System Integration for the ENRICHME Project: A Service Robot for Care Facilities for the Elderly

François Ferland and Adriana Tapus
Robotics and Computer Vision Lab, U2IS
ENSTA ParisTech, Université Paris-Saclay
828 bd des Maréchaux, 91762 Palaiseau cedex France
francois.ferland@ensta-paristech.fr, adriana.tapus@ensta-paristech.fr

***Abstract*—The ENRICHME project, which involves introducing assistive robots in residential care facilities for the elderly, has adaptability as a core requirement. This paper briefly describes the various modules that are being used to enable ENRICHME robots to properly perceive its users, learn from their habits and reactions, and adapt to their preferences in long term usage scenarios.**

I. INTRODUCTION

Automatically adapting the behavior of assistive robots involves the integration of multiple perception and action capabilities into a single system. On one side, multiple sensors and signal processing are necessary to properly detect information such as the user's intention or its emotional response to an action by the robot. And on the other side, behaviors and action selection need to be sufficiently advanced to adapt to subtle variations in user preferences, which can also evolve over time.

The EU Horizon 2020 ENRICHME project aims at introducing assistive robots in four care facilities across Europe (UK, Poland, Greece, Italy) for elderly people with mild cognitive impairment (MCI). Adaptability is a core requirement of the ENRICHME project. It will manifest itself in multiple forms on a short- and long-term basis, through three main processes: real-time, contact-less physiological monitoring, long-term data collection and analysis, and a control architecture that includes an episodic-like memory to infer future events based on past experiences. For instance, contact-less physiological monitoring can help detecting stress [1], and as users progress while performing physical exercises suggested by the robot, the difficulty level can be adjusted accordingly.

This paper describes how all of these capabilities are combined in a single system for the ENRICHME project, and discusses the results of a first integration test that was performed with actual users in a real home environment.

II. SYSTEM DESCRIPTION

The ENRICHME system is a large collection of hardware and software modules, both on-board and out-board the robots that will be delivered to the testing sites. Figure 1 presents an overview of these modules, with more details given on the modules coordinating the robot behavior and thus its adaptability in different human-robot interaction settings. This coordination is based around the Hybrid Behavior-Based Architecture (HBBA) [2], a three-layer control architecture, which can be likened to the Belief-Desire-Intention (BDI) model. The following sections describe the role of each of these modules.

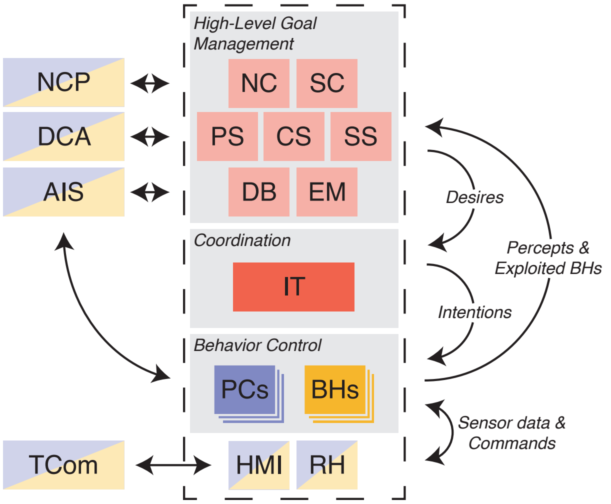

Fig. 1: The ENRICHME system, with modules embedded on the robot shown in the dashed rectangle.

A. Outboard modules

The ENRICHME project relies on three main outboard modules: the cloud-based Networked Care Platform (NCP), long-term Data Collection and Analysis (DCA), and site-specific Ambient Intelligence Servers (AIS).

The NCP is a web interface for healthcare professionals to monitor users and control the robot remotely. For instance, it can be used to send a request to seek users in their home to communicate directly with them. The DCA module gathers physiological data and other user-related information over multiple days to detect specific patterns such as a decrease in physical activity, and inform healthcare professionals through the NCP. An AIS is installed in the care facility and act as a bridge between the robot and devices such as human presence detectors and alarm systems. For instance, it can be used to inform the robot of the most probable current location of the user.

B. High-Level Goal Management

High-level goals for the robot are managed by a set of five motivation modules and two support modules. Each motivation module acts as a source of desires for the robot, which are descriptions of specific goals for the robot to achieve, and are not limited to actions to be taken. For instance, a motivation module can request face recognition to be performed when a new person has been detected in the environment. The Networked Care Relay (NC) directly translates requests that healthcare professionals entered on the cloud-based NCP. The Schedule Coordinator (SC) manages appointments set-up by the user or healthcare professionals for activities such as taking medication. The Physical, Cognitive, and Social Stimulation (PS, CS, SS) modules suggest activities such as light physical exercises, memory games, or communicating with friends, based on user-related events such as detecting restlessness or previously observed activity patterns.

