SocialRobot: An Interactive Mobile Robot for Elderly Home Care

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Abstract— **SocialRobot is a collaborative European project, which focuses on providing a practical and interactive robotic solution to improve the quality of life of elderly people. Having this in mind, a state of the art mobile robot platform has been integrated with virtual social care technology to meet the elderly individual needs and requirements, following a human centered approach. In this paper, we make an overview of SocialRobot, addressing mainly the integration of the platform and the architecture developed for the project, as well as the existing robot services, the human-robot interactive scenarios prepared, and results extracted from experimental tests with the mobile robot platform.**

I. Introduction

Several demographic studies report that Europe's population is aging, as the average life expectancy over the years increase [1]. As a consequence, the elderly care market is growing, revealing a huge unexplored potential. In order to address these challenges, there is growing attention for assistive technologies to support seniors to stay independent and active for as long as possible in their preferred home environment. Robotic systems are among those initiatives offering 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. The SocialRobot Project[1] aims to provide an answer to this demographic change challenge. Therefore, an integrated Social Robotics system is under development to address key issues for improved independent living and quality of life of the elderly people.

The solution involves a practice-oriented home care mobile robot platform targeted to people with light physical or cognitive disabilities who can find pleasure and relief in getting help or stimulation to carry out their daily routine. The platform provides personalized services based on user information, their preferences and routines, tackling the area of preventive care at an early stage of the aging process. This is possible by integrating state of the art, standardized and interoperable robotic technologies and ICT-based care and wellness services, and benefiting from a virtual social care community network.

In the remaining of this paper, we overview seminal work on Social Robotics and Assisted Living, with special focus on domestic and service robots for elderly care. Afterwards in Section III, the SocialRobot solution is described. In section IV we outline a representative use-case scenario to showcase the robot operating in an indoor environment and discuss the results. Finally, the article ends with conclusions and future work.

II. Related Work

Several domestic robots with distinct features and configurations have been proposed to assist the elderly in the past. One of the pioneer robots in this area was Flo [2] developed at Carnegie Mellon University. It used natural language to provide information related to activities of daily living obtained from the web, and it also enabled remote caregivers to establish telepresence in people's home. A totally different approach is behind the seal robot Paro [3], which can be found in several care institutions around the world. This is a therapeutic interactive robot that resembles a baby harp seal, which has been found to reduce stress, stimulate interaction with caregivers, and improve relaxation, motivation and socialization of its user. The robot responds to sounds and petting by moving its tail and opening/closing its eyes. It can also simulate emotions such as surprise, happiness and anger.

Recently, innovation in robot and sensor technology, as well as in human-robot interaction [4], people detection [5], and autonomous navigation [6] have allowed the emergence of new and more advanced social robots. In [7], 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. Similarly, the Florence robot platform [8] aimed to improve the well-being of the elderly by providing connectivity, reminders, fall detection, encouraging activities, gaming and interface with home devices. Other notable service robots include the Care-O-Bot [9], PR2 [10] and Linda [11].

Nevertheless, there are still several issues to be taken into account concerning the use of robots for elderly home care. For instance, it has been shown that robots are more likely to be accepted by humans when they are modeled to show an infant similar behavior [12]. Furthermore, different older persons care studies [13], have identified that the combination of emotional, behavior and environmental

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[1]http://mrl.isr.uc.pt/projects/socialrobot

factors play a key role in the older person care experience. Additionally, technological solutions that address all of these factors lower social and economic barriers towards a more universal usability [14]. Acceptability depends not only on what robots can offer to people (*e.g.* entertainment, status gain, practical benefits), but also on people's intrinsic features (age, needs, gender, experience with technology, cognitive ability, education, culture, role, expectation and attitude towards robots), as well as robot intrinsic features (safety, usability, intelligence, appearance, humanness, facial expressions, size, gender, personality and adaptability) [15], [16], [17].

