A Multi-Actor Framework Centered around an Assistive Mobile Robot for Elderly People Living Alone

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Abstract— **In a social and economic context characterized by a constantly aging population, the research for new technologies able to assist elderly people is getting more and more attention. In this extended abstract we illustrate the main components of the European project MoveCare, a multi-actor framework designed to assist pre-frail elders living alone. The proposed system is centered around an assistive mobile robot that provides the user with a set of functionalities to support cognitive and social stimulation, assistance, and transparent monitoring.**

I. Overview

In this extended abstract we present the general framework of the H2020 MoveCare project [1]. The main aim of the project is to develop an innovative, multi-actor platform that supports the independence of elderly people living at home through monitoring, assistance, and stimulation provided through activities developed to counteract physical and cognitive decline, as well as isolation.

Lifestyle changes and increase of activity have been proposed as an effective way to contrast or limit cognitive decline when dealing with on-pharmaceutical treatment of Mild Cognitive Impairment (MCI) [2], [3], but a definite solution for this problem tackling early stage cognitive decline is largely missing. Assistive robots for elders with MCI or with cognitive impairment have been introduced in several projects as [4], [5], with promising results.

In order to target our approach to a specific set of needs, depending on each person's age and health (both cognitive and physical), we decided to focus on specific users. Namely, on people who:

- have retired from work,
- are living on their own in their home and are responsible for their Activities of Daily Living (ADL),
- are classified as in a pre-frailty state, having at most mild cognitive impairment (MCI) and little to none physical impairment [6].

This decision resulted in a set of inclusion criteria (not explicitly provided for brevity) that are roughly satisfied by relatively healthy elders, aging between 65 and 75, that live alone, and that aim to continue living independently at home as long as possible.

The MoveCare project supports such aim by tackling several potential risk factors (such as social isolation) by

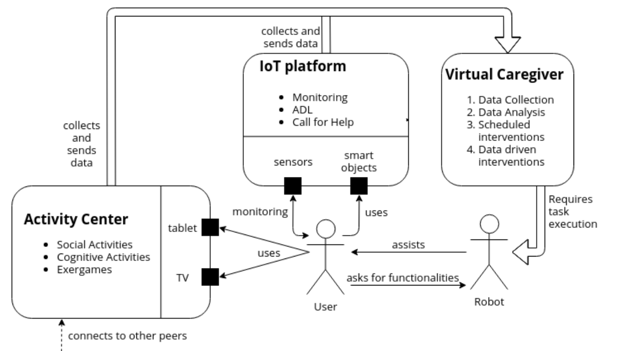

Fig. 1. Outline of the main components of the project and of their interaction.

focusing on two main targets: the development of direct *interventions* in order to encourage the elder to keep an active lifestyle and to socialize, and a continuous and transparent *monitoring* operating at home.

More precisely, interventions are targeted at suggesting and leading physical, cognitive, or social games, as well as physical activities, and at supporting and strengthening the social network of the elder. At the same time, monitoring is performed by collecting data with a pervasive but unobtrusive system composed of physical components (sensors) and virtual components (data collection from digital activities).

The developed system will be tested during a *pilot* phase (to be held for three months in 2019) where all the system's components will be deployed inside the houses of thirty selected participants. Several components developed for the project are already undergoing preliminary testing and evaluation sessions (either in the laboratory or at elders' homes). The first results, not reported here for brevity, are bringing useful insights in terms of acceptability of the platform.

A. Project Outline

MoveCare is a multi-actor framework both composed of virtual and physical actors embedded in each user's home. A partial representation of the main components and of their interactions can be found in Fig. 1. In the following section, we describe such components in detail.

The physical actors are connected together in an Internet of Things (IoT) subsystem, based on Message Queue Telemetry Transport (MQTT, a widespread lightweight publish/subscribe messaging protocol used for mobile devices), deployed in each participant's house, and connected to a centralized cloud-based server, which receives, stores, and analyses all data coming from each user. The IoT subsystem

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is composed by:

- a set of sensors deployed in the environment such as door sensors, proximity sensors, smart plugs, and others, that are used for monitoring. No sensors are worn by the participants.
- A set of smart objects that the user interact with such as smart insoles, a smart pen for monitoring writing, a smart anti-stress ball for measuring grip strength.
- An autonomous mobile robot, based on the Giraff robot platform (see Section II), which is used to provide assistance and direct interventions. The robot's functionalities are detailed in Section II.

