USING ROBOTIC SYSTEMS IN A SMART HOUSE FOR PEOPLE WITH DISABILITIES

Viorel Stoian and Cristina Pana
CCMR Craiova - University of Craiova, Decebal Street No. 107, Craiova, Romania

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Abstract: We present in this paper several ideas about the usability of the robotic arms and mobile robots as an assistive technology in a smart house where people with disabilities daily live. First, psychological and social aspects of smart home technology are presented and after that the modularity and standardization processes are discussed. Next we propose a smart house plan, equipped with a mobile robot which has a manipulator arm. This robotic system is used to help vulnerable persons, the handicapped men vehicle seat being equipped with a robotic arm which can manipulate objects by a hyper-redundant gripper. For the control of the processes in the smart house, we propose a hierarchical control system and for the mobile robot we use the artificial potential field method. Also, this paper points out the edutainment concept (EDUcation and enterTAINMENT) by robotics. Finally, some applications are presented.

1 INTRODUCTION

Technology can play a major role in assisting process of the people in their daily life. Designing smart environments is a goal that appeals to researchers in a variety of disciplines, including artificial intelligence, pervasive and mobile computing, robotics, middleware and agent-based software, sensor networks, and multimedia computing (Cook, Das, 1989). Because smart environment research is being conducted in real-world, physical environments, design and effective use of physical components such as sensors, controllers, and smart devices are vital.

We define a smart environment as one that is able to acquire and apply knowledge about the environment and its inhabitants in order to improve their experience in that environment (Youngblood et al., 2005).

Systems are required to be robust and reliable as the person with disabilities will rely on the installed devices and they will become internalized within their self-concept (Dewsbury, Edge, 2000, 2001), (Lupton, 2000).

Some of the properties of the environment need to be captured and they can be measured thus: motion properties (position, velocity, angular velocity, acceleration), presence (tactile/contact, proximity, distance/range, motion), biochemical (biochemical agents), physical properties (pressure, temperature, humidity, flow), contact properties (strain, force, torque, slip, vibration), identification (personal features, personal ID) (Lewis, 2004).

The information required by smart environments is measured by sensors and collected using sensor networks. These sensor networks are responsible for acquiring and distributing data needed by smart buildings, utilities, industries, homes, ships, and transportation systems. Sensor networks need to be fast, easy to install and maintain, and self-organizing.

There are many potential uses for a smart environment. With the maturing of smart environment technologies, at-home automated assistance can allow people with mental and physical challenges to lead independent lives in their own homes. Pollack (Pollack, 2005) categorizes such assistive technology as meeting the goals of assurance (making sure the individual is safe and performing routine activities), support (helping individual compensate for impairment), and assessment (determining physical or cognitive status) (Cook and Das, 1989).

Pineau, et al. (Pineau, 2003) demonstrate the benefits of robotic assistants in nursing homes, while Helal, et al. (Helal, 2005) provide a visitor-

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identifying front door, inhabitant-tracking floor and a smart mailbox to volunteer seniors living in the Gator Tech Smart Home. Kautz, et al. (Kautz, 2002) show that assistance is not limited to a single environment. Using their activity compass, the location of an individual can be tracked, and a person who may have wandered off can be assisted back to their goal (or a safe) location.

Finally, smart environments can be used to actually determine the cognitive impairment of the inhabitants. Carter and Rosen (Carter and Rosen, 1999) demonstrate such an assessment based on the ability of individuals to efficiently complete kitchen tasks.

While performance measures can be defined for each technology within the hierarchical architecture, performance measures for entire smart environments still need to be established.

(Mann and Bendixen, 2007) makes a distribution of the assistive technology in a smart house on eight levels, from the lowest level (basic communications) to eighth level (household arrangements).

Most people see robotics as being a vital technology for providing society with the assistive solutions that it needs in present and will need in the future. The purpose of Assistive Technology (AT) is to provide assistance, without to be a substitution for personal care, to enable people to lead a better quality of life. This technology was applied to devices for personal use created specifically to enhance the physical, sensory and cognitive abilities of people with disabilities and to help them function more independently in environments oblivious to their needs (Story, Mueller and Mace, 1998). People with disabilities are the principal beneficiaries of the technological growth.

