Research on Autonomous Robotic Wheelchairs in Europe
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Autonomous robotic wheelchairs (ARWs) represent an important class of autonomous mobile robots (AMRs) [1-3] that is receiving increasing attention all over the world. This is due to the strong need of easier wheelchair mobility throughout a longer average life of the handicapped. In the European Union (EU) there are more than two million people with particular disabilities that could benefit from semiautonomous/autonomous wheelchairs. Basically, the design of these powered wheelchairs follows the general principles, technologies, and methodologies of the other AMRs, but they must possess particular characteristics (maneuverability, navigation, control, safety) that call for specialized designs.

During the last decade a great effort was concentrated in European institutions, universities, and companies toward developing semiautonomous and autonomous wheelchairs with several degrees of navigational intelligence. The aim of the intelligent/autonomous wheelchair is to provide the capability of natural wheelchair control to persons with severe handicaps. Standard electric wheelchairs have been in use for a long time, but many severely disabled people cannot control an ordinary electric wheelchair. Thus, further mobility aids are under development to enhance the independent mobility of these people.

This special issue of the IEEE Robotics and Automation Magazine contains five articles that present the design, architectural, implementation, and operational issues of high-autonomy systems built in European laboratories. To increase the coverage of the subject, some other R&D results are briefly overviewed here.

A Quick Look at Some European ARW-Related Projects

Much of the recent work in the EU in the ARW field was carried out under the “Technology Initiative for the Disabled and Elderly” (TIDE), which aimed at advancing the assistive research and technology development (RTD) so as to improve the quality of life for the disabled and elderly as well as enhance the relevant commercial products. Some ARW-related projects other than the TIDE ones include: (i) the MANUS project, (ii) the IMMeDIATE project (an EU SPRINT project), and (iii) the SMART Wheelchair project of Edinburgh University’s CALL Center.

CALL’S smart wheelchair is an augmentative mobility aid for the education and therapy of children who cannot operate conventional powered wheelchairs [4-5]. It is built on a commercial chassis and can be equipped with up to three sensing systems (collision detection, line following, remote detection) that provide good coverage of the chair’s surrounding tem-

plate. The user can take on some of the driving tasks with safety and reduced fatigue.

The MANUS manipulator, one of the most popular wheelchair-mounted manipulators, is suitable for everyday living tasks [6-8]. With MANUS, the wheelchair user can pick up objects from the floor, get plates from shelves, pour himself a glass of water, open the refrigerator, and so on. The MANUS arm is mounted on a rotating and telescopic base unit, so it can be attached to a large variety of commercial wheelchairs. Presently, MANUS is manufactured in the Netherlands (with a reach of about 850 mm and lift capability up to 1.5 kg).

The two TIDE projects that resulted in high-autonomy wheelchair robotic systems are the OMNI (Office Wheelchair with High Manoeuvrability and Navigation Intelligence for People with Severe Handicap) and the SENARIO (Sensor Aided Intelligent Wheelchair Navigation System) projects.

The OMNI project started in January 1994 and was finished in December 1996 [9-11]. Its objective was the development of an intelligent wheelchair with omni-directional maneuverability and navigational capabilities, thus well suited for vocational rehabilitation. Novel sensor and navigation modules guarantee the user’s safety and the required driving accuracy. The system actually produced has the ability to move in any direction, with the linear motion being combined with a rotation around any given point, including the center of the wheelchair.

