Chapter 38
On the Development of a Multi-Modal Autonomous Wheelchair

Andrea Bonarini
Politecnico di Milano, Italy

Giulio Fontana
Politecnico di Milano, Italy

Simone Ceriani
Politecnico di Milano, Italy

Matteo Matteucci
Politecnico di Milano, Italy

ABSTRACT

The purpose of this chapter is twofold: on one hand, it aims at defining a clear framework for the design and implementation of autonomous wheelchairs, highlighting the main challenges; on the other hand, it presents a complete and working system of such type, called LURCH. This incorporates technology from autonomous robotics, and interacts with its user through a multi-modal user interface, including joystick, touch screen, electromyographic control, or brain-computer interface. If required, other input methods and controllers can be seamlessly integrated. The result is an autonomous wheelchair capable of supporting user mobility while adapting its level of autonomy both to the abilities and to the requirements of the user. Moreover, the capabilities of such a system (in terms of perception, data processing, user interface, communication) open the way to novel modes of interaction between environment and wheelchair users, really making the latter differently able, i.e., endowing them with abilities that walking people cannot access without special equipment.

INTRODUCTION

Being capable of moving autonomously through the environment is extremely important for the wellbeing of human beings. For this reason, conditions or ailments (physical or otherwise) that affect this capability are perceived as extremely debilitating. Unfortunately, the number of people who are not able to walk at all, or who can walk only for limited distances, is not small. Such number includes not only disabled people, but also whoever is suffering from temporary or permanent physical weakness: for instance, elderly people or people recovering from injuries or surgery.

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The simplest tool that can alleviate such problems is a *manual wheelchair*. This device relies on the muscular power of the user's arms for propulsion, and—being based on bicycle technology—is cheap and simple to build and maintain. However, manual wheelchairs require physical strength: therefore they are not suitable for many categories of non-deambulating people, such as children or elderly people, and can be uncomfortable for all users. Even when strength is not an issue, prolonged or long range mobility with a manual wheelchair can be very tiring. For these reasons, in many cases it is necessary to ask for the help of a caregiver, who could manually push the chair.

For the previously stated reasons, in the last decades manual wheelchairs have been flanked (and, especially for outdoor operation, often substituted) by *electric wheelchairs*. An electric wheelchair is fitted with electric motors which act on the wheels, powered by on-board batteries. The first example of such device, depicted in Figure 1, was developed by George Klein in the 1950s at the National Research Council (NRC) of Canada to meet the needs of the veterans from Second World War. Throughout the entire design process, Klein's team worked closely with patients, integrating their feedback after field tests and adapting the wheelchair controller to their residual capabilities. For instance, for one patient a control system was developed to allow him to operate the chair with pressure from his chin instead of his hands.

Modern products are much more advanced, but retain the same structure and functionalities. Driving of the electric wheelchair is almost always performed by the user. Electric wheelchairs afford the possibility of autonomous movement to most non-deambulating people, and are a key element to restore their quality of life. Unfortunately, driving a wheelchair (manual or electric) in anthropic environments can be cumbersome, even where paths suitable for wheelchair users have been devised. For this reason, and considering that currently available wheelchairs do not provide any additional advantages to the user besides the ability to move, wheelchairs are currently only employed when no other options for personal mobility are available.

The functionalities of electric wheelchairs did not significantly evolve over time: notwithstanding technical advancements in their construction, until today such machines have been nothing more

Figure 1. George Klein works on the first practical powered wheelchair at the NRC (Image property of National Research Council of Canada Archives)