Nowadays, various ways to improve monitoring and assisted services have been target of keen research by different groups with a strong support by the European Commission. In fact, the EU funded different specific research programmes, such as the Ambient Assisted Living Joint Programme (AAL-JP). Examples include Miraculous-Life (FP7)[2], which aims to design, develop and evaluate an innovative user-centered Avatar based solution, attending to the older person's daily needs and behavior changes, while they go about their normal life; CogniWin (AAL)[3], which targets older people in working environments by providing an innovative personalized system to support and overcome eventual aging related cognitive degradation and gradual decreasing of memory and cognitive capabilities; or DOREMI (FP7)[4], which targets the three main causes of premature mortality: malnutrition, sedentariness and cognitive decline, by developing a systemic solution for the elderly, able to prolong the functional and cognitive capacity by unobtrusively monitoring their daily activities, thus empowering and stimulating them so as to promote active lifestyle management and social inclusion.

Following a user-driven approach, we consider the elders as active collaborative agents able to make personal choices and the care model is adapted to their lifestyle, personalized needs and capabilities changes over the aging process. This elderly support paradigm maintains their self-esteem in managing the daily routine at home. In this paper, we present an appealing mobile robot able to navigate in indoor environments and provide affective and empathetic user-robot interaction, taking into account the capabilities and acceptance by elderly users, and the issues of size, shape, color and acoustic. The SocialRobot platform concentrates on the essentials of personalized care provision to reach affordability. It leverages a modular architecture, which enables seamless integration of new modules and capabilities. Therefore, the existing platform can be expanded with new functions, knowledge and services to continuously meet user needs. As a technological solution, this presents a clear economic benefit, able to exploit the rapid technological advances and also to cope with the constantly changing needs of elderly people, thus avoiding becoming obsolete.

[2]`http://miraculous-life.eu`
[3]`http://cogniwin.eu`
[4]`http://doremi-fp7.eu`

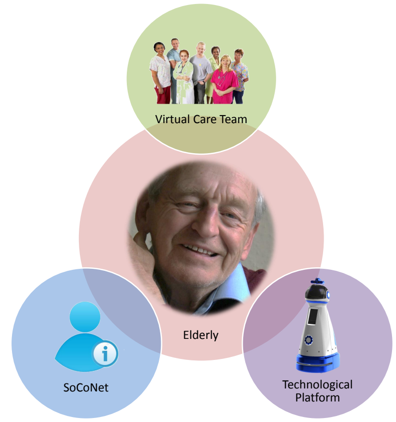


Fig. 1: SocialRobot General Concept.

III. The SocialRobot Solution

In this project, a modular service robot architecture, following a user-driven philosophy, has been proposed. This is shown in Fig. 1. A Social Care Community Network (SoCoNet) encourages and supports communication, assistance and self-management of senior citizens, promoting seamless connection and interaction to different people in their virtual care team (VCT) of all ages at any time, where the robotic platform will act as a form of an intermediate agent between the elderly and the social care community. In the following subsections, we will overview the architecture defined in the project, the hardware and sensors included in the mobile robot platform, and the robot services that expose intelligent capabilities for human-robot interaction.

A. Architecture

Development on the SocialRobot project followed the principles of a Service-Oriented Architecture (SOA), whose modularity design maximizes the benefits of multidisciplinary contributions from researchers of different areas. It is virtually impossible to identify all the elders' needs in advance, since their sensitive condition leads to constantly changing needs. The proposed methodology fosters services adaptability. It allows for them to continuously fit elderly specific needs efficiently and improve the quality of a service without requiring redeveloping it entirely. Thus, we propose a hierarchical approach where complex servicing tasks are recursively broken down into simpler operations. The proposed SOA-based model is presented in Fig. 2.

SoCoNet was implemented so as to provide a secure web-based virtual collaborative social community network that enables the effective administration and coordination of the user profiles and VCTs around the elderly person [18]. SoCoNet has been designed and maintained regardless of the robotic platform used. Therefore, robot services are supported by SoCoNet towards an active and personalized assistive care. This way, it ensures a unique personalized profile of disabilities and abilities, special needs and preferences, stored in a secure database (*cf.* Fig. 2, left-hand side), thus promoting personalized care provision. Furthermore,