The SENARIO project started in May 1994 and ended in April 1997 [12]. The SENARIO ARW can operate in two modes: semiautonomous mode and fully autonomous mode. In semiautonomous mode, the system accepts commands to move in a direction, or to take an action (e.g., go ahead, turn left, stop, etc.) and realizes the instructed action, while preventing risk conditions and avoiding obstacles during execution. In this mode, the user can override system actions (e.g., move closer to a wall than the system’s alarm distance). In these cases the system applies the minimum speed limit in all instructed commands. Fully autonomous mode is a superset of semiautonomous mode. The system accepts all the commands of semiautonomous mode, along with “go to goal” (e.g., go to living room) commands. In this case, the system locates itself and then the target position in the environment map. It then plans and executes a path to the specified destination, avoiding all obstacles and risks on the way. The SENARIO system prototype was integrated on a commercial wheelchair and has achieved a very good autonomous performance in indoor laboratory and rehabilitation environments. Within SENARIO, novel obstacle avoidance and path planning
methodologies based on a network of ultrasonic and infrared sensors were developed [13-16].

Two other TIDE projects that have led to products useful for the intelligent autonomous wheelchair are the M3S and MECCS projects.

The M3S (Multiple Master Multiple Slave) project produced a general-purpose interface and bus specification for input equipment and end effectors in rehabilitation systems [17]. Examples of end effectors include a wheelchair motor controller, a wheelchair manipulator, a service manipulator, a workstation, a voice synthesizer, an environmental controller, etc. Using the M3S interface, a variety of devices from different manufacturers can be integrated in a unique system while guaranteeing full compatibility and safe operation. The M3S specification describes: (i) a basic hardware architecture; (ii) an intelligent bus communication system; and (iii) a protocol for system initialization, configuration, and usage. The M3S project was continued by FOCUS in the TIDE bridge phase, and it produced an integrated generic wheelchair-robot-environment control system that can be configured via the M3S standard for the individual user at a moderate cost [18,19].

The aim of the MECCS project was to integrate environmental control on the wheelchair system via a home bus. The final result is a controller terminal that can be mounted on a wheelchair and that allows the use of control devices in the surrounding environment through a radio gateway link to a home bus control system. The use of input devices, other than the keyboard, to the system’s laptop is made possible by a special hardware unit, while the user interface to the home control bus is provided by special software running on the laptop.

Out of the nine TIDE robotics projects (four in the pilot phase and five in the bridge phase) the four projects outlined here (OMNI, SENARIO, M3S, MECCS) are the ones that have addressed ARW design/implementation and ARW-related problems. A survey of the work carried out in Europe in the more general field of rehabilitation robotics through 1995 can be found in [20].

The Articles of this Issue
The first article in the issue, by Bourhis, Horn, Habert, and Pruski, describes the smart wheelchair prototype developed during the second phase of the French ARW project VAHM. In particular, the hardware and software architectures are presented in detail along with the embedded modes of motion and the man-machine interface employed.

Next, Lankenau and Röfer present the Bremen autonomous wheelchair, emphasizing the safety layer, the hierarchy of elementary skills (smooth speed control, obstacle avoidance, turning round), and the complementary assistants developed and implemented.

Then, Prassler, Scholz, and Fiorini describe the MAid wheelchair, which is based on a commercial wheelchair and was designed so as to be able to execute local maneuvers in small cluttered spaces. The article discusses the hardware design, the control system architecture, and the navigation problem in crowded environments. MAid was tested in the railway station of Ulm and in the Hannover Messe ’98 exhibition halls under crowded conditions.

The fourth article, prepared by the research group of the SIAMO project led by M. Mazo, presents the system architecture, the human–machine interface, the sensory subsystem, and the navigation and control subsystems of the SIAMO wheelchair. The user can guide the wheelchair via a linear or discrete joystick, several buttons or switches, a breath-expulsion device, vocal commands, or eye or head movements. The system can be easily configured according to user’s capacities and environment structure.

Finally, in the article by Martens, Ruchel, Lang, Ivlev, and Gräser, the Bremen-IAT robotic system FRIEND is presented, which consists of a commercial wheelchair armed with a MANUS manipulator. The issues addressed include: hardware set-up, software architecture, speech processing, motion programming, gripper positioning, and docking action. After a short training time, the user can grip objects and move them close to him.

Taken together, the above systems, along with the ones briefly outlined in the previous section, provide a good picture of the work going on in Europe.

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References


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