Design of Cloud Robotic Services for Senior Citizens to Improve Independent Living in Multiple Environments

M. Bonaccorsi*,[1], L. Fiorini*,[1], S. Sathyakeerthy[2], A. Saffiotti[2], F. Cavallo[1], P. Dario[1]

[1] The BioRobotics Institute, Scuola Superiore Sant'Anna, Viale R. Piaggio 34, 56025 Pontedera, Italy
[2] Center for Applied Autonomous Sensor Systems (AASS), Orebro University, Sweden
Corresponding Authors: (`m.bonaccorsi@sssup.it, l.fiorini@sssup.it`)

Abstract. The paper proposed a cloud robotic solution for the healthcare management of senior citizens, to demonstrate the opportunity to remotely provide assistive robotic services to a number of senior citizen regardless to their position in the monitored environment. In particular, a medication reminding, a remote home monitoring and an user indoor localization service were outsourced in the cloud and provided to the robots, users and caregivers on request. The proposed system was composed of number of robotic agents distributed over two smart environments: a flat at the Domocasa Lab (Peccioli, IT) and a condominium at the Angen site of the Orebro science park (Orebro, SE). The cloud acquired data from remote smart environments and enabled the local robots to provide advanced assistive services to a number of users. The smart environments were able to collect raw data for the environmental monitoring and the localization of the users by means of wireless sensors, and provide such data to the cloud. On the cloud, specific algorithms improved the local robots, by providing event scheduling to accomplish assistive services and situation awareness on the users position and environments status. The indoor user localization service, was provided by means of a sensor fusion algorithm on the cloud, and was evaluated in terms of localization accuracy over the two experimental sites. The entire cloud solution was evaluated in terms of Quality of Service (QoS) to evaluate the effectiveness of the architecture The proposed system was able to locate multiple users over different environments with a meter-level accuracy, while the cloud assured a mean time of respond for service delivery of at least 142 ms and a data loss less than the 0.5%.

Keywords. Aging well, cloud robotics, intelligent systems,indoor localization

1 Introduction

EU population ageing is a long-term trend that will almost triple the share of those aged 80 years or above between 2011 and 2060. This will increase the demand for Nurse Practitioners (+94% in 2025) [1] and Physician Assistants (+72% in 2025) [2]

---

* equal contribution to the work

with several implications for quality of care and for the configuration of future cost-effectiveness care delivery systems. One of the greater challenge in the next years will be to fit to the reduction of funds for social-medical services, with the opportunity to provide socially sustainable home care services to senior citizens. Seniors prefer to live as independently as possible [3] and to maintain their quality of life. Their well-being depends on the opportunity to efficiently managing medications and cares. Often they lost their independency because of the difficulties in medication self-management and health status monitoring [4]. Cognitive impairments and the complexity of the cares negatively impact on their independent living [5]. For these reasons, several works [6] investigated the opportunity to provide medication reminders, self-monitoring, and family therapy, and demonstrated that this could reduce hospitalizations from 33 to 69%.

Furthermore the number of single elderly persons and single-person households is increasing and one-in-six of all 74 million elderly people now living in EU are at risk of poverty [7], in particular in the EU countries more suffering from the economic crisis such as Bulgaria (61,1%), Romania (35,3%), Greek (29,3%), Portugal (24,5%), Italy (24,2%) and Spain (22,3%) [8]. These processes will require new technologies, services and forms of housing to be developed in order to make population ageing socially sustainable. EU ageing seniors want to remain in their familiar environment, to live as independently as possible and maintaining a good quality of life [9]. Their well-being strictly depends on the opportunity to have good social relationships with family, friends and neighbors as well as participating in social activities [10].

As a consequence, the decreasing of worker population [8] and the reduction of funds for social-medical services, due to the current economic crisis, couldn't fulfill the demand for care. As a consequence, the society has to sustain high costs to guarantee an high level of assistance and quality of life to senior citizens, in terms of medical cures, socio-medical and home care services. These processes will require new technologies and services in order to make population ageing socially sustainable.

2 User and Stakeholder Needs

In order to design services and technological solutions that will effectively promote and support the idea of “ageing well”, it is fundamental to analyse the needs and requirements of all stakeholders.

