Proceedings of the 27th IEEE International Symposium
on Robot and Human Interactive Communication,
Nanjing, China, August 27-31, 2018

Towards a robust robotic assistant for Comprehensive Geriatric Assessment procedures: updating the CLARC system*

J. Martínez[1], A. Romero-Garcés[1], C. Suárez[2], R. Marfil[1], K. Lan Hing Ting[3], A. Iglesias[4], J. García[4], F. Fernández[4], Á. Dueñas[2], L.V. Calderita[1], A. Bandera[1] and J.P. Bandera[1]

***Abstract*— Socially assistive robots appear as a powerful tool in the upcoming silver society. They are among the technologies for Assisted Living, offering a natural interface with smart environments, while helping people through social interaction. The CLARC project aims to develop a socially assistive robot to help clinicians perform Comprehensive Geriatric Assessment (CGA) procedures. This robot autonomously drives some tests and processes, saving time for the clinician to perform more added-value activities, like designing care plans. The project has recently finished its first two phases, and now it faces its final one. This paper details the current prototype of the CLARC system and the main results collected so far during its evaluation. Then, it describes the updates and modifications planned for the next year, in which long term extensive evaluations will be conducted to validate its acceptability and utility.**

I. INTRODUCTION

World population is significantly growing older. This demographic change is specially relevant in more developed regions such as the United States, Japan or the European Union (EU). According to the EU estimations, by 2050 one out of every five people will be over 60 years old [1]. Moreover, while actually the average number of EU workers supporting those in retirement is four, in 2060 this number will be halved to just two. Additionally, more economic, social and technological resources will be demanded to guarantee the quality of life of this aging population.

New models and action plans have to be designed to deal with these changes. *Active ageing* becomes a key concept for these plans. It is defined as *the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age* [2]. The concept can be applied to both individuals and population groups. It aims towards inclusive societies, in which people remain as independent as possible, as long as possible. They can contribute and participate in the society, while they are provided with adequate protection, security and care. To do so, personalized treatments and long-term follow-up plans, based on a continuous evaluation of the patient's state of health, need to be developed [2].

Proposed by Dr. Marjory Warren in the late 1930s [3], Comprehensive Geriatric Assessment (CGA) is the multidimensional diagnostic instrument designed to capture data on the medical, psychosocial and functional capabilities and limitations of elderly people. CGA improves the diagnosis, creates right, customized and proportional therapeutic plans, increases functional autonomy, and also reduces complications during hospitalizations and mortality. CGA processes usually involve interdisciplinary teams of experts and can last for some hours. However, some of their parts are formulated as standard tasks, that can be automated or parallelized. If these activities could be delegated in an autonomous agent, such as a robot, clinicians would save time to focus on activities with more added value, like deciding, together with the patient and relatives, the appropriate care plan. This is the aim of PDTI-healthcare, a Public end-user Driven Technological Innovation (PDTI) challenge proposed by the ECHORD++ project[1].

One of the approaches funded by ECHORD++ is the CLARC project[2], that focuses on the use of robots in CGA [13]. This paper describes the current prototype developed in this project, and discusses its original design requirements in contrast to the feedback extracted from the evaluation activities that concluded the first two phases of the project. CLARC addresses its third and final phase in 2018, which involves long-term tests with real patients in different institutions, including hospitals, nursery houses and day care centers. The robots that will be deployed in these places will incorporate the modifications and improvements suggested by existing evaluations, which imply changes in both hardware and software modules and interfaces [4]. Therefore, the main contributions of the paper are:

- A fruitful discussion regarding our experiences with CLARC until now, which we consider relevant for researchers and professionals in the social assistive robotics community.
- A detailed description of our software architecture that can be useful for robot designers, specially the modifications and improvements needed in order to fulfill

*This work has been partially funded by the EU ECHORD++ project (FP7-ICT-601116), the TIN2015-65686-C5-1-R, the CSO2017-86747-R (MINECO and FEDER funds) and University of Malaga/Andalucia-Tech

