# COALAS : A EU multidisciplinary research project for assistive robotics neuro-rehabilitation

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***Abstract*— The prevalence of chronic neuro-disability, wheelchair use and cost of caring is increasing in Europe and US. The policymakers are advocating research and use of assistive technology as a way to address this challenge. We will describe a multinational and multidisciplinary project - "Cognitive Assistive Living Ambient System - COALAS" funded by EU research grant of 1.6 million Euro. Our aim is to develop innovative technology based on robotics and ICT for caring the patients to enhance their independence and quality of life. We adopted a user-centred co-production process. The project has three milestones: expectations and recommendations, design and development, evaluation. This article presents the project methodology and the preliminary results in terms of user recommendations and assistive robotics for user autonomy**

## I. INTRODUCTION

The prevalence of chronic neurodisability, wheelchair use and cost of caring is increasing in Europe and US. The shortage of caregivers is leading to an increase in demand for social care both from family and from the welfare states [1]. The prevalence of chronic neuro-disability and wheelchair users are steadily increasing. A survey conducted by the World Health Organization (WHO) estimates that 1 billion people around the world live with some form of disability. Approximately 10 million people in UK have disabilities with a neurological diagnosis [2]. A recent estimation shows that 60-200 per 10 000 people are using powered wheelchairs. This estimation is expected to increase with improved survival from neurological conditions (e.g. 80% of people with spinal cord injury are expected to depend on a wheelchair for the rest of their lives). The cost of caring for neuro-disabled persons in Europe has been estimated as 795 Billion Euro [3]. The policymakers are advocating research and use of assistive technology as a way to ensure the support of disabled. The use of technologies (ICT, robotics, etc.) is emerging for enhancing user independance, increasing societal role and the quality of life [4], [5]. Within this framework, the European project INTERREG IVA COALAS (Cognitive Assisted Living Ambient System) aims to develop innovative technologies based on robotics and ICT for caring the patients, to enhance their independence and quality of life. A user-centred co-production process is adopted. The project has three milestones: expectations and recommendations, design and development, evaluation. This article presents the project methodology and the preliminary results in terms of user recommendations and assistive robotics for user autonomy.

This paper is organized as follows : section II gives a general overview of the projects and details the key actions. Section III presents the results obtained in terms of social surveys and technological developments. A conclusion and perspectives are given in section IV.

## II. COALAS PROJECT

### *A. General overview*

The COALAS project has started in November 2012, will finish in 2015. The project is funded by European cross-border programme INTERREG IVA France (Channel) England. The project is focusing on developing an autonomous cognitive platform, combining an intelligent wheelchair coupled with the assistive capabilities of a humanoid robot. Three milestones are defining the project (Fig. 1):

- expectations and recommendations
- design and development
- evaluation

The "expectations and recommendations" action is achieved through a survey of the end-users needs and views. Correlated with the partnership competence mapping, these feedbacks will lead to the development of several scenarios, a framework for the technical design and development of the demonstrable innovative technology. The concluding section of the project will be to conduct translational research in real-life patients with neuro-disabilities.

### *B. Expectations and recommendations*

This action is based on a social survey. Semi-structured interview and direct observation were chosen as data gathering techniques. The interview takes into account of the personal context of the individuals using assistive technology:

- to observe the participation in social and life roles (daily activities and occupations, leisure activities, etc.) [6];
- to specify the current living environment (mobility and communication equipment, difficulties in the home with regard to housing, wishes, etc.)