The primary needs of senior people are to maintain, as long as possible, an adequate quality of life, to be active and to participate in community life and to retain control over their own life even when they need care and assistance [11]. However, ageing causes a physiological decrease of motor, sensory and cognitive abilities of the people as well as the consequent frailties and disabilities. As a consequence, their independence may be reduced. On the other side, people suffering of cognitive impairments have trouble on remembering, learning new things, concentrating or making decision about everyday life. Most of older when affected by one or several chronic diseases, may require the frequent taking of different drugs, the performance of specific therapies, the periodic monitoring of health parameters and the adoption of a specific and healthy life style. These care procedures are often complex and can induce mental confusion in senior patients; consequences of improper medications can be serious. Preventable errors contribute to 33-69% of hospital admissions [12]. Besides better managing the effect of polypharmacy on older persons, these need to be supported and helped to monitor their treatments [13]. In addition senior citizens need help in managing daily activity and remembering appointment because of cognitive impairment.

Informal caregivers sometimes assist and monitor their old-aged relatives continuously [14], with several implications on their personal and professional life, the quality of the assistance and the responsiveness and effectiveness in case of critical situations.

Professional care providers too, are facing new challenges in the today word,to provide home-care, long-term care and intermediate solutions, like day care, night care and senior housing. All these services require the massive involvement of professional caregivers that are expected to be insufficient in number [8] and inefficient for the growing number of elderly citizens.

Thus, the planning actions and policies to look for innovative solutions to improve effectiveness and cost efficiency of the elderly care formal and informal systems are of interest to all citizens and public and private service providers.

3 Background

In this context, ICT systems and robotics services have been developed to provide a valid solution to support the independence of elderly people and improve a sustainable healthcare system. For example, the European Seventh Framework Programme for Research and Technological Development (FP 7) focused the fifth challenge on the needs of senior citizens (ICT Challenge 5: ICT for Health, Ageing Well, Inclusion and Governance).

Analyzing the current state of the art, it is possible to recognize a trend over the use of robotic solutions(see Fig. 1). Earlier solutions for elderly assistance were based on the use of stand-alone assistive robots or sensor networks dedicated to accomplish specific tasks, like home cleaning, walk support or escorting, improve personal communications, perform activity monitor, provide safety and security services.

Recently standalone robots are been integrated in smart environments to act as simple companion robot [15] [16] or to provide complex assistive services [17] [18]. In this new paradigm, called networked robotics [19], robots provides a number dedicated services to the users anywhere and anytime, by leveraging the use of wireless communications and the cooperation between robotic agents. In this way smart environments and intelligent agents extend the effective sensing range of robots improving their planning and cooperation capability. Nevertheless networked robots present limited computing capabilities and they could be not sufficient for continuously support daily activities and have. Some of these constraints can be overcome integrating robot with cloud computing resources through the concept of cloud robotics [20]. This concept leads to more intelligent, efficient and cheaper generation of robotic networks. The big opportunity to develop and improve this idea is now [21] because of the rapid and exponentially growing of wireless communications both outside (3G, LTE) and inside home (Wi-Fi) and recent innovations in cloud computing technologies[22]. In addition smartphone penetration is on the rise all over the world allowing the possibility to be connected everywhere [23].

The future development in this field should be tended to develop distributed ICT and robotic healthcare services which assist and support the entire population from home to hospital. Furthermore these systems should be developed and implemented very close to humans, with some peculiarity of human beings, in order to achieve the next generation of cloud social robotics.

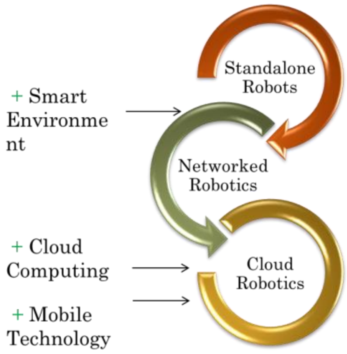


Fig. 1. Trend of development of robotic solution in unstructured environments starting from stand-alone solutions toward a cloud social robotics

4 Proposed Solution

The proposed system aims to provide a paradigm of care where one caregiver is able to manage more elderly people at the same time, regardless to the time, the location of the seniors and the number of services to be addressed simultaneously.