Besides interacting with the above components, the user can access a virtual community of users through an application called Community-Based Activity Center (CBAC). Inside such virtual community, the user can participate to social activities with peers. The CBAC also provides other digital activities like exergames, cognitive games, and serious games.

B. *Digitalized Activities*

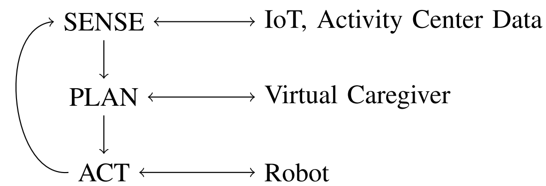
While sensors and smart objects are mainly used for monitoring purposes, the data collected by the digital activities are also exploited for stimulation and intervention. Activities are provided through the CBAC by means of a native Android application on an Android tablet or on a media center connected to the TV (both tablet and media center are provided and installed).

The main goal of activities mediated by the CBAC is to provide a constant but unobtrusive stimulation in order to encourage socialization as well as an healthy and active lifestyle. The activities provided by the CBAC connect elders with peers and caregivers and, at the same time, with the whole MoveCare ecosystem. The social aspect of all activities is particularly stressed within the project. As an example, a set of cognitively-challenging digital games are proposed. In order to discourage alienation, all these games can be played only with two or more participants, and all activities embed an audio/video conference between all participants, so that they can talk and see each other while playing. Besides this, the platform allows to discover and attend together a set of suggested public local events (like concerts, exhibitions, or festivals) based on the user preferences and location, thus bringing the social aspect of the project also outside the user's house. Training sessions are encouraged with a guided platform for performing exercises (training) trough a social activity or trough exergames.

C. *Virtual Caregiver*

The data collected by all physical agents and from the participation and execution of the virtual activities are stored and processed by a cloud-based AI, a digital actor called Virtual Caregiver (VC), which oversees and coordinates all the components of the project.

The entire interaction between all components can be seen, from an abstract point of view, as an instance of the classic Sense-Plan-Act paradigm where the VC collects all the data coming from each 'sensor', namely from each actor of the entire platform. Under this premises, the role of the assistive robot is crucial as it is the only tool in the hands of the virtual caregiver to autonomously interact with the user and to perform actions in the environment.



Consequently, the robot is the connection and the interaction method of the VC with the real world and with the user. This is done by identifying the elder's position (using the IoT sensors), by interacting with him, by providing indications on performing an activity, and by assisting him during its execution.

One example of these interventions involves the suggestion of activities. MoveCare users can freely use the activities proposed by the project. However, if required, the system can detect that user would benefit from participating to one of the activities and can directly intervene with an invitation provided by the robot in order to promote his attendance. In this sense, activities can be promoted or initiated directly by the MoveCare framework. The VC is responsible to tune the frequency and timing of these interventions, in order to find a good balance between their effectiveness and their acceptability. Imagine a situation where the system detects that one of the users has spent a lot of time alone in the last week, also reducing his interaction with other peers. As a response, the robot can reach the elder in order to encourage to play a social game that he likes, on the platform, with a list of suggested peers. More details about interventions are provided in Section II.

The VC is also responsible for collecting all the information obtained trough monitoring for triggering interventions. Monitoring is performed at different granularities. As an example, low frequency data are collected at a daily to a monthly basis, while data indicating an emergency situation (for example, a fall) trigger an immediate response.

II. Robotic Platform

The Giraff robot is a platform progressively developed with the support of projects framed in Eurpean Union calls for ambient assisted living, namely AAL (ExCITE [7]), FP7 (GiraffPlus [8]), and now MoveCare. This robot is especially designed for HRI with elders, including a number of sensors and devices that enables an adequate communication.