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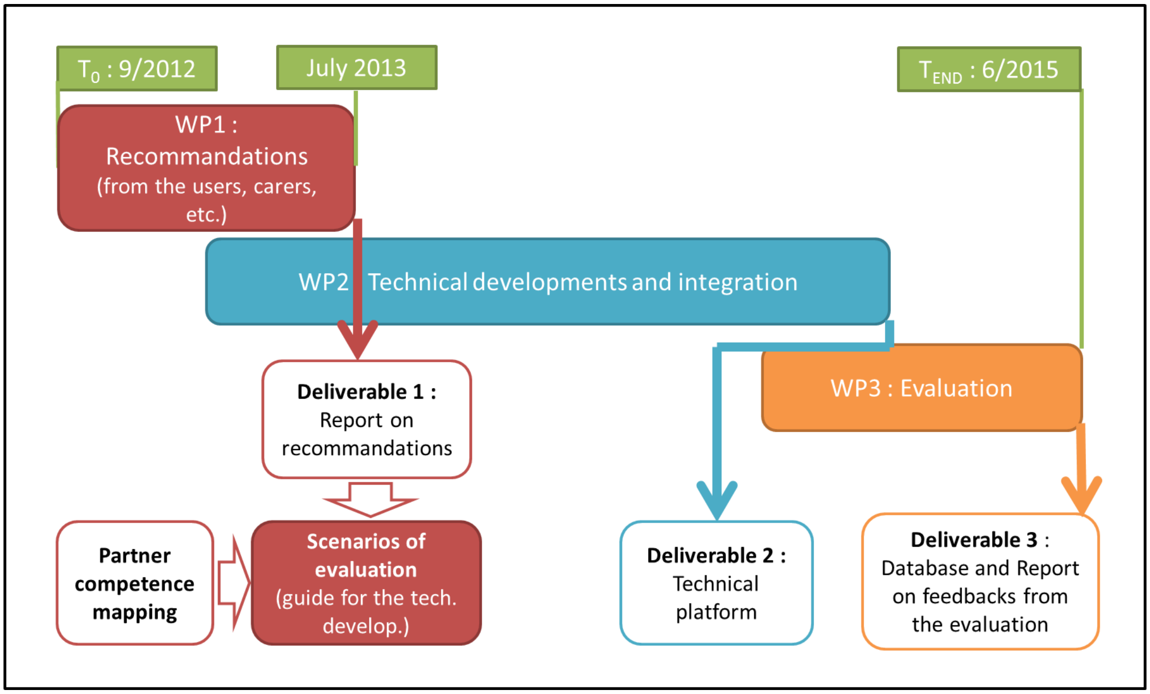


Fig. 1. Timeframe and deliverables of the COALAS project

- to describe and hold discussions involving the COALAS systems.

This framework has enabled interviews to be carried out with disabled people and those around them (family, carers, etc.). Three specific disability situations have been targeted leading to a non-representative but characteristic sample:

- people in wheelchairs (electric or manual),
- people who can only move with difficulty using a walking frame or support bars requiring the contribution of services for actions essential to daily life without being present permanently,
- people with Alzheimer's disease or similar requiring regular surveillance.

Finally, four to five people were interviewed around a same disability situation. Other interviews were held with the administrative and service managers. These people do not work directly with the disabled people. They are considered as knowledge vectors, holding a certain level of expertise which they stated during the interviews. Moreover, they work directly in advising decision makers and in the design of tools and equipment provided to the professionals.

### C. Design and development

The COALAS project aims to design and develop a demonstrator based on the feedbacks from the survey. This demonstrator is mainly made of a humanoid robot, an electrical powered wheelchair (EPW) and a set of heterogeneous sensor fixed on the EPW (kinect, ultra-sound, omni-camera, lidar) to achieve the scenarios of evaluation (Fig. 2).

*1) Assistive navigation of a EPW:* The development of assistive navigation for electrical powered has been a large topic of interest since this is a key issue in the enhancement