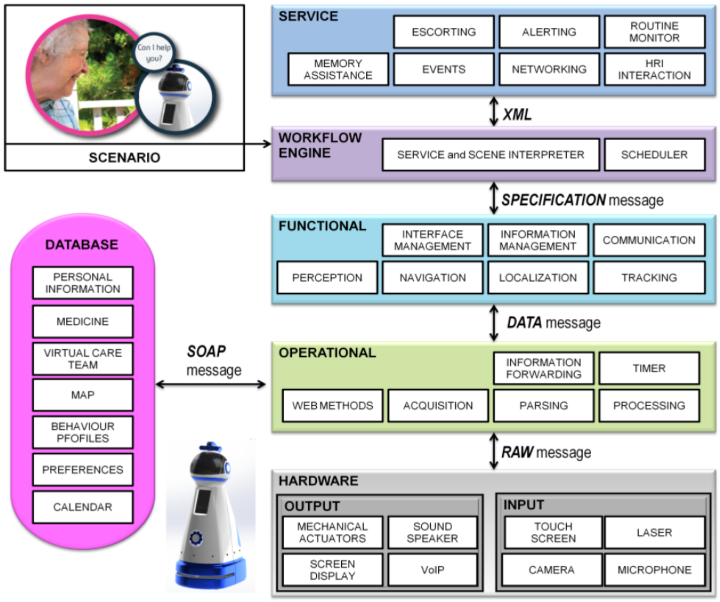


Fig. 2: Architecture Overview.

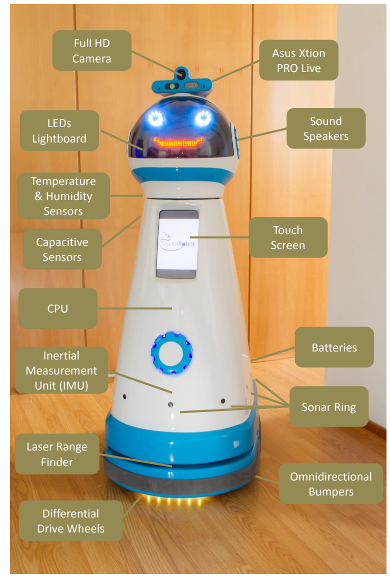


Fig. 3: Platform Hardware, Sensors and Devices.

SocoNet supports intelligent management techniques, which dynamically adapt the content included in the database throughout the elderly aging process, enabling the update of preferences, priorities, routines and so on.

Moving on to the remaining modules of the architecture, the hardware layer includes physical components that provide input/output resulting from the interaction of the mobile robot with the real world. The operational layer encompasses low-level methods, mainly to retrieve, parse and process data from the physical components and the intelligently managed SoCoNet database. The functional layer includes intelligent algorithms for decision-making and cognitive reasoning capabilities. The Workflow Engine is responsible for the interpretation of a service that the robot provides to the older person, and orchestrating a sequence of required functionalities to fulfill the service provision to the user. Finally, on top of the hierarchy is the definition of all services that the robot is expected to deliver to the elder.

To promote scalability and layer abstraction, inter-layer communication is minimized, such that it is limited to adjacent layers. This approach mitigates functional dependencies. In addition, interaction between adjacent layers makes use of a standardized set of inputs and outputs. The Robot Operating System (ROS) is the supporting framework located in the robotic platform. The SoCoNet uses a Microsoft SQL Server and a set of Java Web-Methods that are exposed via web services. Communication between both frameworks is ensured by SOAP-based messages and standard web communication protocols. This architecture aims to establish a clear separation between service design and low-level development.

B. Hardware and Sensors

Services are actively provided by an appealing and affordable mobile robot platform [19]. Illustrated in Fig. 3, the platform is a two wheels robotic base, with a structured body and robotic head with several integrated sensors. The robot's height is 125 cm in order to be socially acceptable and dynamically stable. This enables to fulfill the goal of promoting the interaction between the elderly, family, friends, and carers supported by the robotic platform and the SoCoNet.

Besides basic physical safety of the people handling the robots, safety concerns are directly related to Ethics issues and of paramount importance in social environments. Safety measures are embedded at both hardware and software levels. Unexpected collisions can be detected at hardware level (triggered by the robot's bumpers) and bypass all decisions levels to stop the robot. Another important issue is the price of the platform. The project is pursuing a solution that can fulfill the project requirements and at the same time minimize the cost of the final technological platform to ease the process of future commercial exploitation.