[1]A. Romero-Garcés (corresponding author), J. Martínez, R. Marfil, L.V. Calderita, A. Bandera and J.P. Bandera are from Universidad de Málaga, 29071, Málaga, Spain {argarces, jmcruz, rebeca, lvcalderita, ajbandera, jpbandera}@uma.es

[2]C. Suárez and A. Dueñas are from Hospital Universitario Virgen del Rocío, Seville, Spain cristina.suarez.exts@juntadeandalucia.es, alvaro.duenas.ruiz@hotmail.com

[3]K. Lan Hing Ting is from Troyes University of Technology, France karine.lan@utt.fr

[4]A. Iglesias, J. García and F. Fernández are from Universidad Carlos III de Madrid, Leganés, 28911, Madrid, Spain {aiglesia, fjgpolo, ffernand}@inf.uc3m.es

[1]http://echord.eu/pdti/pdti-healthcare/

[2]http://www.clarc-echord.eu/

978-1-5386-7980-7/18/$31.00 ©2018 IEEE

Authorized licensed use limited to: SHANDONG UNIVERSITY. Downloaded on March 29,2025 at 17:30:01 UTC from IEEE Xplore. Restrictions apply.

requirements in terms of performance and robustness.

The paper is structured as follows: Section II details related works in the research field of socially assistive robots. Section III briefly describes the CLARC system in its current implementation. Section IV presents and discusses the main results obtained in the evaluation of this prototype, along with additional feedback collected in the continuous user-centered design process followed in this project [4]. Section V focuses on the modifications and improvements considered for the third phase of the project. Finally, we give our conclusions and future work in Section VI.

II. Socially Assistive Robots

In the upcoming *silver societies* it will be necessary, on the one hand, to provide daily life environments (i.e. houses, offices, etc.) with a certain level of medical infrastructure. On the other hand, medical facilities (i.e. hospitals, nursery houses, etc.) should also be upgraded to increase their efficiency and scope. If part of the solution to achieve this objective is a political will towards increased financial means to institutions, the other part of the solution is technological. Indeed, smart environments, including sensors, actuators and agents, have the potential to help monitor the health state of elderlies, conduct autonomous rehabilitation, propose maintenance exercises, or provide remote assistance [5]. These new technologies for *Assisted Living* represent interesting business opportunities [6], specially considering how the elderly generations are becoming quickly familiar with tech usage [7].

In this context, robotics occupies a relevant position among the technologies employed in these new environments [5]. Clinical robots, rehabilitation robots, prosthetics, or specialist supporting assistant robots are among the most promising agents being currently researched, and developed [5]. But a new application domain has recently been added to the list above: socially assistive robots [8]. These robots are defined as the intersection between socially interactive robots and assistive robots [8]. They use social interaction to assist people. Hence, they differ from socially interactive robots, in which social interaction itself is a goal, not a tool. On the other hand, while they are designed to assist people, they do so without requiring physical contact. Moreover, when compared to medical assistant robots, their context-of-use is different. Socially assistive robots are more autonomous, and they are designed to cooperate with healthy people, in daily life environments (not necessarily clinical environments, but home, work, etc.). These robots are able to be proactive: looking for people, initiating interactions, sharing information, remembering and proposing events or activities. They benefit from the fact that people are more motivated to interact with physically embodied agents (people, pets, robots) than with screens [9]. They are classified as consumer devices, not clinician devices, and they do not use physical interaction. These factors ease their certification, commercialization and usage [5]. Finally, they are conceived as a part of a smart environment, in which they communicate with other devices, and act as an interface between people and these connected environments [5][10].

