Cognitive and physical stimulation services with a robotic agent in a domestic setting

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Abstract. In this paper, we present the service developed for cognitive and physical stimulation of elderly or handicapped people. The services rely on an assistant mobile robot composed of a mobile platform on top of which is set up a manipulator arm. Stimulation relies on scenarios defined together with the partners of ITEA Midas project. In order to build the scenarios, we developed object recognition from vision to facilitate object manipulation, as well as to improve the dialog between the end user and the robot. In order to structure the information, we designed and implemented a dedicated ontology about robotics manipulation. The scenarios are defined using an original event robot programming language. In order to be independent from the hardware, we structure our software layers in a web service architecture. These new functions come on top of those existing in the aviso software, and already assessed by experiments with quadriplegic people. They all contribute to design an assistant robot that can be used and set up by people (end users and care takers) very intuitively in a domestic setting.

Keywords. Rehabilitation, cognitive stimulation, physical stimulation, assistive robotics, man machine interface, computer vision, object manipulation, ontology, web service.

Introduction

Today, the global population is aging faster than ever [31] and worldwide governments are facing the issue of elderly care. They are also trying to integrate as well as they can people who have suffered life accident and are now impaired with physical disabilities.

While most often the answer is a caretaker, either professional or a family member, a caretaker can nevertheless be easily overwhelmed with everyday demands. If some basic daily tasks could be performed automatically, it would free time for the carer, in order for him to spend with their patient for human exchanges.

Automatic assistance via a mobile robot appears as a rapidly growing subfield, as one possible direction for robotic service to persons (e.g., [32] [37] [36]), but current concepts in medical assistance involve mostly remote control of the robotic agent by a nurse.

Figure 1: The mobile robot SAM, composed of a ROBULAB 10 mobile base and a MANUS arm.

A more comfortable solution would be for the robot to be able to grab and carry objects in a domestic environment, without the permanent need for a pilot. With an adapted control interface and a communication system, it would enable the disabled/elderly people to command the robot themselves, thus increasing their autonomy.

The ITEA 2 MIDAS project aims at maintaining elderly people in their home environment as long as possible, by providing them with multiple evolving devices to offer customized support. One of the features of the project, developed by the CEA-LIST, is the robot SAM (Smart Autonomous Majordomo): a mobile robot equipped with a manipulator arm able to recognize and grab objects autonomously (see Figure 1).

The paper is organized as follows: We first present the Midas project and its position regarding rehabilitation robotics. We then illustrate the robot abilities exploited in the project, for with physical and cognitive stimulation, and object fetching. We describe the hardware and software elements of the robot, and we explain the various techniques behind the capabilities of the robot. Finally, we present results of early user tests, a description of future tests, and sum up our contribution.

1. The ITEA2 Midas Project

1.1. Related work in rehabilitation robotics

The mains goals of Midas project are to develop a system providing customized support and assistance to people, according to their own specific situation (age, handicap, etc.), and to provide ubiquitous assistance, both indoor and outdoor.

Rehabilitation robotics is one possible answer to the project's indoor problematic, with a variety of approaches such as object manipulation, transfer (e.g., of a person from a bed to his wheelchair), or companion robots.

Several projects have addressed those prospects:

– Transfer assistance proposes either to replace a four-point cane by a small mobile robot capable of localization, obstacle avoidance and user's health monitoring (see projects SMARTCANE [9] and SMARTWALKER [33]), or to help deambulation and posture transition using a mobile robot (see MOVEMENT project [16][26], and one use of the TWENDY ONE robot [17]).

– With the recent developments of animal-shaped robots, or animaloids, companion robotics has flourished. Relying on emotional / affective involvement of the ageing person through interactions, the AIBO robotic dog by SONY has been used as robot-mediated pet-therapy for old people with light cognitive deficits [29]. Along the same line, emotional interaction is studied via a robotic baby seal (PARO [40]) or via a Teddy Bear-like companion robot, involving touch [34]. The KOMPAI robot [23] plays a role of secretary with vocal interaction.

– Personal autonomy via object manipulation has been widely addressed [14], via workstation systems (a robotic arm fixed to a desk, with access to several elements, as in projects RAID [8], DEVAR [37] and Master [6]), standalone manipulators (adding sensor data within the control loop to the previous approach, see Tou [7] and ISAC [21]), wheelchair mounted systems (robotic arm, most often MANUS or RAPTOR, fixed onto the wheelchair [1]), and mobile platforms (robotic arm mounted onto an independent mobile platform, hence leading to the problem of automated guided vehicles, as in projects WALKY [27], CARE-O-BOT 2 [11], ARPH [15] and HERMES [4]). Recent object manipulation projects - not necessarily dedicated to rehabilitation - involve mobile platforms PR2 from Willow Garage [35] and JUSTIN from DLR [30].