2 PSYCHOLOGICAL AND SOCIAL ASPECTS OF SMART HOME TECHNOLOGY

The use of technology appears to present dramatic compromises in social activities, role definition, and identity (Gitlin, 1995).

Approximately all older persons and people with disabilities might feel that they are not included in discussions on technology, as it is perceived as irrelevant to their needs.

Isolation is a major problem for any person who is older or has a debilitating disability (Marshall 2000).

People who are incapacitated in some way are at the mercy of others to provide the simple basic needs. People who do not have disabilities should not to be concerned with food, shelter or human contact as they are part of every day life. It is there essential that people with disabilities are not given substandard care packages that do not meet their needs in all areas: social, psychological, physical, social and emotional. Similarly, care packages should not be over technologies so that the person is reduced to being the slave of technology (Dewsbury, Edge and Taylor, 2001; Dewsbury, 2001).

3 EDUTAINMENT BY ROBOTICS FOR PEOPLE WITH DISABILITIES

Edutainment is a neologism with is derived from the expression "EDUcation by enterTAINMENT" (Muscato and Longo, 2003). It means "Learning and playing". In the edutainment systems or products are included different elements that have been designed to teach or to train persons and at the same time to entertain those persons. For young people with disabilities is very important to learn reading and writing. In the future is very important toad to these processes initiation and learning new assistive technology and devices (computer science, internet, telecommunications, robotics, flexible automation etc.) with will be present inside each smart home. Edutainment has a great success, especially, to young people. A person with disabilities can get through 5 levels of the edutainment which cover a large period of time, from pre-school level to researchers' and practitioners' level: pre-school, kindergarten, school, university, and applications/ research (Stoian, Bizdoaca and Pana, 2006). On the last level the researchers design systems and applications for the others levels.

4 MODULARITY AND STANDARDIZATION

(Virk, 2003) focuses on the state of play of component modularity and standardization in a number of application sectors that have good potential for adopting the robotics technology in the near future. In a smart house for people with disabilities there are many and different technological systems. Because the design of such mechatronic systems is very complex, is necessary to split this design problem into specific areas of mechanics, sensor systems, actuators and powering systems, communication interfaces and hardware and software components of the computing process. In this mode is easier to develop a generic methodology.

The modular design methodology supposes to enable the individual modules to be designed as black boxes that interact with one another via an interaction space (data buses, intelligent actuators, intelligent sensors, intelligent power supply, mechanics, and controllers). The design process should include aspects of standardization so that wider issues of open components can be determined. This can be done by looking for specific application areas and establishing the status in each from the viewpoint of where the technologies are and what the status as regards standards is and what are the future requirements.

5 A PROPOSAL FOR A SMART HOUSE DESIGN

Here we propose a map of a smart house where live vulnerable people (Figure 1). HMVS means *Handicapped Men Vehicle Seat* and MR means *Mobile Robot*. These devices with locomotion facilities are controlled by smart systems (controllers or computers) and implement some methods or algorithms lake in Section 7.

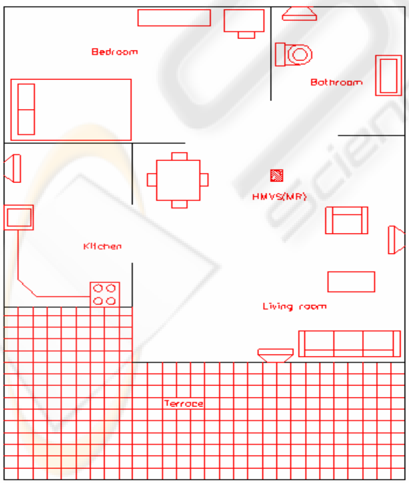

Figure 1: A smart house map.

The external areas can be compound from garden, terrace, drive way, entrance, and stairs. The internal areas can be termed circulation and external for the others and can be compound from: kitchen, living room, bedroom, bathroom, and general. This area has minimal physical barriers between the rooms. Technological systems could be allocated to these functional areas. Some systems (for example, motorized windows or doors), may be the same (physically and functionally) in more than one functional area. This is especially the case for people with long-term degenerative conditions whose quality of life can be enhanced by judicious introduction of this technology (Edge, Taylor, Dewsbury and Groves, 2000).