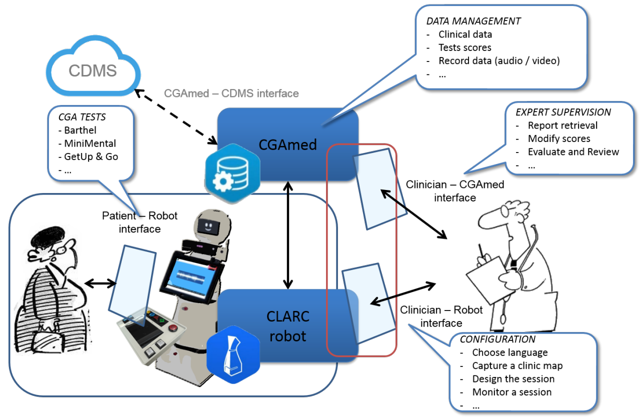

Fig. 1. Overview of the CLARC system

In recent years, an important effort has been made in the research and development of socially assistive robots. A good example is the Accompany project [10], in which a prototype interacted for two weeks in the houses of elderly people. The results were promising in terms of potential benefits, but they also show long term acceptability and utility issues. These same issues appear in other projects in which general purpose socially assistive robots were employed [5][11]. After the novelty effect wears off, they may not be accepted nor used by the people if they do not meet the expectations they produce, or if they are not really useful. Socially assistive robots that focus on specific tasks achieve better results [12]. However, long term evaluation of acceptability and utility, through extensive reproducible experiments involving a relevant population sample, are still to be robustly conducted in this research field [11]. This is what the research project presented in this paper aims at bringing a contribution. Within the CLARC project, these evaluations are planned for the third (and final) phase: the robot will be tested for several consecutive months in different real application scenarios. In these evaluations the robot will autonomously help patients complete three common CGA tests: (i) the Barthel test; (ii) the Minimental test; and (iii) the Get Up & Go test [13]. These tests are a representative example of functional, cognitive and motion CGA procedures, respectively. In order for this experimentation to provide useful insights, the robot needs to be updated, from the current prototype, to successfully address this extensive evaluation process.

III. The CLARC System

Fig. 1 shows the architecture of CLARC. From a conceptual point of view, the system can be divided into three main components: the Robot (hardware), the Cognitive Architecture (the software inside the robot, which governs it) and the CGAMed platform (the software in the cloud). Communication channels between the robot software and the CGAMed allow the latter to start a new session of tests, during which a patient interacts with the robot. They also

Authorized licensed use limited to: SHANDONG UNIVERSITY. Downloaded on March 29,2025 at 17:30:01 UTC from IEEE Xplore. Restrictions apply.

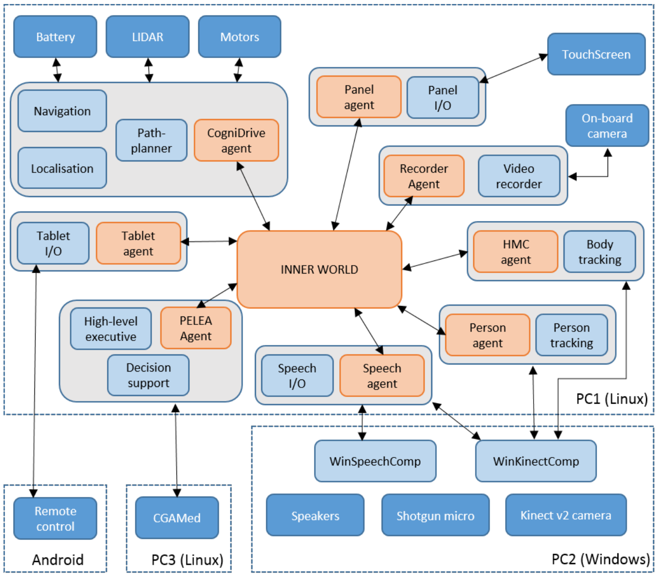

Fig. 2. CLARC cognitive architecture

Fig. 3. Remote control used to interface the robot

allow collecting the results of the tests, including session recordings. Hence, all the configuration information and the results of the session travel through these channels.