The database (DB) is a key-value data storage module for items such as user preferences, performance in cognitive games, and scheduled appointments coming from the NCP. The Episodic Memory (EM), based on EM-ART [3], is a neural network-based episodic-like memory that monitors data such as the current mood of the user and robot actions, which can then be used to predict repeating interaction events. It is mainly used by the PS, CS, and SS modules to infer what kind of outcome can be expected when suggesting an activity. Together, DB and EM are key elements in the adaptability of the project, as they store user's preferences that were either set explicitly through a configuration interface, or implicitly as the robot learn them from past experiences.

C. Coordination and Behavior Control

The coordination layer contains the Intention Translator (IT). Its role is two-fold: managing conflicts between concurrent desires, and translating the goals described by those desires into the Intentions of the robot. Intentions are sets of activation and configuration directives for the perception and behavior producing modules found in the lower layer of the architecture. For instance, if a person has to be followed by the robot, these instructions might include the activation of leg and face detection modules, and a motion planner module will receive the last known position of that person.

The low-level control of behaviors is split between two categories of modules: perception modules (PCs), and behavior producing modules (BHs). PCs are modules that take care of percepts-producing tasks such as face detection and recognition, physiological monitoring, or mapping of the environment. Based on the output of PCs, BHs produce motor commands in parallel, and conflicts are solved by order of priority.

D. Robot Hardware

The robot hardware (RH) consists in a new revision of the Kompaï robot, developed by Robosoft. It has a differential drive mobile base with a laser range finder for navigation, a rotating torso integrating a touch display, a RGB-D camera mounted on a motorized tilt support, and a head that can show various expressions with eyes displayed on an embedded LCD screen. For the ENRICHME project, two devices are added: a thermal camera allowing contact-less monitoring of physiological data, and an RFID antenna to detect the presence of pre-tagged objects in the environment. The Human-Machine Interface (HMI) refers to the graphical interface shown on the touch display. Along with voice, this is the main interaction channel between the robot and its user, as the robot does not possess arms or other actuators to interact with its environment. It is thus used to display cognitive stimulation games and physical exercises directives to the user. It can also be used to communicate with friends or healthcare professionals through a telecommunication protocol (TCom) such as Skype.

III. Discussion and Conclusion

In May 2016, a first integration test with real users in one of the pilot testing care facilities (in the UK) has been performed. It used a previous version of the Kompaï robot, and lacked links to the NCP and AIS. However, it featured a laser range finder-based people tracker, a face detection and recognition system with a pre-trained database of its future users, a RFID-based object location system, and a subset of the cognitive games planned for the final version. The test scenario involved autonomous navigation and reaching a person to propose cognitive and physical activities. The configuration of the motion behavior was based on a study currently conducted online where participants control a simulated Kompaï robot to demonstrate how it should approach a person as to not appear dominant or hostile. As preliminary results suggests that some parameters such as the curvature of the trajectory can be linked to friendliness or submission, they can be used as a baseline for the robot behavior. Furthermore, they justify adaptation through customization, as results also suggest that variations exist from user to user for some of the parameters.

This paper presented the current state of the system used for the ENRICHME project, which introduces assistant robots in retirement facilities for elderly users with MCI. In Fall 2016, a second integration test will be conducted, this time with all the final hardware elements. It will serve as a starting point for the first pilot tests in two different sites over multiple weeks, where long-term adaptability will be evaluated.

Acknowledgments

This work has been partially funded by EU Horizon2020 ENRICHME project grant agreement no. 643691C.

References

[1] M. Sorostinean, F. Ferland, and A. Tapus, “Reliable stress measurement using face temperature variation with a thermal camera in human-robot interaction,” *Proceedings of the IEEE-RAS Conference on Humanoid Robotics*, 2015.

[2] F. Ferland, F. Leconte, A. Tapus, and F. Michaud, “An architecture with integrated episodic memory for adaptive robot behavior,” in *2014 AAAI Fall Symposium Series*, 2014.

[3] F. Leconte, F. Ferland, and F. Michaud, “Design and integration of a spatio-temporal memory with emotional influences to categorize and recall the experiences of an autonomous mobile robot,” *Autonomous Robots*, pp. 1–18, http://dx.doi.org/10.1007/s10 514–015–9496–2, 2015.