Systems map to one or more rooms (functional areas). A system that is not mapped to any functional area is not required. Also many of these systems will interact with each other. Some systems may be sufficiently interconnected that they would be better treated as two parts of one bigger system.

It is concluded than that there are two basic types of mapping: either a system will map to one or more rooms (functional areas) or a functional area will map to one or more systems.

6 THE MOBILE ASSISTANT ROBOTS

In this section we propose two solutions which presuppose the use of the robotic systems. First, we propose the installation of a robotic arm on the handicapped men vehicle seat (Figure 2).

Figure 2: Handicapped men vehicle seat with robotic arm.

This arm can execute different actions and different functions which the vulnerable persons are deprived of. It is endowed with a hyper-redundant gripper. The gripper can manipulate different objects with different forms (Figure 3).

Figure 3: The hyper-redundant gripper of the arm.

Second, we propose a mobile robot with anthropomorphic arm which is endowed with an anthropomorphic manipulator (Figure 4).

Figure 4: Mobile robot with anthropomorphic arm.

This device can run inside of internal and external areas and can satisfy many needs of the resident. For example, it can grip and bring a cup of tee, milk or coffee.

7 MOBILE ROBOT CONTROL BY ARTIFICIAL POTENTIAL FIELD METHOD

7.1 The Artificial Potential Field Approach

In order to avoid the difficulties associated with the dynamical model, the control law is based only on the gravitational potential and a new artificial potential. It is shown that to drive the mobile robot to a desired point in an unconstrained movement is necessary the artificial potential to be a potential functional whose point of minimum is attractor for the system. Also, this method is used for a constrained movement in the environment with obstacles. The target position is represented by an artificial attractive potential field and obstacles by corresponding repulsive fields, so that the trajectory to the target can be associated with the unique flow-line of the gradient field through the initial position and can be generated via a flow-line tracking process. This approach is suitable for real-time motion planning of robots since the algorithm is simple and computationally much less expensive than other methods based on global information about the task space. It is difficult in the artificial potential field framework to regulate the transient behaviour of the generated trajectories such as the movement time to the target and the shape of the velocity profile. For example, even if the potential function without local minima is used, it is difficult to estimate the movement time required for reaching beforehand.

Potential field was originally developed as on-line collision avoidance approach, applicable when the robot does not have a prior model of the obstacles, but senses them during motion execution (Khatib, 1986). Using a prior model of the workspace, it can be turned into a systematic motion planning approach. Potential field methods are often referred to as "local methods". This comes from the fact that most potential functions are defined in such a way that their values at any configuration do not depend on the distribution and shapes of the obstacles beyond some limited neighbourhood around the configuration. The potential functions are based upon the following general idea: the robot should be attracted toward its goal configuration, while being repulsed by the obstacles.

In order to make the robot be attracted toward its goal configuration, while being repulsed from the obstacles, $\prod$ is constructed as the sum of two elementary potential functions:

$$\prod(\mathbf{x}) = \prod_A(\mathbf{x}) + \prod_R(\mathbf{x}) \qquad (1)$$

where: $\prod_A(\mathbf{x})$ is the *attractor potential* and it is associated with the goal coordinates and it isn't dependent of the obstacle regions.

$\prod_R(\mathbf{x})$ is the *repulsive potential* and it is associated with the obstacle regions and it isn't dependent of the goal coordinates.

In this case, the force **F**(t) is a sum of two components: the *attractive force* and the *repulsive force*:

$$\mathbf{F}(t) = \mathbf{F}_A(t) + \mathbf{F}_R(t) \qquad (2)$$

7.2 Attractor Artificial Potential Field

The artificial potential is a potential function whose points of minimum are attractors for a controlled system. It was shown (Takegaki and Arimoto, 1981; Douskaia, 1998; Masoud, and Masoud, 2000; Tsugi, Tanaka, Morasso, Sanguineti and Kaneko, 2002, Mohri, Yang, and Yamamoto, 1995) that the control of robot motion to a desired point is possible if the function has a minimum in the desired point. The attractor potential $\prod_A$ can be defined as a functional of position coordinates **x** in this mode:

$$\prod\nolimits_A(\mathbf{x}) = \frac{1}{2}\sum_{i=1}^{n}\left[k_i(x_i - x_{Ti})^2 + k_{n+i}\dot{x}_i^2\right] \qquad (3)$$