In MoveCare, its configuration has been enhanced with additional sensors for a better awareness of the robot's surroundings (refer to Figure 2).

A. *Specification*

In its factory configuration, the robot's hardware consists of a motorized wheeled platform (two wheels with independent drive motors plus two caster wheels) with an on-board

Fig. 2. The Giraff Robot.

computer connected to the Internet through a dual band Wi-Fi dongle, and an height/tilt adjustable *head* consisting of a videoconference setup with a touch-screen, a microphone, a speaker, and a 5Mpx fish-eye webcam. Two physical buttons are placed at the front part for interaction with the user (accept/reject buttons).

Apart from these, in MoveCare, a set of new sensors has been added to the platform to enhance its localization, navigation and interaction capabilities:

- Two Astra Orbbec RGB-D cameras employed to perform user and object recognition, obstacle avoidance and 3D localization and mapping.
- A NVIDIA Jetson TX2 module to process costly operations as user localization and 3D geometric and semantic mapping.
- A Hokuyo URG-04LX-UG01 2D laser rangefinder for robust localization and navigation purposes.
- A RF-ID module and two antennas to perform RF-ID-based object localization.

B. Software Architecture

The on-board PC runs the Robotic Operating System (ROS) as the main environment to execute the software architecture that controls the behavior of the robot. Standardized ROS nodes (e.g. MoveBase, AMCL, etc.), specifically-implemented (e.g. TaskManager, *Human-Robot Interaction* –HRI–, etc.) and third-party ones (e.g. OpenNI, PCL or OpenPose) have been integrated into this framework to provide the functionalities defined in the project. Fig. 3 shows a simplified schema of the nodes in the proposed robotic architecture and their interactions. These nodes are structured into five layers according to their scope and purpose:

HW & Sensors: This layer encompasses nodes traversal to the architecture since they implement the drivers for the sensors and actuators on-board the robot.

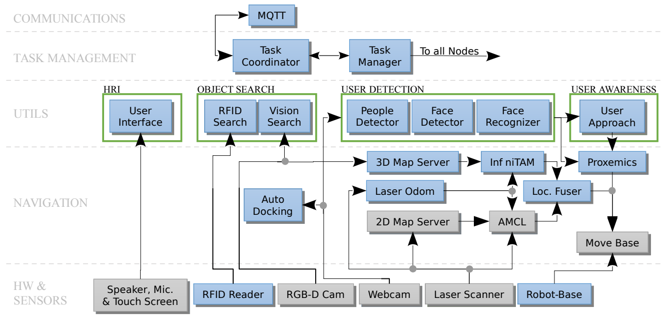


Fig. 3. Diagram of the robot software architecture displaying the connections between the nodes at different abstraction layers. Blue blocks represent nodes implemented specifically for the MOVECARE project, while grey ones are standard ROS nodes.

Navigation: Nodes in charge of autonomously moving the robotic platform, including the generation and management of 2D and 3D maps of the environment, self localization and path planning at both global and local levels (i.e. reactive navigation). Furthermore, autonomous docking/undocking and proxemic navigation (i.e. tacking into account the organization of spaces in the communication between people and objects) are implemented. The latter is handled by means of the so-called *costs maps* defining how and from where the robot should approach the user once he/she is detected.

Utilities: Nodes belonging to this layer provide four main utilities: (i) HRI performed through a multi-modal interaction system composed of voice and visual interfaces, as well as two buttons (green/red) to get the user feedback. (ii) *Object Search*, including nodes for detecting and recognizing objects from either image and depth data from the RGB-D cameras, or by RFID technology. (iii) *User Detection*, in charge of detecting, locating and recognizing users in the house. (iv) *User Awareness*, to safely approach the user attending to the proxemic rules and the obstacles in the environment.

Task Management: This high-level layer includes a task coordinator in charge of scheduling all the intervention requests sent to the robot (e.g. by their priority, their time of arrival, etc.), and a task manager that plays the role of an executor. The latter creates, for every intervention request, a decision-tree-based plan with multiple sub-tasks in order to accomplish the request, executes it and provides feedback.