Particularly suited for nurseries, assisted residential buildings or whatever caregivers assist senior citizens continuously. The system was intended to provide a personalized medical support to the users in a continuous manner and with high quality, by leveraging the use of companion robots, distributed sensors in the environment and a cloud platform. In such situations, assistive robots could provide advanced services with a high reliability and service availability, to improve the quality of life of caregivers, alleviating the amount of stress and workload. Exploiting the cloud robotics paradigm, they could offload part of the computation-intensive tasks to the cloud, access to a vast amount of data and increase the storage capabilities. Whereas, indoor user localization and environmental monitoring algorithms were developed and offloaded onto the cloud considering Software as a Service (SaaS) paradigm. This architecture improved the robot’s functionalities without increasing the computational load on-board. Furthermore, different users and robotic agents could use the proposed services without caring about software maintenance. The list of the implemented SaaS is below reported:

1. **User indoor Localization Based Service** (LBS)- The system was able to locate the user to support robots in the continuous care. A localization software acquired data from heterogeneous commercial and ad-hoc sensors, to estimate the position of the user. A sensor fusion approach was investigated to locate people in a robust and scalable manner. Accuracy and cost of the indoor localization service depends on the typology and the number of the installed sensors. In case of a sensor fault, user position was estimated, by fusing data from the remaining ones improving the reliability and the robustness of the service.
2. **Care reminding service** - A calendar for medication and care management was integrated in the system, and provided as a service to caregivers and users. This service was based onto Google Calendar tool. In this way, users and caregivers were allowed to schedule therapies and medical visits on the calendar. The system automatically addressed a robotic reminding service at the scheduled time, to remind the user about appointment or medication.
3. **Environmental monitoring service** – A sensor network monitored the home status by using a switch on the entrance door, PIR (HC-SR502 from Elecfreaks), light (ISL29023IROZ-T7 from ST Microelectronics), humidity (HIH-530 from Honey-well), temperature (STCN75 from ST Microelectronics) and water leak sensors (from Cleode). Data acquired from the sensor network were collected and processed by a software module on the cloud. The software monitored the home status and alerted users and caregivers in case of critical situations.

4.1 Aims of the paper

This paper aims to go behind the state of the art distributing the computing workload over sensor networks, robot and cloud. According to cloud robotics paradigm, the localization algorithm provided the position of users as a service, either to the companion robots for service delivery, and to caregivers for environmental monitoring and to improve the situation awareness. In this way, the authors investigated the advantages to rely user localization service on the cloud to improve assistive robotics in a multiple users and multiple stakeholders scenario.

5 System Description

The proposed cloud networked solution was composed of a mobile robotic platform and a smart environment in two remote experimental sites, integrated through a cloud platform (see next paragraphs for details). In each experimental site, two WSNs were installed, one for user localization and the other for environmental monitoring, whereas the algorithms were stored into the cloud.

5.1 Hardware modules description.

The two experimental sites were provided of the same hardware resources to implement cloud based health management service (Fig. 2).

Personal Robot. The personal robot was developed in the Robot-Era project [24], it was based on a SCITOS G5 platform (Metralabs, Germany); it communicated with the user by means of an embedded touch screen. It exchanged data with the cloud through a Wi-Fi module and was provided by a SICK3000 laser scanner (from Sick AB, Germany) for navigation and obstacle avoidance in indoor unstructured environments.

Smart Environment. The user Localization Network (LN) was designed to locate multiple users at the same time, using the Received Signal Strength (RSS) [25]. It was composed of a ZigBee coordinator, a Data Logger (DL), a wearable mobile node and a set of fixed ZigBee routers, also called anchors. The mobile node periodically sent messages to all anchors within one communication hop. Each anchor computed the RSS on the received messages and transmitted this value to the DL. The Sensor Network (SN) was developed for home monitoring and presence detection. It was composed of a ZigBee coordinator, a DL and a set of sensor nodes, that was connected to a selection of sensors described in the previous paragraph. The two networks were set on different channels to avoid interferences and ensure the proper bandwidth for the localization and environmental monitoring services. Each DL was connected to a low cost PC using USB connection, to upload data on the cloud platform.