The function $\prod_A(\mathbf{x})$ is positive or null and attains its minimum at $\mathbf{x}_T$, where $\prod_A(\mathbf{x}_T) = 0$. $\prod_A(\mathbf{x})$ defined in this mode has good stabilizing characteristics (Khatib, 1986), since it generates a force $\mathbf{F}_A$ that converges linearly toward 0 when the robot coordinates get closer the goal coordinates:

$$\mathbf{F}_A(\mathbf{x}) = k(\mathbf{x} - \mathbf{x}_T) \qquad (4)$$

Asymptotic stabilization of the robot can be achieved by adding dissipative forces proportional to the velocity $\dot{\mathbf{x}}$.

7.3 Repulsive Artificial Potential Field

The main idea underlying the definition of the repulsive potential is to create a potential barrier around the obstacle region that cannot be traversed by the robot trajectory. In addition, it is usually desirable that the repulsive potential not affect the motion of the robot when it is sufficiently far away from obstacles. One way to achieve these constraints is to define the repulsive potential function as follows (Latombe, 1991):

$$\prod\nolimits_R(\mathbf{x}) = \begin{cases} \frac{1}{2}k\left(\frac{1}{d(\mathbf{x})} - \frac{1}{d_0}\right)^2 & \text{if } d(\mathbf{x}) \le d_0 \\ 0 & \text{if } d(\mathbf{x}) > d_0 \end{cases} \qquad (5)$$

where k is a positive coefficient, $d(\mathbf{x})$ denotes the distance from **x** to obstacle and d_0 is a positive constant called *distance of influence* of the obstacle. In this case $\mathbf{F}_R(\mathbf{x})$ becomes:

$$\mathbf{F}_R(\mathbf{x}) = \begin{cases} k\left(\frac{1}{d(\mathbf{x})} - \frac{1}{d_0}\right)\frac{1}{d^2(\mathbf{x})}\frac{\partial d(\mathbf{x})}{\partial \mathbf{x}} & \text{if } d(\mathbf{x}) \le d_0 \\ 0 & \text{if } d(\mathbf{x}) > d_0 \end{cases} \qquad (6)$$

For those cases when the obstacle region isn't a convex surface we can decompose this region in a number (N) of convex surfaces (possibly overlapping) with one repulsive potential associated with each component obtaining N repulsive potentials and N repulsive forces. The repulsive force is the sum of the repulsive forces created by each potential associated with a sub-region.

We propose the mobile robot to move from initial point (x, y) = (0, 0) to final point $(x_T, y_T) = (7, 5)$. If any obstacles are not between the two point, the trajectory is a straight line. If we consider that there is a dot obstacle, in the point $(x_R, y_R) = (4, 3)$, with *distance of influence* $d_0 = 0.4$, the trajectory is like in Figure 5.

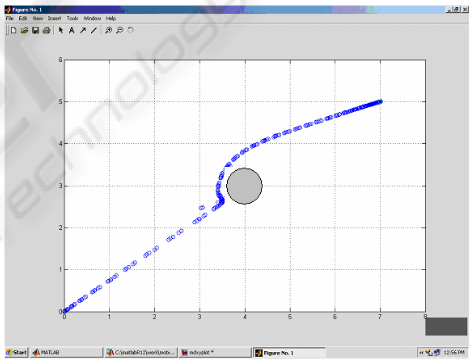

Figure 5: The constrained robot trajectory by one obstacle.

8 CONCLUSIONS

Most people see robotics as being a vital technology for providing society with the assistive solutions that it needs in present and will need in the future. The purpose of Assistive Technology (AT) is to provide assistance, without to be a substitution for personal care, to enable people to lead a better quality of life. This technology was applied to devices for personal use created specifically to enhance the physical, sensory and cognitive abilities of people with disabilities and to help them function more independently in environments oblivious to their needs. People with disabilities are the principal beneficiaries of the technological growth.

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