Our project aims at accompanying the elderly through every stage of aging, and provides devices to assist every level of dependency. Once the person is not capable of moving by himself any longer, we propose the one-arm mobile robotic platform SAM, with an autonomous object fetching procedure [39]. SAM's constitution, and particularly its arm, also allows physically exercising the ageing person.

1.2. Assistant Robot in the Midas Project

MIDAS' core idea is to maintain ageing persons in their home for as long as possible, therefore a large part of the project revolves around health and well-being.

Regular exercise is the surest way for elderly people to keep balance, avoid falls and resulting injuries, prevent joints stiffness and preserve overall health [28]. Consequently, the project includes a physical stimulation program, which goal is to provide soft gymnastics movements for the user to perform at home, when they are not

able to join a training group. They are designed as a complement of regular session with a physiotherapist, to keep practicing between visits.

In this context, the CEA-LIST proposed to use SAM, an assistive robot developed in its laboratories, to perform some fitness activities. With the help of MIDAS partner Siel Bleu (a French health prevention association), we established a set of exercises with the robot, involving upper limbs and joints in particular. The robot's arm is used as a guide, to indicate how far the user must push his movement. The arm positions can be computed randomly within a given range, which can be readjusted with the physiotherapist regularly to adapt to the user's fitness level. The arm gripper can also be used to hold objects and allows additional interactions, such as the use of a guide to work with both hands at a time.

Among elderly population, the MIDAS project targets persons with mild cognitive impairments, such as those in an early stage of the Alzheimer's disease. It has been observed that regular stimulation can strengthen spared cognitive abilities and slow their loss [10]. For this reason, the project also includes various cognitive stimulation exercises. The development of cognitive stimulation exercises is under the responsibility of another partner in the project, but we also used the opportunity of object recognition to develop a "Memory game". The robot asks the user to memorize two to five objects, and then to put them on a table in front of the robot. The exercise can indicate if the user made any mistake when picking the objects.

Another goal of the MIDAS project is to avoid unnecessary motions to the user, who may suffer mobility limitations. One of the issues in this situation is the fetching and carrying of everyday objects around the home. Here again the use of a robot able to move around the habitation and grab object autonomously is a convenient answer.

Thanks to the navigation functions of the mobile platform provided by Robosoft, another partner in the project, the robot is able to plan his path through the house toward a given room. It is also able to avoid obstacle that could be present on the computed trajectory.

The CEA-LIST previously developed algorithms to control a manipulator arm so as to automate most of its movements to catch small, light objects (less than 10 cm wide and lighter than 1 kg) [32]. With the addition of scene comprehension thanks to image recognition, the complete grasping motion is now automated. Moreover, the object recognition allows the automated research of a know object around the home.

2. Implementation

2.1. Robot Description

Taking into account all the requirements of the MIDAS project, the robot must provide mobility, object grasping and scene recognition abilities. It is currently composed of a non-holonomic mobile base ROBULAB 10 from Robosoft, equipped with a 6-DOF MANUS arm with its gripper (see Figure 2).

The base is an indoor mobile platform with 2 propulsive wheels, equipped with various sensors: front- and back-bumpers, sick laser for obstacle avoidance and navigation, as well as ultrasound sensors for proximity detection; a panoramic camera

is located on top of the base to provide a large view of the robot environment. The arm is fixed on top of the base.

The arm is also equipped with sensors: 2 webcams are located above the gripper on the end section of the arm; they are used for object recognition, distance stereo-measurement, and visual servoing of the arm movements. An optical barrier, located in the gripper, allows the detection of objects within the clamps, and pressure sensors on each side of the clamp enable controlled grasp of objects [32].
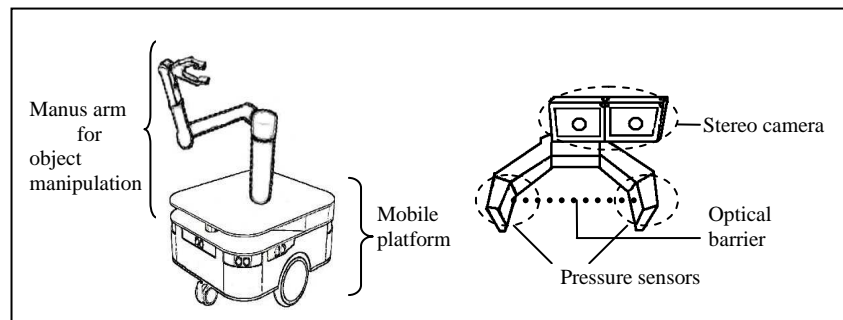

Figure 2: The robot (left) and its gripper (right).