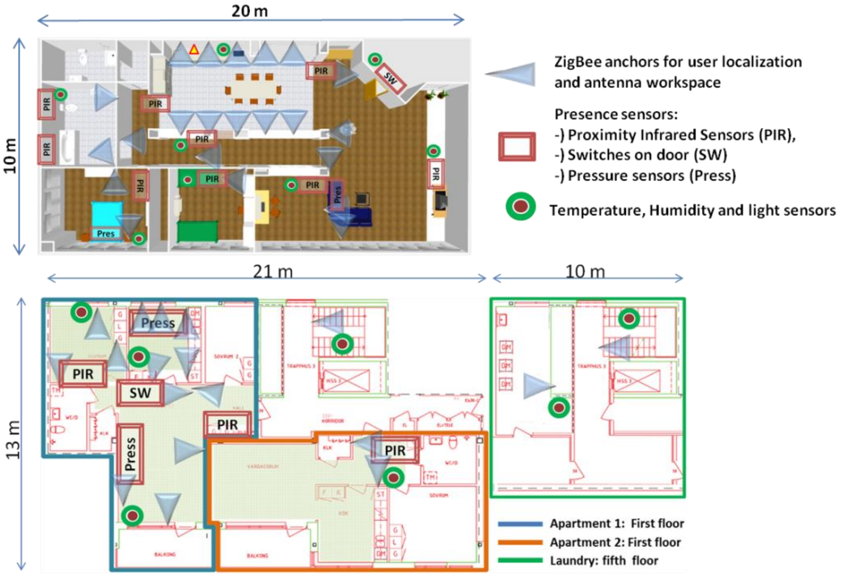


Fig. 2. The description of the two smart environments.

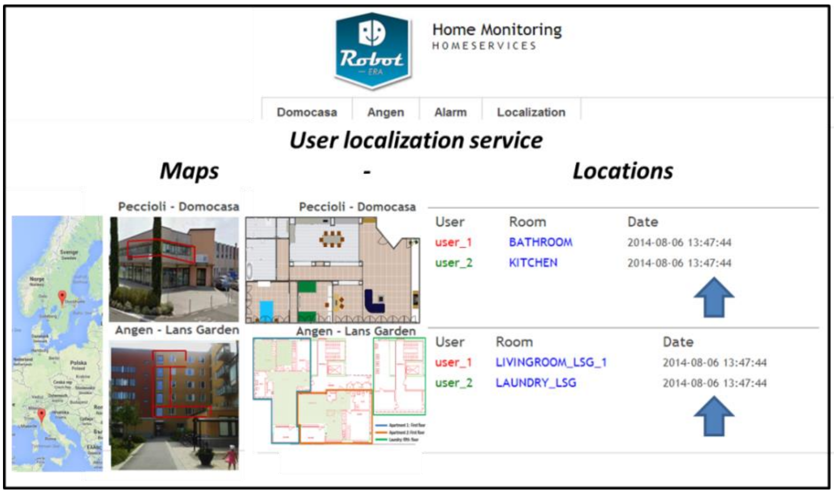
5.2 Software and Intelligent Modules Description

All the Software modules were stored into the cloud to improve service accessibility, availability and robustness. The system intelligent was composed of the User Localization Module (ULM), the Data Base (DB) and the Event Scheduler Module (ESM). The ULM and the ESM were related to the DB, which contained all the information. Also these modules used DB entries to be scalable in terms of number of users, environments and service typologies. The extension of the services to new users and environments can be realized by simply adding new records in the DB, without modifying the ULM and the ESM algorithms.

User localization. The User Localization Module (ULM) provided multi-users localization service in large environments. The software collected data from heterogeneous commercial and ad-hoc sensors, fusing data to estimate the position of each user. A sensor fusion approach based on a Kalman Filter (KF) for user localization was implemented exploiting both range-free [26] and range-based [27] localization methods, according to [28]. Presence sensors were used to improve positioning accuracy and perform host detection. In order to estimate the users positions, sensors outputs and information on the sensor positions were pulled from a cloud data base, in order to made the ULM flexible and scalable. Whenever a new sensor or an entire smart environment is connected to the cloud system, only the DB has to be updated, while the algorithm will just relies to the new entries to perform the localization tasks. Numeric values (x,y) and semantic information on users position were provided to the robots as a service.

Event Scheduler Module. The ESM scheduled robotic services and provided an alarm event analyzing data stored in the DB. To improve the users' sense of safety, specific alarms were implemented; these alarms concerned the entrance door opening during the night and water leakages on the bathroom and kitchen floors to prevent accidents and slipping by users.

Database. A cloud Data Base Manager Software (DBMS) and a Data Base (DB) were designed to improve scalability of the system and services. DBMS managed all the DB entries and queries while the DB all the data from the connected robotic agents, and all the information for the delivery of the assistive services, like for the user localization and monitoring services. The DB was composed of several tables, collecting data on the monitored environments, the installed sensors, the data from the sensors and the position of the users. In particular, tables collected the observations from sensors, the list of installed sensors, the sensors typology, the position of the sensors in the environment, and the estimated positions of the users.