A. The Robot Hardware

The robot is based on a Metralabs SCITOS G3[3] platform updated with new features and elements to meet the requirements of CGA tests. The robot moves using a differential drive system, consisting of two powered wheels and a caster wheel for stability. This system enables the robot to rotate on the spot and drive at a speed of up to 1 m/s. The platform contains a 40Ah lithium battery which allows for up to 18 hours of autonomous operation, and can be fully recharged within 4 hours. A safety bumper socket sensor is used to prevent the robot from exerting force against animate or inanimate objects.

As mentioned before, we have included new elements to the SCITOS platform for multi-modal human-robot interaction: screens, a Microsoft Kinect V2 sensor, an Audio-Technica AT875 Short Condenser shotgun microphone, speakers, cameras for recording and monitoring, a LIDAR laser to navigate through dynamic indoor environments and a laser pointer to indicate the patient where to turn in the Get Up & Go test. After the evaluation of usability tests, we have also incorporated a new external device (known as *remote control*), that integrates a tablet and big physical buttons to help patients complete the Barthel and Minimental tests (see Fig. 3). It has been designed and prototyped to offer an alternative to the voice and touch screen interfaces.

B. The Cognitive Architecture

CLARC uses the CORTEX [13][14][15] cognitive software architecture to control its behaviour. CORTEX proposes a distributed architecture, where action execution, simulation, and perception are intimately tied together. In the CGA scenario, they share a common internal representation of the robot, the patient and any other significant event captured from the outer world. This internal representation is known as the Inner World (see Fig. 2), which allows task-solving elements in CORTEX to share data at different abstraction levels, in order to get information and to plan next actions.

The behaviour of the robot emerges from the activity of many software components, which are connected to the Inner World through a specific communication end-point (called *the agent*). Each component is currently able to endow the robot with a specific ability. Some components are connected to sensors, and they process their raw data to enrich the inner representation with fast perceptions. Some others are connected to actuators, allowing the robot to interact with its environment. But a component can also manage other data sources as well. For instance, the PELEA deliberative component (in charge of providing a high-level executive for learning abilities and decision support), works exclusively over the data provided by the Inner World and the CGAMed module.

Most of the architecture runs in an embedded Linux computer, acting as a container where components execute. We use an additional embedded computer to run the WinKinectComp and the WinSpeechComp components, which manage the Kinect sensor and the microphone, and perform the text to speech translation, respectively. They process raw data from hardware and provide a continuous stream of information to other components such as Speech, Human Motion Capture and Person/Close Interaction. Both computers are connected through an internal network link, that allows also sending data from the remote control to the corresponding agent.

C. CGAMed

The CGAMed module (see Fig. 1) is the part of the system that manages data from CGA sessions and allows the interaction between the clinician and the robot. It also controls the Data Base Management System and its integration with the Clinical Data Management System (CDMS) of the Hospital. The two interfaces depicted in Fig. 1) provide the clinician with the tools needed to configure CGA sessions, to monitor them in real time, or to evaluate the results after a session has finished. It is developed as a web interface that can be accessed from any device using a web browser. Among other features, the clinician can select a patient from the list of registered ones, access her clinical data (and test records)

[3]http://www.metralabs.com/en/

Authorized licensed use limited to: SHANDONG UNIVERSITY. Downloaded on March 29,2025 at 17:30:01 UTC from IEEE Xplore. Restrictions apply.

and schedule new tests (including starting time and location). The sessions can be started, paused, stopped and monitored in real time, and they are also recorded in video. The clinician can get information at any moment regarding the records for past sessions, along with the current status of the robot and the test scheduling plan.

IV. EVALUATION OF THE SYSTEM

The system was evaluated using a user-centered approach, in which feedback from users was collected via questionnaires, 20-minutes debriefing and semi-directive interviews [13]. Three main features were evaluated: the execution of CGA tests, the degree of robot autonomy and behaviour, and the usability of the interface for the clinician.