2.2. Software Architecture

The robot SAM is controlled by a software application called AVISO, which provides a simple graphical user interface. From this GUI, the user can control the arm and check its cameras, locate the robot on the home map and send it in another room, identify objects in the field of vision of the camera. Since elderly people are targeted by the MIDAS project, the control interface of the robot must be easily accessible.

The application is divided into several modules, implemented as web services to which the global application is a client: one for the mobile platform movements, one for the arm movements, one for the object recognition. Each module can be tested and modified separately, simplifying the maintenance and evolution of the project. Those web services are based on a DPWS architecture [19], allowing "plug and play" of modules and language interoperability. This compartmentalized architecture allows more versatility in hardware, as only the impacted module will have to be modified rather than the whole application.

2.3. Object recognition and manipulation

As explained in section 2.1, the robot must be mobile, and able to grasp objects autonomously thanks to visual clues. The navigation part is entirely provided by the Robosoft platform; the CEA-LIST offers manipulation skills, presented in this section.

Various methods of grasping for the assistance to people in loss of mobility have been designed in the past. Some rely on a controlled environment (knowing the object position [8] [6], or using a tactile surface to determine it [38]), others require an a priori 3D object model ([5] [11]), or need the user's indications (via a GUI [32] or a laser cursor [18])

Our method does not need 3D geometric models, but a group of 4 to 8 2D images corresponding to different points of view on the object. For each picture, the interest

points [13] (or keypoints) are extracted using the SIFT method [25] and indexed in a database. Their acquisition does not require any specific competences and it can be semi-automated by putting the object on a motorized turntable and taking pictures of object's views with a nearby camera. This way, new objects can be easily learned to enrich the database.

The matching is done by Evolution robotics' software ViPR; it extracts the keypoints from the image and searches the database for potential object matches. Several objects can be identified in one image, including partially occulted objects, even if the luminosity varies. We are able to recognize 13 objects from a distance of 30 to 50 cm, in an average of 450ms. The object does not have to be within user's view, so that object recognition can take place in another room. The CEA-LIST is currently working on its own version of image recognition software, PiRiA [20]. It offers the choice of several descriptors including SURF [2], and is now performing well comparatively to ViPR.

Our application is aimed at people with physical impairments that can prevent them from making precise movements, e.g. click a specific point on a computer screen. This was a limitation in our previous object selection on screen [32]. To get around this issue, we use keypoints coordinates to draw "bounding box": a rectangle enclosing all keypoints found in an image so as to enclose the matched object. With this method, when the user wants to choose an object in the scene, all recognized objects are shown with their bounding box and the selection is done by a click in the desired box. Unknown or unrecognized object can still be selected with the previous method.

Object recognition gave us the opportunity to adapt the grasping to the 10cm wide-gripper, e.g. to catch a box from the side or top if its front is too wide. Knowing the geometry of an object allows us to catch it from the right angle. Once an object is identified, the grasping strategy is obtained from an ontology [12], created with the software XMLSpy, where objects are categorized according to their morphology: symmetric by revolution, cuboids, or more complex shapes. To each category and each point of view on the object, a grasping strategy is associated, describing particularly how to position the gripper opening to the object so as to grab it.

An ontology is also an effective way to represent more complex concepts regarding objects, such as their fragility (and how much pressure they can bear without breaking), their use (e.g., a cup can contain liquids, it is used for breakfast) or most likely location (e.g., the toothbrush in the bathroom). This information can be used for an oriented research of an object, or an elaborated manipulation (e.g., a full cup should not be carried upside down). We are currently working on the development of this richer ontology, with the software PROTÉGÉ [22].

Conclusion

This paper proposed an overview of the robot developed by the CEA-LIST and its implication in the project MIDAS. The project aims at designing solutions for ageing well. First we presented the scenarios created to assist elderly people in their daily life activities. We then described the technical solution (mobile platform with arm manipulator) to implement those scenarios. Finally we presented the capabilities of the robot: Object recognition, manipulation and knowledge representation.

We are now preparing experiments to validate our approach with end-users in a realistic daily life environment.

We were able to assess the acceptability of the robot SAM, by quadriplegic people, and its efficiency to grasp objects via a dedicated interface, with evaluations in rehabilitation centers of Berck (Centre Jacques Calvé) and Kerpape (Centre Mutualiste de Rééducation et de Réadaptation Fonctionnelles), in France. The conclusion was positive, as the robot was perceived as both useful and easily maneuverable [3] [24].

In the context of the MIDAS project, experiments will be realized in February 2011 with elderly people suffering from mild cognitive deficiencies. The evaluation protocol within the MIDAS project is being defined by the LI2G, of Grenoble CHU. The tests will be supervised by occupational therapist of the Siel Bleu association. During those tests, we will try to assess the interest of using our assistant robot for physical and cognitive stimulation exercises.

Acknowledgment

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