Communication: The robot interacts with the other components in the system (e.g. Virtual Caregiver, Activity Center, etc.) by means of a set of JSON messages that code both the command and the feedback messages that define each intervention. This communication is carried out with a ROS node that bridges ROS with the widespread MQTT protocol, enabling an efficient and robust communication. The MQTT protocol is used (with the same communication modalities) by all components of the project, thus reporting all messages to shared cloud platform, in a IoT fashion.

C. Functionalities

In Movecare, the Giraff robot provides a set of functionalities or services as the main actuator of the system, embedding the caregiver at the elder's house. These functionalities can be categorized in four classes according to the involved actors:

- **Services requested by the VC with the user as target**. These functionalities are triggered automatically by the VC according to a schedule or information inferred from the environment, and involve the robot to look for the users within the house and approach and interact with them. This service is triggered in scenarios such as: *spot questions* (the user is asked to answer a set of questions to assess indications of cognitive decline), *reminders* (the user is informed about some scheduled task they should perform: e.g. measure their weight), or *invitations* (the user is informed about an activity suggested by the VC: e.g. going out if the weather is nice).
- **Services requested by the user targeted to the VC**. These functionalities play their role in help and emergency scenarios. In this case, the user triggers the intervention by asking the VC for help. The robot is then commanded to look for the user, confirm the emergency and establish a communication with the caregiver (e.g. providing video-conference capabilities).
- **Services requested by the user without implying the VC**. In this category we include the *search for lost objects* service, which is directly triggered by the user by asking the Giraff to find a particular object. The robot will navigate while trying to locate it, depending on the object, either through RF-ID (if it has an RF-ID tag attached to it) or artificial vision.
- **Self-management**. This functionality is triggered by the robot itself in order to maintain a proper autonomy level, including performing auto-docking if the robot has been idle for a long time or the battery level is critical.

III. Pilot Validation and Current Status

The MoveCare project foresees the deployment of a total of 18 Giraff robots: 15 will be used in two testing stages, while the other 3 will remain for development refinement and testing. In this line, the evaluation of the project will be performed with a pilot study involving 30 elders that match the description provided in Section I. The entire system will be deployed for three months inside the house of each participant (in Spain and Italy). There, the complete system will be evaluated according to different factors: (i) social (e.g. impact on the elders' life, usability or user's acceptance), (ii) clinical (e.g. cognitive decline) and technical (e.g. robustness or fail tolerance). Naturally, preliminary tests of the entire system will be performed in advance both in laboratory environments and selected elder homes.

The project is currently in progress ($\sim 50\%$), ending the development phase and entering the pre-pilot experiments. For brevity, we summarize here the tests performed to date using the assistive robot platform. To complement this summary, we provide a video `http://mapir.uma.es/work/MoveCare-IROS18` illustrating the current status of the Giraff robot withing the MoveCare project. Besides the several independent components of the system, which are already undergoing preliminary testing and evaluation sessions, the assistive robot has been tested in different scenarios to evaluate the fulfillment of the expected functionalities (see Section II-C). Current experimental status include: (i) providing reminders and delivering invitations to the user from the VC, (ii) assisting the user when a *call for help* is detected (verifying the need for help), and (iii) the set of functionalities related to self-management, namely auto-docking and battery control. The evaluation of the *search for objects* functionality is still in an early stage.

For most of these scenarios the robot follows this sequence of actions: (i) receives the intervention via MQTT, (ii) undocks, (iii) safely navigates to the expected user location (updated by the system in real time), (iv) locates and approaches the user, taking into consideration the proxemic distances, (v) interacts with the user to carry out the specified action (HRI), (vi) provides feedback to the VC through MQTT, and (vii) returns to the dock station if there is not any other intervention planned in a short time interval.

Further details about the testing and validation of the other components of the system, as well as more details about all the components of the project that have been sketched in this abstract, can be found in the set of publications of the MoveCare project [1].

Acknowledgments

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