A. Evaluation of CGA Tests

As stated before, the CLARC robot performs three different CGA tests: Barthel, Minimental and Get Up & Go [13]. These tests have different features and their implementation within the CLARC system achieved different degrees of success.

The Barthel test is a functional test in which questions can be answered using voice commands, touching the screen or using the buttons of the remote control. The possible answers for each question are strongly constrained [13][4]. Therefore, it was possible to create robust grammars and easy interfaces in CLARC. This kind of test was robustly performed and positively evaluated and the insights produced by the evaluation allow the hypothesis that the remote control will be, by large, the patients' preferred option to provide the answers.

The Get Up & Go test was also robustly conducted in the cases where the patient knew how to perform it from previous experiences [17]. This kind of test involves the robot giving explanations, moving around and guiding the patient, and it seems to be complex to achieve for people who meet the robot for the first time. As the test usually requires a companion (at least in the first executions), it would be possible to reinforce the robot's explanations in these situations, and following executions could be conducted fully autonomously for the same patient. The overall result of the evaluation was also very positive: patients were able to perform the test without further issues once correctly instructed, usually just after seeing a demo video. On the other hand, the ability of the robot to autonomously differentiate between safe gaits and those that present a certain risk of falling is promising [17].

Finally, the Minimental test is a cognitive test with different types of questions, more open responses, and exercises involving not only answering questions, but also writing, doing movements, drawing, etc [13]. This kind of test resulted to be annoying and tiresome for the patients, specially for some specific questions. Our overall impression is that the Minimental tests could be successfully automated to a certain point: hence, while the robot is able to collect the results for all the questions, it may provide a score only for certain ones. The clinician can provide missing scores, as the session is completely recorded (see [16] for a similar case). We will also evaluate the possibility of completely discarding some questions from the repertoire of the robot, and leaving the clinician the responsibility of evaluating them in a different session (i.e. the Minimental test would be divided into two tests: one for the robot, and the other, containing complex to automate questions, for the clinician).

B. Robot autonomy and behaviour

The CLARC robot moves around dynamic, daily life environments thanks to the MIRA navigation system [13]. In the CGA scenarios considered for this project, the robot needs to move in a safe and autonomous way from one room to another, which has been successfully done for all evaluated scenarios. The measured operation time between consecutive battery charges is over 8 hours for normal operation. Besides, the robot is able to move automatically to its charging station when it detects that it is running out of batteries.

The robot is equipped with hardware and software tools that provide it with limited reactive abilities: the robot is able to detect when the person interacting is not present, or not answering the questions of the CGA test. It may also detect if he/she is not correctly located in the Get Up & Go test. While these abilities may seem too constrained, they may reveal to be enough in the case researched in this paper, which is a robot focused on autonomous CGA evaluations. The pilot evaluation will allow to investigate this issue, and how users - both clinicians and patients - perceive the robot's autonomy in this specific context of geriatric evaluation, and the particular tasks at hand. Indeed, as described above, each test requires different actions from the user, and therefore different modalities of interaction. These particularities which strongly influences the human-robot interaction will also be examined in detail during the pilot evaluation.

C. The interface with the Clinician

We took into account the evaluation results obtained from different categories of health professionals at the Virgen del Rocio University Hospital in Seville. The interface between the clinician and the CGAMed has had positive evaluations in terms of usability. It offers clinicians a fast access to the data collected during the tests, allows reviewing the evolution of the patient, and eases the scheduling of the CGA sessions. Moreover, the clinicians consider really useful its web-based interface, because they can access CLARC from any kind of computer or mobile phone.

D. Discussion

It is worth noting that comments from the health professionals mainly focused on improvements in the test procedures and the kind of data available through the web interface. For instance, they requested the creation and management of a profile for each patient that includes not only information about the CGA tests, but also about personal and functional characteristics (such as mobility) and other contextual data. We see this new requirement as an

Authorized licensed use limited to: SHANDONG UNIVERSITY. Downloaded on March 29,2025 at 17:30:01 UTC from IEEE Xplore. Restrictions apply.

opportunity to tune both the interaction process of the robot, and the type of tests and questions to be offered.