User	Room	Date
user_1	BATHROOM	2014-08-06 13:47:44
user_2	KITCHEN	2014-08-06 13:47:44

User	Room	Date
user_1	LIVINGROOM_LSG_1	2014-08-06 13:47:44
user_2	LAUNDRY_LSG	2014-08-06 13:47:44

Fig. 3. Web interface – Localization page. The LBS algorithm stored in the cloud was able to localize, in the same time, multiple users in multiple environments

Web interface. The system interface consisted of a Web application for remote home monitoring (Fig. 3). It was connected directly to the DB on the same remote server with a public static IP, and the access was restricted to authorized people only. The interface home page provided mean light, humidity, and temperature values for each sensorized room in each pilot site. In addition, an alarm webpage provided a list of alarms that occurred, while the localization webpage reported the room where the users were located (both in Sweden and Italy).

6 Implementation and Experimentation

In order to set a multiple stakeholder and multiple users scenario, the cloud assistive services were provided in two remote and heterogeneous sites: a domotic flat home located in Italy (Domocasa Lab, Peccioli, IT), and an assisted residential condominium in Sweden (Angen site, Orebro, SE).

6.1 Domocasa Lab Peccioli – Italy

The DomoCasa Lab places itself as a complete and integrated laboratory for testing frontier research in the field of robotics and AAL, attracting people to give their own contribution for experimentation and new results. The DomoCasa Lab is a real apartment located and the 1° floor of a business incubator building. It is composed of a living room, a kitchen, a restroom and two bedrooms. Each DomoCasa room was instrumented with at least a temperature, an humidity and a light sensor, while fifteen anchors, six PIRs, and five sensorized carpets and pillows were installed for user localization.

6.2 Angen Assisted facility- Sweden

The Angen site is a 5 floor residential facility composed of private flats, common areas and two domotic apartments dedicated to research activities, where the environmental monitoring and the localization were performed.

The localization and the sensor networks workspaces covered an area of approximately 145 m^2, distributed over two flats at the first floor and the common area of the laundry at the fifth floor. The ZigBee stack provided the opportunity to tackle the challenge to monitor such five floor indoor environment, by leveraging the multi-hop message routing and mesh the network topology of the installed localization and sensor networks.

6.3 Experimental Set-Up description

A low cost PC with a Wi-Fi module was used in the Domocasa and Angen sites to gathered all the sensor outputs and sent them to the remote-PC that acted as a cloud and implemented the assistive robotic services. In this experimental set-up, the remote-PC was located in Peccioli, and had a public IP.

In order to investigate the accuracy of the localization service over different environments, two users worn a MN and moved over a pre-planned trajectory either in the Domocasa and in the Angen site (see Fig. 4) . In particular, the Angen site was selected to demonstrate the opportunity to remotely manage residential facilities and provide AAL services, by implementing a cloud robotic solution. In Domocasa, the user went from the Living room to the double bedroom and backward within an overall localization workspace of 92 m^2. Start and end points of the trajectory coincided, the user crossed the kitchen and the bathroom standing on 18 specific positions of interest marked as a dots in Fig. 4.

In Angen, the user walked according to fig XX, and moved over the two sensorized apartments and the laundry at the fifth floor. The user stood for one minute in 12 specific positions selected on the 145m^2sensorized area in Angen. The trajectory was intended to simulate an ordinary day where the user went visiting his neighbor and then went to the laundry to wash clothes. Positions of interest were selected for their significance in the activity of daily life, like for example in front of the sink, the bath, the sofa or the bed.