In terms of sensors and devices, the robot is endowed with a Full HD *Microsoft LifeCam Studio* Camera; a RGBD *Asus Xtion PRO Live* camera, which also includes an infrared sensor and two microphones; a programmable array of LEDs forming the SocialRobot's face; audio amplifier and stereo sound speakers (in the robot's ears); a 10″ touch screen for user interaction; temperature and humidity sensors (inside the robot body); capacitive sensors to detect if a person is touching (in the robot's back); an *MPU6050* inertial measurement unit (IMU) inside the robot provides the estimation of orientation as well as accelerometer, gyroscope and compass data; 12 *Maxbotix EZ4* ultrasonic sensors around the robot to detect proximity of obstacles; an *Hokuyo URG-04LX-UG01* Laser Range Finder for navigation and mapping; omnidirectional bumpers; and two differential drive wheels (together with two omnidirectional wheels on the back).

The robot is also equipped with a *mini-ITX* computer board with an i7 quad-core processor, RAM, SSD and several peripherals (USB ports, Ethernet ports, audio ports, etc.). In addition, several electronic boards were installed for sensor management and motor control. Finally, the robot is powered by three 12 V, 14Ah LiFePO4 batteries, providing autonomy of up to 5 hours in continuous operation.

C. Service Provision and Robot Capabilities

Unlike other service robot solutions, the SocialRobot architecture offers an intuitive XML-based service orchestration, minimizing the need for expert developer intervention. The service module is designed so as to allow non developers to define new services themselves. This is done through XML format descriptions, which are comprised by a sequence of functional modules and parameters such as execution order, to adequately assist the elder.

This way, by applying the proposed architecture, a service robot can for example search actively for an elderly person to assess his/her status (feeling sad, bored, etc.) and perform specific actions in a personalized way, according to his/her preferences. In order to do so, the Workflow Engine is responsible to interpret the XML description of the service called, assess its integrity (*e.g.* guarantee the required models are running), and execute any necessary algorithm from the functional layer of the architecture to provide the requested service. A clear and simple example of an XML service definition is given below.

```
<Service>
        <ServiceName>Skype Call</ServiceName>
        <Description>Robot goes to the older person's room to make a
        daily call to a friend via Skype</Description>
        <Function>
                <Name>Navigate to Person's Room</Name>
                <Callback>Navigate_To</Callback>
                <Order>1</Order>
                <Mandatory>True</Mandatory>
                <Preemptive>True</Preemptive>
        </Function>
        <Function>
                <Name>Identify Person's Face</Name>
                <Callback>Face_Recognition</Callback>
                <Order>2</Order>
                <Mandatory>True</Mandatory>
                <Preemptive>False</Preemptive>
                <Dependencies>Navigate_To</Dependencies>
        </Function>
        <Function>
                <Name>Call friend on Skype</Name>
                <Callback>Social_Connection</Callback>
                <Order>3</Order>
                <Mandatory>True</Mandatory>
                <Preemptive>False</Preemptive>
                <Dependencies>Face_Recognition</Dependencies>
        </Function>
</Service>
```

The robot is fully integrated in ROS (*cf.* Fig 4), being capable of performing several tasks, such as indoor navigation and mapping [20], and provide affective and empathetic user-robotic interaction, taking into account the needs of the elderly users. Therefore, the robot capabilities are exposed to the Workflow Engine as ROS Services[5].

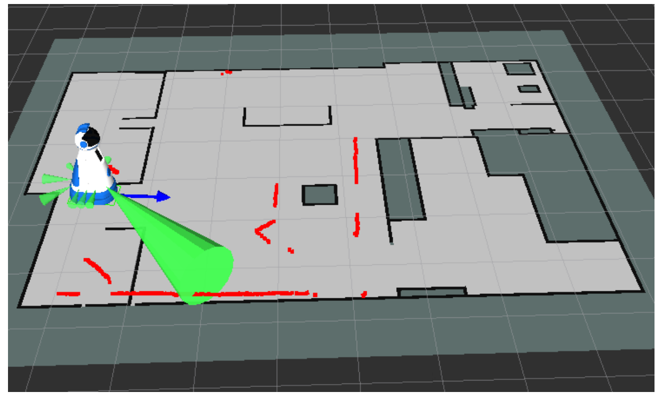


Fig. 4: SocialRobot platform navigating in an indoor office-like scenario, as seen in the ROS visualization tool (*rviz*). Green cones and red dots correspond to sonar and laser range readings respectively.