As discussed above, there are patients for whom some questions of the test may not be adequate (e.g. a person who does not know how to write cannot answer the question "write a semantically correct phrase"). Clinicians suggested to use the first step of the interaction process, in which the robot teaches the person how to interact with it [4], to extract relevant data about the patient such as her educational level, reading/writing capabilities and so on. These data would be included in the patient profile stored by the CGAMed module. In the case of the Get Up & Go test, there are also relevant data to include in the profile, such as the duration of the exercise (i.e. the result of the Timed Up & Go test), number of steps, speed, or symmetry, among others. These data are being already collected by the robot to perform the autonomous gait evaluation, hence they can be easily uploaded to the CGAMed as requested.

We must also consider scenarios in which patients leave questions unanswered. In these cases, these questions would not be part of the final test score shown to the clinician. Moreover, CLARC should not provide false positives when evaluating the level of autonomy of a person. If the result for a certain question is not absolutely clear, the CGAMed interface should give indications to the clinician in order to review that question and get the right score.

Finally, the connection between the CGAMed module and the data system of the Hospital seems to be no longer necessary, despite initial specifications (see Fig. 1). Clinicians do not really care about data being shared or not, as long as CGAMed can automatically generate CGA reports that they can copy and paste when filling their evaluations.

V. New Developments and Open Challenges

This section describes the changes and new features expected in the third phase of CLARC. They are based on the external feedback and evaluations, our current experience with the software that has been used or created specifically for the project, and the original requirements of the system.

A. Adjusting the interfaces

One of the most important requirements in the final phase of CLARC is to ensure that all the patients and clinicians are capable of, and enjoy, interacting with the robot, and that it is socially accepted.

Therefore, the system will be improved in order to collect data for these evaluations regarding usability, social acceptability and the overall user experience. The new version of CGAMed will register (and update) a *patient profile* during every patient-robot interaction. It will include quantitative data such as patient's functional characteristics, known abilities/disabilities and some metrics of the interaction with the robot in the context of a specific CGA test. External feedback from users will be collected through qualitative-ethnographic methods, and will include information regarding the familiarity and attitude of the patient regarding CLARC and its main interface, along with any accessibility barriers. This feedback will be also added to the patient profile and will guide us in the refinement and personalization of the system interfaces.

B. Software in the cloud

It is worth noting that having software in the Cloud improves the availability, scalability, maintenance and evolution of distributed services [18]. Therefore, required resources such as memory, disk, CPU, bandwidth or IP addresses for these services can be provided on demand. However, the physical location of virtual machines is also a major concern for performance optimization, energy consumption, reliability, and costs associated to CLARC.

In fact, there are some communication issues regarding the interaction between the clinician and the robot that must be considered in detail. In order to minimize the impact of latencies on the overall performance of the system, we plan to improve the software architecture of the CGAMed system to follow the microservices paradigm [19]. This approach aims at designing fine-grained and loosy-coupled modules (services) with clear boundaries that communicate themselves via (asynchronous) network calls.

The resulting modules of CGAMed will scale better whether support for many concurrent robots running in parallel is needed. These microservices could be deployed seamlessly on different cloud infrastructures, such as future private clouds available at each hospital [18][20], or as part of the new fog computing approach [21]. This solution would have impact on latency and bandwidth savings but also would help CLARC to meet current or future requirements such as country regulations or laws regarding security and privacy for sensitive data.

