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Assistive Mobile Robot Technology for Real-Time Task Implementation

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Abstract. The tasks for service robots are to carry out difficult, dangerous, unpleasant, and assistive work for humans in unpleasant, hazardous, and even friendly environments. The main objectives of this article are to gain an understanding of the problems arising when developing service robots in the field of the **MAT M**obile **A**ssistive **T**echnology, to identify significant characteristics of theoretical solutions to **MAT**, and to develop feasible solutions to **MAT** using a mobile robotics framework. These solutions are tested and implemented in a simulated environment and will be further implemented on a real mechanical platform whose architecture will be further defined (the **MRP M**obile **R**obot **P**latform).

Keywords. Assistive technologies, mobile robotics, control

1. Introduction

In the XXIst century **A**ssistive **T**echnology (**AT**) should be defined as a scientific and technological approach to developing products and services oriented to support elderly people and people with disabilities in their daily activities, thereby maximizing their personal autonomy, independence, health and quality of life. Actually, AT plays a fundamental role in equalizing opportunities and in improving the quality of life of people with disabilities, since it provides solutions oriented to the rehabilitation or compensation of functional abilities and helping in the elimination of barriers in all kinds of environments. The satisfactory use of these kinds of solutions enables a better integration of people with disabilities into current society.

Assistive **T**echnology **AT** is, therefore, an instrument for the improvement of the well being, full social participation, and quality of life of people with disabilities, their families and professionals involved in their care. The portfolio of services and products within AT field includes a great diversity of solutions, from prosthetics to accessibility in the work place. There are few areas in which technology can make such a great difference as in *mobility assistance for the disabled and aged market*.

However, despite the technological development and the opportunity it opens, the situation of AT field is not as desired and there is still a long way to go.

As demonstrated by the study carried out by the EU Commission "Access to Assistive Technology in the European Union" (Deloitte, 2003), it is still an unstructured market with lack of transparency that exists in poor communication channels. As consequence, the end user of AT products is dealing with lack of information when deciding about the most suitable product to purchase. Additionally, AT assessment processes still do not integrate the required interdisciplinary vision and are carried out by single persons who, in most of the cases, do not have the suitable education. This scenario leads to situations where the provided solution is not the most suitable one from the integral point of view, generating unsatisfactory and even delicate situations.

New challenges are defined regarding these new assistive technologies. Besides mechanics and electronics, also ambient intelligence, smart and advance materials, nanoelectronics, biomechatronics and even bionics can offer important options for suitable solutions for people with disabilities and elderly people (Eizmendi, 2007).

During the last years, the **AT** field has been involved in a great development, mainly because of the technological revolution. This development is evident in "high tech" products (e-health, computer based systems, etc.) and also in traditional products as the *wheelchair*. An 'intelligent' wheelchair could enhance the freedom of users, reducing their dependency on relatives, friends, and personal assistants (Dragoicea, 2007a). One prospective user group would be severely handicapped individuals who would otherwise find it difficult to steer a wheelchair. Ultimately this new technologies can be used to guide the blind and sight impaired as a complement to the cane. Since the technology also should be able create to a map, it can also assist people who suffer from dementia and impaired memory.

This article proposes a research for infrastructure set up of a dedicated embedded software architecture for the control of a personal transportation vehicle helping disabled people in fulfilling daily operations, like moving from one place to another, or executing repetitive tasks that impose specific sequences of movements between certain locations, with desired velocities. Considering the degree of handicap of the owner, such a device might also need to possess some abilities to navigate with certain autonomy, for example to follow a painted path (a series of marked points) or to recognize landmarks and to pilot towards a destination target with obstacle avoidance and continuous spatial localization. In this respect, this paper presents a general framework for increasing accessibility and mobility of personal transporters, that naturally integrates methods of artificial intelligence.

2. Guidelines for MAT development

Europe, as all other developed regions in the World, is facing a new social challenge: population ageing. This issue will introduce new type of needs and demands in terms of care, support and prevention that AT will have to face. **I**ntegrating **D**esign for all philosophy in the development of regular products and even AT products will speed up the integration process, reducing the gap between context requirements and functional abilities of people with disability.

Making **MAT** **M**obile **A**ssistive **T**echnology products affordable to end users is definitely one of the big challenges for the incoming years. Based on the degree of personal handicap, personal transporters should fulfil specific tasks in indoor or outdoor environments, urban or non-urban areas, friendly or not-engineered human environments.

The idea is that the "intelligent" **MAT** (our mobile device, or our mobile robot in the respect of this research study) could work together with disabled people in order to fulfil specific tasks in indoor or outdoor environments, in a nice synergistic relationship. We want the the robot to adapt to the world of the disabled people, not the world to adapt to the robot.