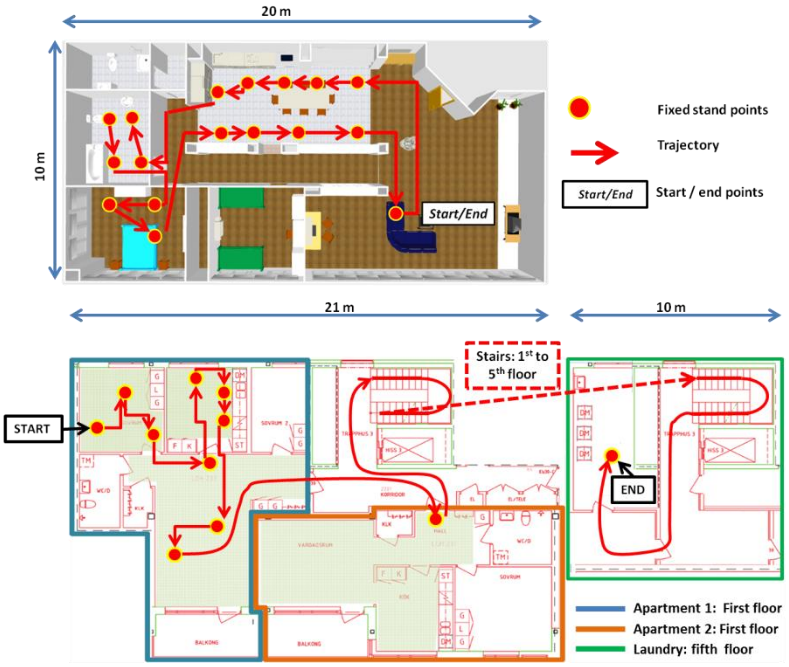


Fig. 4. The pre-planned trajectories in the Domocasa and in the Angen site

Seven experimental trials were performed to provide a consistent dataset and highlight the advantages of the proposed sensor fusion approach and system architecture. The localization error was computed as the difference between the actual position and the position estimated by the localization service on the cloud.

6.4 Application Scenario

As described before, the LBS could be used as a starting point for design and develop other services. For instance:

Reminding Scenario. The caregiver sets for each user commitments and drug reminder on Google calendar. At the scheduled times, the personal robot automatically moved into the house to reached him/her and remind to take drugs (based on to LBS service). After the interaction with robot, the user gave a feedback for the reminding service through a specific app installed in the robot's tablet. In this way, a single caregiver could monitor and check several users. A typical application of this scenario is in a residential facility where a single nurse have to take care of multiple users.

Monitoring Scenario. Data from the sensors networks were sent to the cloud for home monitoring and critical situation recognition. When an event occurred, the system alert the robot, which reached the user.

Fig. 5. Domocasa Lab – IT, the robot reach the user in the kitchen and acted as a physical reminder

6.5 Metrics

The aims of this paper are mainly focus on to the evaluation of the performance of the cloud platform and the accuracy of the multiple-users localization.

The performance of the cloud platform was qualitative and quantitative estimated through two parameters: the Round Trip Time (RTT) and the Data Loss percentage (DL). The RTTis the time required for a signal pulse or packet to travel from a specific source to a specific destination and back again [29].Instead the DL value was given in percent and calculated as the ratio between the succeeded requests and the total requests.

The localization accuracy was evaluate to assess the ability of the system to provide localization based services for AAL applications. for each point of interest in the trajectories performed by the user in Angen and Domocasa, the mean localization error and the Root Mean Square Error (RMSE) were computed. Those values were mediated over the seven experimental trials, and eventually the mean localization errors over the entire trajectories were estimated to assess the localization accuracy of the system.

7 Results

Quality of Service was assessed by the analysis of RTT and DL both in the Domo Casa and in the Lansgarden environments. In particular, RTT was computed as the mean time over 24 h and as a mean time during the night and during the day.

As regard Domocasa, Italy system total time of service was 49.59 ms plus transmission time, whereas for Sweden the total time was 143.29 ms. The total service time was computed as the sum of RTT over 24h plus processing time. The localhost RTT value was 7.46 ms. It was acquired during the experimentation as a benchmark. The Table 1 reported the complete results of RTT analysis, including the results from the night/day analysis. The RTT night data was computed from midnight to 8 a.m., while RTT day data was computed from 8 a.m. to 6 p.m.

Further Fig. 6 reported the trend of RTT value computed for 24 h, at the frequency of 1 Hz. Fig. 7 reported the RTT difference between the RTT night and the RTT day.

DL value was computed as the ratio between successfully requests for user position and total request. This module inquired for user position at the rate of 1 Hz. The number of service fails was less than 0.5% in Italy, and 0.002% for Sweden. The mean time taken by the robot to reach the user was not included in the table because it was strongly dependent on the environment and relative position between the robot and user.

