only.
	word_spotting	Using CMU PocketSphinx software, we are able to robustly recognize 20 different words, in a semi-controlled sound environment.
	gesture_recognition	Capability of recognizing 5 different hand gestures and 5 body movements to interact with the robot. Experimental phase only.
Navigation	go_to	Using the ROS navigation stack, the robot goes to specific locations in the environment. It requires a model of the environment, where real time data detects changes and updates the existing model.
	person_tracking	Using the ROS Openni2 stack we can detect body skeletons whose data is used to control the navigation for appropriate interactive robot pose.
	patrol_location	Given a map of the environment, the robot uses an optimized patrolling strategy [10] to go around the environment.
Comm.	soconet_call	Set of functions responsible for accessing and managing the elderly information located in the SoCoNet database.
Interaction	speech_synthesis	A database of pre-defined speech recording is used by to robot to verbally interact with the user. The voice and tone are selected according to specific parameters.
	information_display	Module responsible for displaying relevant information in the tablet interface, e.g. agenda or calendar.
	social_connection	We use a skype interface to establish remote communication between the elderly and members of the Virtual Care Team. In the future will support SMS messaging system.
	dialogue_management	Uses the above modules to orchestrate an intelligent dialogue with the user to efficiently execute a service according to elderly needs.

Order: Functions may need to be executed in a specific order, this parameter defines such order.

Mandatory: Some functions are mandatory, some are not. For example, there might be different ways of identifying a person: by the voice or face for example, the first function achieving this goals, stops the other.

Preemptive: This parameter gives a function the ability to stop other functions, issuing a signal when it finishes its job.

Dependencies: this parameters identifies if this function depends on information coming from other functions, and only executes after all dependencies have finished their jobs and published the required information.

3.3 Personalizable Service Provision

Existing robots are built to provide limited services which have been programmed *a priori*, upon analysis of end-user group requests. A pre-defined service will surely fail to fulfil elderly needs throughout the ageing process. We argue that a service should attend, if possible or applicable, to all aspects of the elderly status at each moment (psychological, physical, etc.). Also, we found that when

```xml
<Service>
    <ServiceName>Skype Call</ServiceName>
    <Description>Robot goes to a person to make a daily call to a friend via skype.</Description>
    <Function>
        <Name>Navigation to Person's Room</Name>
        <CallBack>Navigate_To</CallBack>
        <Order>1</Order>
        <Mandatory>true</Mandatory>
        <Preemptive>true</Preemptive>
    </Function>

    ... //Includes close tracking to position itself in front of a person.

    <Function>
        <Name>Face Recognition</Name>
        <CallBack>Face_Recognition</CallBack>
        <Order>3</Order>
        <Mandatory>true</Mandatory>
        <Preemptive>false</Preemptive>
        <Dependencies>Navigate_To</Dependencies> //Only performs face recognition after
        //... Navigation concludes.
    </Function>
    <Function>
        <Name>Skype</Name>
        <CallBack>Skype_Call</CallBack>
        <Order>4</Order>
        <Mandatory>true</Mandatory>
        <Preemptive>false</Preemptive>
        <Dependencies>Face_Recognition</Dependencies> //Needs a positive ID to locate
        //... friends name from SoCoNet.
    </Function>
</Service>
```

Fig. 3. Example of a XML definition of a service.

proper education is given to elderly on how to properly use a service providing platform, it increases it acceptability, as other success stories have already shown (e.g. Co-LiVing Project[1]). Moreover, services are often limited to monitoring and reminding. Typically, these platforms are passive, which means they wait for the user to engage on the interaction process or forward relevant information to other responsible parties, such as caregivers of family members. By exploiting personal information, we propose an active service providing strategy that uses its monitoring capabilities to actively start a service. A situation which is best explained through a simple example scenario from the SocialRobot project.

Scenario: *In its regular walk around, SocialRobot navigates to Mrs. Johnson's room using the known house model and the navigation stack. It then calls the person tracking (based on RGB-D data), that together with the navigation stack allows it to position itself in front of her. The robot asks Mrs. Johnson if everything is fine with her. Mrs. Johnson response is captured by the microphones and the signal is given to the openEar-based functionality, detecting that her emotional state is "sad". It queries SoCoNet for a list of Mrs. Johnson preferred actions that are known to make her "happy". (From the knowledge base of personal profiles, the robot has access to the information that certain actions are likely to influence Mrs. Johnson emotional state). Therefore, the robot suggests her, based on yes/no questions, if she would like to call her daughter on skype, or to engage in a social activity, which will take place a few minutes later. Mrs. Johnson wants to talk with her daughter and SocialRobot calls the Skype function to fulfil her wishes.*

The solution to solve this scenario is an example of the efficient exploitation of the information in the database. Preference and priorities for different persons allow each user to have an engaging and personalized experience with the services provided by the robot. When the detected emotion states are under a specified threshold, the robot will request confirmation of the emotional state using a yes/no question (e.g. "Are you sad?").