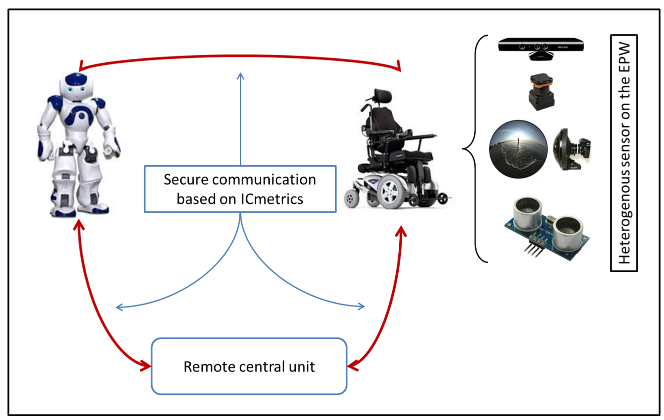


Fig. 2. Illustration of the COALAS demonstrator

of disable people since it must provide relevant, reliable and safe conditions for people motion in houses, hospital or any environment. Several studies have recently emerged, dealing with assistive semi-autonomous or autonomous navigation of EPW. Low level wheelchair behaviors as obstacle avoidance and doorway passing are generally based on range sensor dataset as ultrasound [7], [8]. Others exploits Lidar or IR structured light sensors [9], [10], [11], [12], [13]. Indeed, while range sensors almost directly bring a distance from a measure these active sensors spend more energy than passive ones and, in some medical contexts, the emission of waves is not allowed. The COALAS falls within these works by developing semi-autonomous/autonomous assistive capacities for a EPW in complex and crowded indoor and outdoor environments. This assistive robotic mobility is performed by the combination of heterogeneous devices such as lidar, vision-based system, ultrasound and RGDB sensor. Preliminary works have been carried out with a vision-based system which is a no-limited range sensor and which is a multi-task system since it can be used for people recognition, etc. for instance. However, computing distances from images may be tedious to always have reliable measures, and this is the core issue tackled by many computer vision works. That is why we propose to equip a wheelchair with a vision sensor in order to implement a photometric based wheelchair navigation (Fig. 3).

Fig. 3. The omnidirectional camera (circled in red) embedded on the wheelchair

The vision sensor is more precisely an omnidirectional one, involving a catadioptric optics, bring a very wide field of view in one shot of a single camera (Fig. 4). The interest of such a camera is to bring and elegant solution to perspective camera issues as occlusions handling for place visual recognition, a key element in navigation or, when considering several cameras, costs, cluttering, synchronization and photometric inconsistency issues.

Omnidirectional vision receive attention from researchers about mobile robot visual path following based navigation [14], [15] but methods needs precise camera calibration and a lot of preprocessing (feature detection, matching or tracking, 3D reconstruction) before producing a control to drive the robot. On the other hand, [16] introduces the omnidirectional photometric visual servoing to control a mobile robot over a visual path, by successive visual homing. The latter work avoids any feature detection and matching issues as motion estimation to compute the robot control inputs from the difference between the current image and the image to be reached. We thus propose to adapt and evaluation the latter work to the autonomous wheelchair navigation issue.

*2) Secure communication devices:* A further major strand of the project deals with the development of a secure communication between the EPW, the humanoid robot and the medical center. This protocol, called ICmetrics is based on digital signatures and encryptions keys directly from the operating characteristics of the devices themselves. ICMetrics represents enables the avoidance of storing any encryption key on the devices, by employing properties from which to generate an encryption key from the hardware and software characteristics.

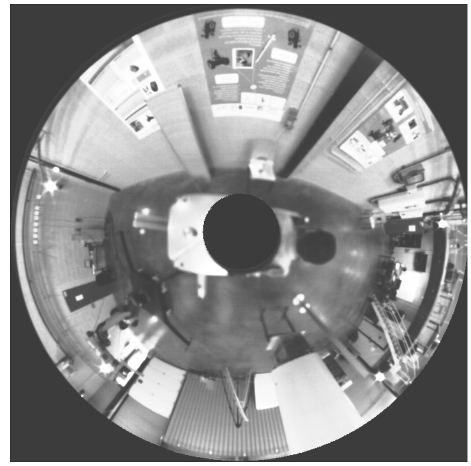

Fig. 4. An omnidirectional image extracted from the learned path.

*3) Humanoid robot:* In the recent years, the humanoid robotics has emerged around the topic of disability and dependancy. The use of these intelligent systems allows a significant reduction of the of providing remote care-services by reducing or eliminating the need for human caregivers when not required by the user. This solution can provide objective monitoring capabilities and round the clock supervision, being easily scalable and having the possibility of centralisation (i.e. in-home systems with a remote central unit of supervision, such as a hospital). The system can provide the option for remote communication with health-care specialists for online consultations and diagnoses, and routine check-ups. By reducing the need to travel to specific locations, it allows users any-time contact with the care-service providers from the comfort of their own home. Also, by using a centralised communication infrastructure such systems improve the efficiency of the health-care services.

## III. RESULTS

This section give a synthesis of the preliminary results obtained within the framework of the project regarding the actions: ”expectations and recommandation” and ”desing and development”

### *A. The survey*

The interviews were analysed and several thoughts are emerging:

- The family : a central role in the support of the disability
- A collection of disability situations

Then, according to these feedbacks, recommendations have been formulated in order to produce the scenarios to be evaluated by the end of the project.

*1) The family: a central role in the support of the disability:* Caring for a dependent person, whether living at home or in an establishment, is a major issue for the family both financially and socially. The family plays a central role in the support process. Sometimes considered as a heavy burden, few families give up their jobs to ensure a fully support. Caring of a disable person may also introduces some divergences both in terms of intervention modalities and financial support. In addition, the active participation of the family members is often unequal: the closest are the often the ones which are the most sollicitated.