C. Changes in the cognitive software architecture

The current dialog established between the robot and CGAMed uses a REST interface over HTTP [22]. This is a convenient way to overcome some typical issues regarding the access to a remote service where firewalls and other security network measures exist. However, the request/response nature of this top-level interface incurs inefficiencies in the responsiveness of the cognitive architecture. For instance, the high-level executive module in Fig. 2 is always responsible for connecting with CGAMed, and any asynchronous event that affects the robot will be known only after a specific request is done. This forces the high-level executive module to poll CGAMed periodically. Our planned design will include a secure websocket interface [23] for full-duplex bi-directional data delivery, which will allow the high-level executive module to be fully reactive to events coming from CGAMed at any time. The use of websockets also benefits from a so-called keep-alive mechanism that prevents existing firewalls from terminating idle connections.

As stated before, our cognitive architecture follows a software component-based approach, where each component shares a globally available inner world through its associated agent. The Inner World is represented as a dynamic graph structure that must be updated and replicated consistently

Authorized licensed use limited to: SHANDONG UNIVERSITY. Downloaded on March 29,2025 at 17:30:01 UTC from IEEE Xplore. Restrictions apply.

everytime there is a change in it. This critical part of the system can have serious implications whether unexpected behaviours occur and, therefore, we will intensify the testing and verification of the distributed dialog between agents, for both functional and non-functional properties. The former properties aims to ensure safety and the absence of deadlocks or livelocks in the source code. The latter properties focus on the performance of the system and the effects of dealing with data inconsistencies or data propagation delays, among others. It is worth noting that the definition and verification of useful and measurable quality-of-service properties is an open challenge and a key goal for researchers in the field of software for robotics [24]. We expect to contribute to the community through our experience with CLARC working in real and complex scenarios.

VI. CONCLUSIONS

After the completion of its first two phases, the CLARC system is now ready to be tested in real application scenarios with real patients. Results obtained so far are promising in terms of robustness and utility for the clinician, as long as the robot keeps being used for what it is good for. Some CGA tests may be completely driven by the robot in an autonomous way (e.g. Barthel and Get Up & Go tests). Other tests, however, should only be partially performed by the robot, leaving some questions (or even entire tests) for the clinician. The Minimental test may fall under this category, and the possibility to automate it only partially will be considered during the pilot evaluation. In any case, the recording of patients' responses, even when not evaluating them, may be a time-saving asset for the clinician, who could review and score these questions off-line through the CGAMed interface.

It is important to highlight that the robot will be useful only if it is accepted by the patients. Their first impressions have been good (satisfactory usability and acceptability rates in the user tests) but it may be due to the novelty effect. Although patients are willing to interact with the robot using the voice interface, this module is not robust enough to allow fluent conversations for now, despite using directional microphones and constrained grammars [13]. Therefore, patients usually switch to the remote control and keep using it for the rest of the CGA session. Hence, this interface will be evaluated extensively during the field trials, as it seems to be the best choice for most users. On the other hand, it may be possible that patients who need to repeat the tests several times find it much easier to interact with the robot via voice once they are familiar with it. Further work will address extensive, long term evaluations in which the interacting abilities and channels of the robot can be tuned and adapted to each patient, once patient profiles are included in the CGAMed module.

ACKNOWLEDGMENTS

The authors warmly thank the members of the "Amis du Living Lab" community, and the patients and medical staff at Hospital Civil de Málaga, for their participation in this research, as well as the interns Marion Olivier and Daniel Saadeddine.