The developed functionalities can be categorized into perception, navigation, data communication and interaction. Below, we provide descriptions of several examples of functionalities developed and in ongoing development on the robot using ROS. Each of these is composed of different low-level methods which interact with the hardware and the database.

- *face_recognition* (perception): visual recognition of known (trained) faces using the robot's camera. Based on the available *face_recognition* ROS package.
- *emotion_recognition* (perception): real-time emotion and affect recognition through speech. Based on the *openEAR* software.
- *word_spotting* (perception): recognition of a limited set of simple words through speech. Based on the *pocketsphinx* ROS wrapper.
- *navigate_to* (navigation): indoor navigation to a specific place/room in the environment, leveraging the ROS *navigation* stack.
- *approach_person* (navigation): generic people detection and safe robot approaching. Based on the ROS *people* stack.
- *monitoring* (navigation): autonomous patrolling of a known environment. Based on the work described in [21].
- *docking/undocking* (navigation): when necessary, the robot drives itself towards a docking station and autonomously recharge its batteries to allow continued operation without human intervention.
- *soconet_call* (data communication): set of functions responsible for retrieving and managing the elderly information located in the SoCoNet database.
- *speech_synthesis* (interaction): predefined text-to-speech recordings via the SAY Speech Synthesis Manager used by to robot to verbally interact with the user.

[5] In ROS, a service is the way of implementing a synchronized request-reply communication. A providing ROS node (application) offers a service, and a client calls the service by sending the request message and awaiting the reply.

• *information_display* (interaction): module responsible for displaying/retrieving relevant information in/from the tablet interface.

• *social_connection* (interaction): skype interface to establish remote communication between the elderly and members of the VCT.

IV. Experimental Scenario and Discussion

After the system integration and extensive testing of the different modules, a validation stage got underway. End-user involvement has been a priority ever since the beginning of the project, namely in the requirement specification stage, system design and prototype testing. Initial feedback has shown positive end user acceptance to the support of the SocialRobot platform, which was found friendly and fun to interact with. A test scenario deemed as useful for the end-users and at the same time representative of the current robot development stage is discussed in this section.

Having in mind that the system should provide ICT-based personalized services such as reminders and assistance, recognition of abnormal behavior and alerting, suggestions and guidance for daily activities, the following scenario was defined:

1) Robot enters a specific room (`navigate_to`).
2) Robot approaches a person (`approach_person`).
3) Robot recognizes person (`face_recognition`).
4) Robot inquires the person (`speech_synthesis`).
5) Robot extracts emotion from response (`emotion recognition`).
6) Robot suggests activity according to the emotional state and personal preferences (`soconet_call: suggest activity`), *e.g.* call a friend or a caregiver (`social_connection`).
7) After completion, the robot says goodbye (`speech_synthesis`), and visits other rooms (`monitoring`).

The presentation of this scenario aims to attract both research and industrial stakeholders, and disseminate the project's results at an European and International level. Therefore, a video of the experiments has been prepared[6]. Important steps of the scenario described above are presented in Fig. 5.

Results have shown that the robot is able to properly navigate indoors, even in tight spaces using its range sensors (*e.g.* when it enters the room's door as shown in Fig. 5a), and leveraging the environment's knowledge, which was mapped by the robot *a priori*. After entering the room, the robot actively looks for the eventual presence of people by visually detecting possible faces based on a cascade of Haar-like features, and then pruning false positives using depth information from the RGBD camera. The 3D position of the person in the depth sensor frame of reference is extracted, and a goal is sent to the navigation software for the robot to move closer and face the unknown person (Fig. 5b). Results have shown the reliability of the person detection software, since even in low lightning condition the robot is able to approach a person thanks to the available depth information.

In the next step, the face recognition process to identify the person assumes 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. This way, using a Haar cascade classifier a person's face can be recognized in real-time due to its unique features (Fig. 5c).

After greeting and inquiring the identified person, the robot extracts emotion from his verbal reply (Fig. 5d) with an accuracy of over 82%. In the scenario presented, two different replies trigger different actions. In the first example, the robot recognizes that the user is feeling *sad* and suggests him to interact with a friend on Skype (Fig. 5e). This is based on the VCT members of the user and their contacts, which are retrieved from the SoCoNet. In the second example, the robot recognizes that the user is feeling *bored* and based on the user agenda and his preferences stored in the SoCoNet, the robot suggests him to play cards with a group of friends.