As this research work identified, personal transporters for people with disabilities should:

- be simple enough to be operated by a limited mobility / locomotion person;
- be reliable in operation with improved stability;
- be a reliable *information system* that process high amounts of data in real-time;
- be easy to program;
- be easy to modify in order to implement more complex navigational tasks;
- must have improved autonomy in fulfilling the navigational objectives.

Such a hardware/software control structure would eventually allow the user to navigate through a confined environment with less difficulty that would other be possible with a conventional joystick-based wheelchair. Improvement of the driving accuracy, human interface and comfort of a personal transporter could be accomplished by altering the wheels, batteries, motor driver cards, joystick, control software, chassis and suspension system (Dragoicea, 2007b).

Navigating a *wheelchair* (the most common **MAT**) through a confined or congested space can be extremely difficult. Conventional wheelchairs require an accurate approach path and a large amount of free space to undertake simple maneuvers such as driving through a doorway. Semi-autonomous control of the wheelchair's motion includes advanced driving methods such as *obstacle avoidance*, *door-driving* and *wall following*. More than that, a higher autonomy eventually requires improved methods for *localization*, *path planning* and *navigation towards target positions*.

3. The MRP hardware setup

From the designers point of view a **MRP** **M**obile **R**obot **P**latform for **MAT** **M**obile **A**ssistive **T**echnology implementation could be a multi-use mobile robot, developed in its basic configuration and having all the most important and vital for its mobile functions systems (Chivarov, 2001). The basic systems of a typical MRP are the following:

- *the locomotion system* (which can be realized on different principles)
- *the driving system* (usually electrically powered by on-board battery)
- *the main control system* (usually microprocessor based)

- *the navigation system* (consist of everything a robot needs to get from one place to another as efficient as - possible without bumping obstacles)
- *the communication system* (connecting all above and the MRP with the environment)

Having the basic **MRP** realized with its main systems and functioning well, it can be upgraded or modified by adding a number of peripheral systems and tools for the performance of different tasks or functions defined either by the designer or by the customer. Using the CAD software program SOLIDWORKS a 3D model of the **MRP** **M**obile **R**obot **P**latform was designed. Figure 1 presents the complete mobile robot test platform (mechanical structure and computing controller).

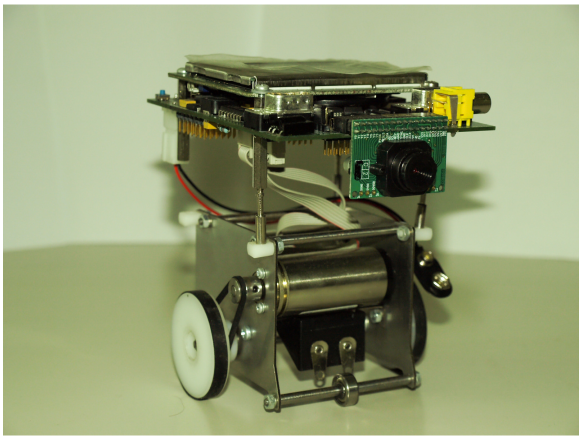

Fig. 1. The complete **MRP** setup for **MAT**

The technical specifications of the **MRP** **M**obile **R**obot **P**latform are presented in Table 1.

Tab. 1. Technical parameters of the MRP

Parameter	Value
Size	10x10x10 [cm]
Speed	Up to 8000 rpm
Gear ratio	17.2:1
Maximum torque	5mNm
Weight	App. 500 gr.

Achieving balance on the **MRP** is very common. We must keep the center of mass between the wheels and as low as possible. This means that we have to place the heavy components like DC motors and battery, in the center of the robot and as low as possible.

The wheeled **MRP** consists of two passive wheels used for keeping the robot in balance, two active wheels used to move the robot forwards or backwards driven by DC motors and a driving belt mechanisms which reduce and transfer rotational motion to the wheels. The robot body is produced from a plate iron and a plastic mandrel, a microprocessor controller, a camera, some additional sensors, a radio module, a 9 V battery and battery holder.

Table 2 presents the technical specifications of the computing controller.

Tab. 2. Technical data

EyeCon EyeBot-Controller M5	**Eyecam Camera C2**
25Mhz 32Bit Controller (Motorola 68332)	usually QVGA mode (320x240, 32bit color)
1MB RAM	wxhxd:4.1cm x 2.8cm x 4.0cm
512KB ROM (system + user programs)	weight: ca. 30 g
1 parallel port	cable: 15 cm length, 4g
3 serial ports (2 V24, 1 TTL)	
8 digital inputs and outputs	
2 motor drives	
large graphics (128x64 pixels)	

4. Model driven architecture for Mobile Assistive Technologies

Robots can be described by their robot architecture. Traditionally, this architecture describes the software aspects that influence its reaction to stimuli, real-time behaviour and deliberative reasoning.