*2) Collection of disability situations:* The alteration in the state of health of an individual often occurs from chronic illnesses, a weakening of physiological capacities, or multiple obvious disabilities: sight problems, motor problems, paralysis. Psychoaffective disorders (depression anxiety etc.) may occur due to a variety of factors (solitude, isolation, suffering, loss of a close relation, etc.). The obvious disabilities may also affect the fine motor control which relates specifically to the hands, enhancin difficulties for holding things for long periods or carrying out manual tasks. A major issue also relates to the falls. At home, the fall mostly occurs in the bathroom and shower. Daily basic actions are also strong issues: personal hygiene, brushing teeth, shaving, dressing, getting up or going to bed, taking medication, moving around without support, etc. Finally, interviews highlighted a lack of mobility of disabled mainly due to a loss of motor functions, a personal choice or because of the ”world is coming to them”.

### *B. Assistive wheelchair navigation*

The implementation of the assistive algorithm navigation is made over a ROS-based software architecture (Robot Operating System [17]). Initial implementation is made on a Pioneer 3AT robot and thanks to the ROS standardization, the autonomous navigation method has been quickly moved on the wheelchair for which a ROS communication node has been implemented too. The system is following these steps:

1) reference visual path acquisition by driving the wheelchair manually through joystick and acquiring images (Fig. 4) approximately every 30 cm to build the visual memory
2) autonomous visual path following: the wheelchair reaches every image of its visual memory, successively, from the beginning to the end of the path and/or in the opposite way

Learning and autonomous trajectories, precisely obtained with a Vicon system for evaluation, show the potential of such an approach for the autonomous wheelchair navigation (Fig. 5).

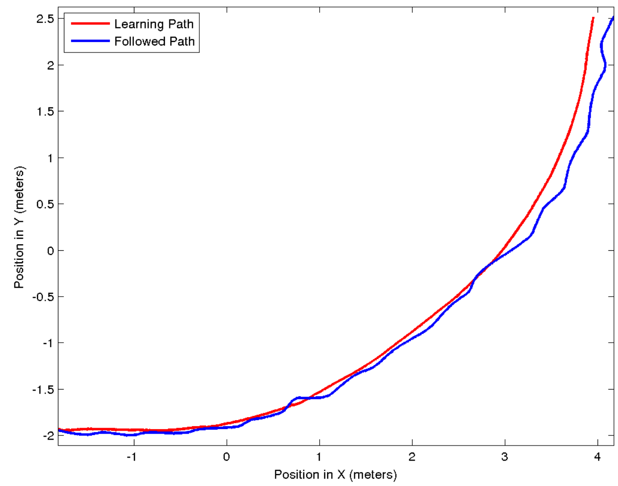

Fig. 5. Learning and autonomous paths for a curved line trajectory of about 9m

## IV. CONCLUSION

This paper outlined the COALAS project, its methodology and its preliminary results, within the scope of developing innovative technologies for improving the autonomy of disable. The project is based on a user-centred co-production process. Therefore a survey has been carried out to get the end-users needs and views. It emerged that the presence of the family or the carer must under no circumstances be called into question while at the same time hoping the systems do not cause inconvenience. Human contact, particularly with the doctor, is highlighted as being reassuring. Moreover, the COALAS system must not substitute for tasks involving human contact, but may be present in the person's environment to help manage unexpected event in place of the carer or the family. Complementarity is, first and foremost, what is required. It is as if the help from the technology must not just be designed for the disabled individual, but for the benefit of the carer as well. It involves relieving the carer so that they can concentrate on the social relationship. These feedbacks correlated with the partner competences mapping have enabled the description of scenarios around the topics of supporting the mobility and fall detection of the disabled. These scenarios provide a framework for the developments of a demonstrator, based on a humanoid robot, a EPW. Preliminary results are related to the powered wheelchair navigation algorithm based on an omnidirectional camera and visual servoing technique. Several trajectories have been experimented. These results have show that the approach is best suited for straight line paths and for slightly curved paths. Future works will focus on how to improve the proposed approach to handle paths with higher curvature. Finally, the evaluation of the demonstrator will be conducted in the hospital of Kent, with real-life patients with neuro-disabilities.

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