Finally, after the interaction is complete the robot bids farewell and leaves the room (Fig. 5f) to resume its monitoring task.

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. Moreover, the semi-controlled scenario presented consisted of limited sound sources, a structured layout and adequate lightning conditions. In the short- and mid-term future, we intend to verify whether the obtained success can be transferred when operating in uncontrolled real world environments.

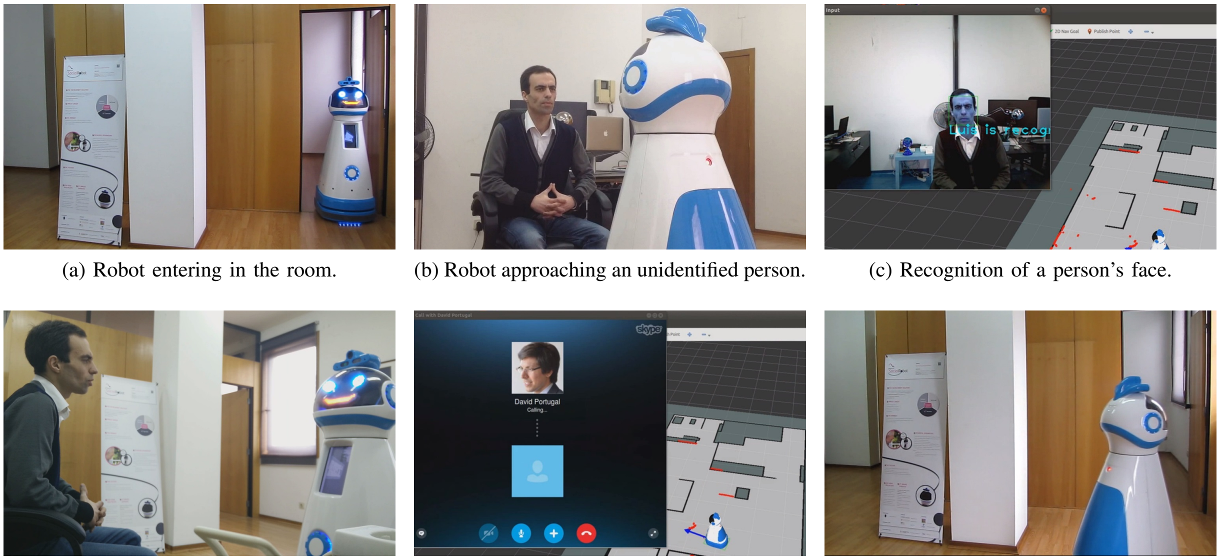
V. Conclusion and Future Work

In this work, an overview of the SocialRobot framework and a use-case test scenario has been presented. The ongoing project places emphasis in supporting the elders to maintain their self-esteem in managing the daily routine by addressing their security, privacy, safety and autonomy. The system not only considers seniors as active collaborative agents able to make personal choices, but also adapts the care model to their lifestyle, personalized needs and capabilities changes over the aging process. Furthermore, it provides a modularly designed platform that supports carers, both family members, friends and therapists, in their daily tasks.

Innovation emerges from the human-robot interaction perspective (*e.g.* emotion and face recognition, and empathetic interaction); the software perspective (*e.g.* adaptation to the related context of daily routine occurrences as elderly age); the robotic perspective (*e.g.* robot design and autonomous behavior); and the social care model perspective (*e.g.* an elderly practice-oriented model integrating new types of social interaction, robotic monitoring and wellness services).

In the future, we plan to develop additional robot services according to the research and industrial stakeholders needs, and further explore the project's results so as to define a penetration strategy in the AAL and elderly care market.

[6] https://www.youtube.com/watch?v=If2FRVdR0K0&hd=1



(a) Robot entering in the room. (b) Robot approaching an unidentified person. (c) Recognition of a person's face.

(d) Robot interacting with a known person. (e) Social connection with a friend via Skype. (f) Robot leaving the room.

Fig. 5: Main steps of the experimental scenario defined.

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