Table 1. Mean Round Trip Time in milliseconds and Data Loss expresses in percentage, both for Italy and Sweden

Location	RTT 24 h	RTT Night	RTT Day	DL 24 h [%]
Processing time	9,21	9,21	9,21	-
DomoCasa - IT	40,38	28,64	46,98	0,49
Lansgarden - SW	134,57	121,59	142,20	0,0018

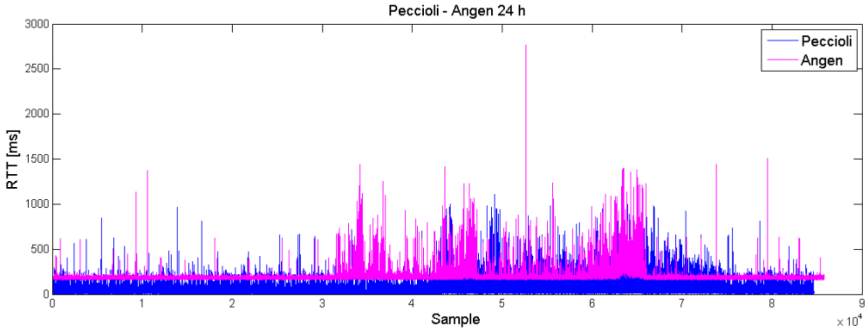


Fig. 6. RTT measurement in Peccioli and Angen during 24 h. Sample 0 was measured at midnight

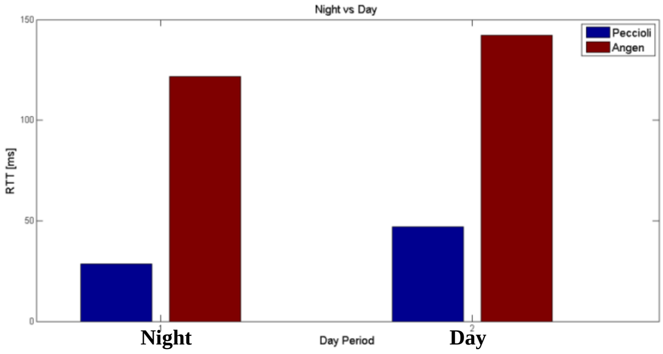


Fig. 7. RTT mean in milliseconds measured during night and during day both in Peccioli and Angen

In Domocasa and Angen, the mean localization errors were respectively 0.98 m and 0.79 m, while the Root Mean Square Errors (RMSEs) were respectively 1.22 and 0.89 m. The cloud indoor localization service was able to locate multiple users in remote environments, at a meter level accuracy. The proposed system may deliver assistive robotic services to a number of users with a in-room level granularity, regardless to the position of the user and the typology of the environment.

8 Conclusion and Future Works

The proposed system was tested in realistic environments, and the cloud robotics approach seemed to be effective in terms of Quality of Service when providing AAL localization based services. The services were provided with a time comparable with classic state of the art robotic services [18], nevertheless, RTT depends on several factors, including the adopted communication technologies and the physical distance from the server. In addition, Fig. 7 shows these differences also during the night and the day. These results, common both in Sweden and in Italy, meaning that other factors which influence the RTT was the internet bandwidth usage.

As show by results conducted in Angen and Peccioli, the entire system was designed to be scalable. The knowledge base and the proposed services could be shared among different users in different environments by using interoperable databases and remote algorithms. The entities stored information about environmental maps, sensor distribution, user/robot descriptions, and the KF matrix. Users who would like to access the service will have to include a map of the new environment (if one is not previously included).

In addition, statistical evidence show how smartphones with wireless broad capability are becoming an indispensable part in elderly daily life [23]. Nevertheless, wireless broadband could negatively impact on the reliability of communication. Further investigations on the proper communication technologies and infrastructures for cloud robotics should be performed. For these reasons, future works will focus on the evaluation of the Quality of Services of the proposed system using LTE and 3G and wired ADSL technologies. In the future specific algorithms for the proper allocation of robotic resources and mission planning should be developed, ensuring a high quality of service and considering dependability issues.

Acknowledgment.

The research leading to these results has received funding from the European Community’s Seventh Framework Program (FP7/2007-2013) under grant agreement no. 288899 (Robot-Era Project). This work was also supported in part by Telecom Italia, Joint Open Lab WHITE, Pisa, Italy.

References

1. Auerbach, D. I. “Will the NP workforce grow in the future?: New forecasts and implications for healthcare delivery”. Medical care, 2012, 50.7: 606-610.