One of the challenges concerning our proposed approach is the learning phase, which is the problem of associating preferences and priorities to a specific person. Presently, this information is inserted and supervised by members of the elderly VCT or obtained from elderly explicit feedback (yes/no questions) during the interaction phase. The information in the database can be accessed remotely through a friendly user front-end, that allows authorized members to manage this information along time. Moreover, the robot by itself maintains a history of information, which from time to time it uses to automatically update the Person Profiles, e.g., frequently attended activities will gain priority over others.

4 First Practical Experiments

Our assessment is divided into two different stages: 1) thorough testing of the different functionalities of the system, as well as their integration using ROS; 2) two simple complete scenario tests. The functionality tests show that in controlled environments (limited sound sources because of speech recognition and controlled environment layout, without significant changes), the perception functionalities have achieved over 85% accuracy in the recognition of persons and emotions. Also, service execution completes successfully most of the trials, where only a residual sample of all performed tests have been interrupted due to technical failures.

After this laboratory assessment, we are already preparing the first pilot-trials. End-user involvement continues to be a priority in the project hence the programmed exploitation activities using the proposed scenarios is being closely accompanied by the end-user institutions and real users. The main outcome of these activities is twofold: 1) to assess end user acceptance of the robot while executing services; 2) verify the obtained laboratory scenario execution is transferred when operating in real environments. One particular concern within user acceptance is to evaluate to what extent do the users feel they are always in control of the operations. To get such feedback, after a battery of tests we will ask users to fill a questionnaire. The target is to get the feedback and increase of motivation and reduction of hesitations in carrying out their daily routine with the support and company of the SocialRobot. Regarding the platform itself, the physical aspect of the platform has been already approved by end-users.

With these goals in mind two different pilot-scenarios were prepared, that have already been exhaustively tested in laboratory. Similarly to the example in Figure 3, we describe service and its execution step by step by the robot:

[1)] goes to a specific room (`go to`).

[2)] approaches a person (`person tracking`).

[3)] recognizes person (`face recognition`).
[4)] checks for medicine in a frame of time (`SoCoNet call: check medicine`).
[5)] checks for activity in a frame of time (`SoCoNet call: check activity`).
[6)] inquires the person (`speech synthesis`).
[7)] extracts emotion from response (`emotion recognition`).
[8)] suggests activity by emotion (`SoCoNet call: suggest activity`).
[9)] resumes its previous task (`patrol location`).

At any instance, if the user starts to feel uncomfortable with the robot, it may shut it down by pressing a big red button, located at the back of the platform. At this instant, the robot will launch an alert to the relevant members of the VCT, warning them that it will be disconnected and they need to take the appropriate measures. After this safety procedure, the robot goes to its base station and shuts down. The tests will occur simultaneously with the forthcoming project's review meeting, with special invitations to interested end-users. Their participation in the tests of this preliminary scenario, aims to attract both research and industrial stakeholders and promote know-how transfer in the projects technology and results at a European and an international level, so as to define a market penetration strategy. The invited end-user institutions will be explained the modularity of the system and promote a discussion of other use case scenarios that can be solved using our proposed architecture. Results and videos will be available in the project's official website http://mrl.isr.uc.pt/projects/socialrobot.

4.1 Discussion

The fact the end-users participate iteratively in the design process of the robot makes it more acceptable in terms of appearance and functionalities. The parametric nature of our architecture allows for new functionalities to be coded and installed seamlessly in the robot by platform developers. This means that new services can be deployed by platform users and defined without requiring additional programming effort but the one of defining the XML service. The use of the SoCoNet allows providing preference aware services that meet elderly needs. This is a characteristics that promotes user acceptability, because they get a real feel that the robot is attending their needs, like it actually knew them. One key issue addresses the robot autonomy and when does it start to get uncomfortable for the user. Initial tests and discussions with end-users indicate a positive reaction to the personalised service provision. However, one specific request is the possibility for them to interrupt the robots operation at any time they wished. At this stage, this is the agreed solution, however long term use of the platform may dictate additional limitations to robot's autonomy and knowledge. Our development efforts had into consideration the boundaries of such knowledge and therefore have mechanisms that may restrict and limit the robot operation to a comfortable level for the elderly. We do not wish for the robot to overcome the elderly in their decisional power, unless, of course, in case of emergencies. Our current limitations are linked on the use of existing toolboxes and algorithms for the perception stage, which like most state of the art, work perfectly in controlled environments but need to be improved to endure the practical challenges of real world operation. We will perform exhaustive pilot-trials of our approach and improve the architecture and functionalities based on the obtained feedback. Apart from the pointed limitations, our efforts are focused on extending the functionalities of the robot and testing different combinations to generate other services that can create value and assist elderly in their daily life.

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