REFERENCES

[1] The 2015 Ageing Report: Economic and budgetary projections for the 28 EU Member States (2013-2060). *http://ec.europa.eu/economy_finance/publications/european_economy/2015/ee3_en.htm/* Last visit in March 2018.
[2] Active Ageing: A Policy Framework. *https://extranet.who.int/agefriendlyworld/wp-content/uploads/2014/06/WHO-Active-Ageing-Framework.pdf* Last visit in March 2018.
[3] D.A. Matthews, Dr. Marjory Warren and the origin of the British geriatrics. J. Am. Geriatr. Soc., vol 34, 253-258, 1984.
[4] K. Lan Hing Ting, D. Voilmy et al. Integrating the users in the design of a robot for making Comprehensive Geriatric Assessments (CGA) to elderly people in care centers. Proc. of the 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), pp. 483–488, 2017.
[5] SPARC: The partnership for robotics in Europe, Robotics 2020 multi-annual roadmap for robotics in Europe. The EU framework programme for research and innovation. Report. 2015.
[6] Embracing the silver economy. *http://bruegel.org/2017/04/embracing-the-silver-economy/* Last visit in March 2018.
[7] A. Smith, Older Adults and Technology Use. Pew Research Center. Report. 2014.
[8] D. Feil-Seifer and M.J. Mataric. Defining Socially Assistive Robotics. Proc. of the IEEE C9th Int. Conf. on Rehabilitation Robotics, pp. 465–48, 2005.
[9] M.J. Mataric, Socially assistive robotics: Human augmentation versus automation. Science Robotics, 2, 2017.
[10] J. Gallego, M. Lohse and V. Evers, D6.3: Acceptability of a home companion robot. Accompany Project. Final Report v 1.3. 2014.
[11] J. Broekens, M. Heerink and H. Rosendal, Assistive social robots in elderly care: a review. Gerontechnology, vol 8(2), pp. 94–103, 2009.
[12] H.M. Gross, A. Scheidig et al. ROREAS: robot coach for walking and orientation training in clinical post-stroke rehabilitation - prototype implementation and evaluation in field trials. Autonomous Robots, vol 3, pp. 679–698, 2017.
[13] D. Voilmy, C. Suárez et al. CLARC: A cognitive robot for helping geriatric doctors in real scenarios. In ROBOT (1), vol 693, Springer, Advances in Intelligent Systems and Computing, pp 403-414, 2017.
[14] A. Romero-Garcés, L.V. Calderita et al. Testing a fully autonomous robotic salesman in real scenarios. Proc. of the IEEE Int. Conf. on Autonomous Robot Systems and Competitions, pp. 124-130, 2015.
[15] R. Marfil, L. Manso et al. Percepts symbols or action symbols? generalizing how all modules interact within a software architecture for cognitive robotics. Proc. Workshop on Physical Agents, pp. 9-16, 2016.
[16] S. Varrasi, S. Di Nuovo, D. Conti, and A. Di Nuovo. A social robot for cognitive assessment. ACM/IEEE Int. Conf. on Human-Robot Interaction, pp. 269-270. 2018
[17] J.P. Bandera, R. Marfil, A. Romero-Garcés and D.Voilmy, A new paradigm for autonomous human motion description and evaluation: Application to the Get Up & Go test use case, Pattern Recognition Letters, available online 16 February 2018.
[18] P. Mell and T. Grance. The NIST definition of cloud computing. Computer Security Division, Information Technology Laboratory, National Institute of Standards and Technology Gaithersburg. 2011.
[19] S. Newman, Building Microservices, O'Reilly Media, 2015.
[20] OpenStack project website. *http://www.openstack.org*. Last visit in March, 2018
[21] F. Bonomi, R. Milito, J. Zhu and S. Addepalli. Fog computing and its role in the internet of things. Proceedings of the MCC workshop on Mobile cloud computing. ACM, pp. 13-16. 2012
[22] Roy Fielding. Architectural Styles and the Design of Network-based Software Architectures (Ph.D.). Chapter 5: Representational State Transfer (REST). University of California, Irvine, 2000.
[23] V. Pimentel and B. G. Nickerson. Communicating and Displaying Real-Time Data with WebSocket. IEEE Internet Computing, vol. 16, no. 4, pp. 45-53, 2012.
[24] The RobMoSys Project and Integrated Technical Projects. *https://robmosys.eu/itp/*. Last visit in March, 2018.

Authorized licensed use limited to: SHANDONG UNIVERSITY. Downloaded on March 29,2025 at 17:30:01 UTC from IEEE Xplore. Restrictions apply.