2. Hooker, R. S., Cawley, J. F., and Christine M. Everett. "Predictive modelingthe physician assistant supply: 2010–2025." Public Health Reports 126.5 (2011): 708.
3. Stula, S. : “Living in Old Age in Europe - Current Developments and Challenges”. Working Paper No. 7 of the Observatory for Sociopolitical Developments in Europe. 2012. Available at: http://www.sociopoliticalobservatory.eu/uploads/tx_aebgppublications/AP_7_EN.pdf
4. Lieto, J. M., and Schmidt, K. S. : "Reduced ability to self-administer medication is associated with assisted living placement in a continuing care retirement community." Journal of theAmerican Medical Directors Association 6.4 (2005): 246-249.
5. Kokurek, B. “Promoting medication adherence in older adults… and the rest of us”. Diabetes Spectrum, 2009, 22.2: 80-84.
6. Ostemberg, L.et al. “Adherence to medication. New England Journal of Medicine”, 2005, 353.5: 487-497.
7. Zaidi A., Available at: http://www.euro.centre.org/data/1156245035_36346.pdf, visited on March,2014.
8. Eurostat, People at risk of poverty or social exclusion ; Available at http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/People_at_risk_of_poverty_or_social_excluson, 2013
9. Socio Political Observatory in Europe, Available at: http://www.sociopolitical-observatory.eu/en/key-issues/eldercare-services.html, visited on September 2014.
10. Gil, Nubia M., et al. "Data visualization and data mining technology for supporting care for older people." Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility. ACM, 2007.
11. AALIANCE2 EU project, AAL Roadmap, official website: http://aaliance2.eu/, 2014.
12. Osterberg L., and Terrence B. "Adherence to medication." New EnglandJournal of Medicine 353.5 (2005): 487-497.
13. AGE Platform Europe, "European Charter European Charter of the rights and responsibilities of older people in need of long-term care and assistance," June 2010. Available: http://www.age-platform.eu/images/stories/22204_AGE_charte_europeenne_EN_v4.pdf.
14. Reinhard S.C, Given B., Petlick G.H. and Bemis A., “Supporting Family Caregivers in Providing Care - Chapter 14,” in Patient Safety and Quality: An Evidence-Based Handbook for Nurses, Rockville (MD), Agency for Healthcare Research and Quality (US), 2008.
15. Iwata H., Sugano S. :“Design of human Symbiotic Robot Twendy-one”. IEEE Interational Conference on Robotics and Automation. 2009. Pages: 580-586.
16. Banks M.R. et al., “Animal-assisted therapy and loneliness in nursing homes: Use of robotic versus living dogs,” J. Amer. Med. Dir. Assoc., vol. 9, no. 3, pp. 173–177, 2008
17. Badii A., et al., “CompanionAble: Graceful integration of mobile robot companion with a smart home environment”. Gerontechnology, 8(3), 181, 2009.
18. Cavallo F., et al. "Improving Domiciliary Robotic Services by Integrating the ASTRO Robot in an AmI Infrastructure." Springer International Publishing, 2014. 267-282.
19. Sanfeliu A., Hagita N., Saffiotti A., “Special issue: Network robot systems. Robotics and Autonomous Systems”, 56(10), 791-791, 2008.
20. Goldberg K., Kehoh B., "Cloud Robotics and Automation: A Survey of Related Work." UC Berkeley Technical Report No. UCB/EECS-2013-5
21. T. Ferratè, Cloud Robotics new paradigm is near, RoboticaEducativa y Personal, Jen 13 http://www.robotica-personal.es/2013/01/cloud-robotics-new-paradigm-is-near.html
22. Cloud Survey 2013 available at http://www.enterthecloud.it/mercato/cloud-survey-2013-anteprima

23. Our Mobile Planet – Google statistic available at http://think.withgoogle.com/mobileplanet/en/ on date 01/07/2014
24. Robot-Era EU project, official website: http://www.robot-era.eu/robotera/.
25. Roper, N., Logan, W., and Tierney, A. The Roper-LoganTierney Model of Nursing. Churchill Livingstone, Edinburgh, Scotland, UK, 2000.
26. Y. Wang, Q. J. Yufeng, M. Jianhua,"Integration of Range-Based and Range-Free Localization Algorithms in Wireless Sensor Networks for Mobile Clouds." IEEE International Conference on and IEEE Cyber, Physical and Social Computing, 2013.
27. J. Arias et al., "Malguki: an RSSI based ad hoc location algorithm."Microprocessors and Microsystems 28.8 (2004): 403-409.
28. Cavallo F., et al. "Development of a Socially Believable Multi-Robot Solution from Town to Home." Cognitive Computation: 1-14, 2014.
29. Rouse M., Round Trip Time, Search Networking, available at: http://searchnetworking.techtarget.com/definition/round-trip-time, visited on September 2014.