This section concentrates on developing a unified framework that not only encompasses state-of-the-art robot architectures, but also encompasses the structure of all components within the robot system, including environments, users and interaction devices.

This work focuses on using object-oriented analysis and the Unified Modelling Language (UML) to define a unified framework for requirements analysis of MAT Mobile Assitive Technologies. Whereas traditionally, robot architectures have focused heavily on segregating hardware and software elements, the proposed unified approach does not attempt to impose such boundaries.

Requirements are specifications of what a system must do independently of how the system is designed (its hardware). Figure 2 present a requirement diagram for a mobile vehicle that operates in exploration mode.

Once requirements being defined, a robot architecture can be designed. The term *robot architecture* commonly refers to the vehicle's software structure and/or its action selection methods. The architecture must be carefully designed as it has been shown to impact heavily on the overall system performance.

Figure 3 presents the high level architecture of the MAT vehicle.

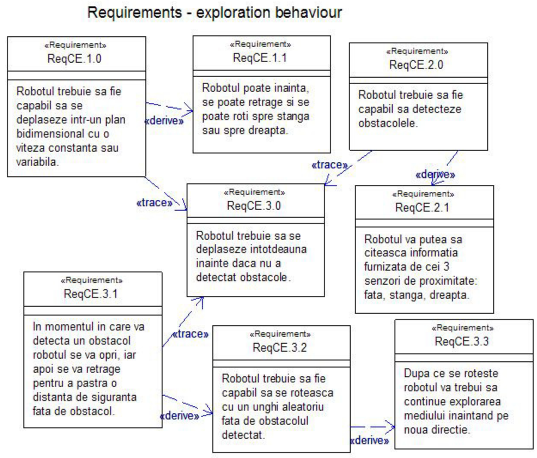

Fig. 2. Requirements diagram - exploration behaviour

The *ModulComportamenteBlock* internal block diagram defines primitive behaviours (collect data, explore, etc), while the *ASC* internal block diagram designs the communication structure for the robot components (user interface, serial communication, control module). The experiments presented in this work specifically describe a framework of defining navigational tasks based on artificial intelligence methods. The research focused specifically on automated learning techniques (artificial neural networks). The set of algorithms was selected in order to increase the level autonomy for complex navigational tasks (exploration and data gathering, obstacle avoidance with the MLP – MultiLayer Perceptrons, landmark navigation with the ART2 Neural Network and SOFM Neural Network, navigation and path planning with the PFM Potential Field Method). These algorithms were tested in simulation (Java implementation) and on the real mobile robot platform.

5. Conclusions

The **MAT M**obile **A**ssistive **T**echnology device is treated here as a special type of mobile robot that eventually would become autonomous after designing specific methods for navigation. Because these vehicles are performing such important jobs, and robust control algorithms should upgrade the functional navigation abilities.. A microcontroller module could be designed to run complex algorithms as artificial neural networks and fuzzy logic controllers in order to assist autonomous navigation abilities. Because autonomous mobile robots are software intensive systems, the rapidly growing code base of robotics projects may require advanced software development methods and technologies. This work proposes a framework for improving design of MAT vehicles by applying the model driven generative domain engineering method to develop self-organizing architectural solutions for mobile robots. Developments were carried out by using the Rhapsody tool, a **MDD M**odel **D**riven **D**evelopment environment for embedded real-time systems based on UML 2.0.

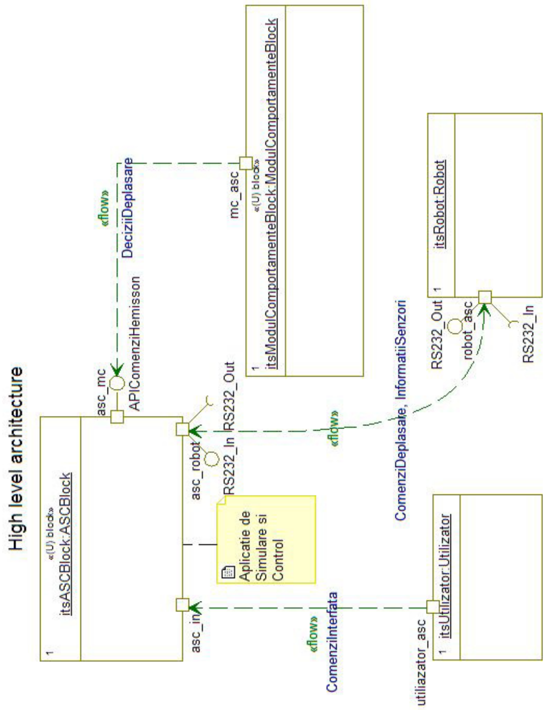

Fig. 3. The high level architecture of the MAT vehicle

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