Chapter XLII
Trends in Adaptive Interface Design for Smart Wheelchairs

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ABSTRACT

This chapter introduces the main trends in the design of interfaces for smart wheelchairs. It stresses the importance of taking into account their similarity with autonomous mobile robots and the restrictions posed by the special characteristics of the users (people with severe motor and speech restrictions) and the task (indoor assisted navigation). With this background, the main features of the user-wheelchair interface are discussed, justifying the need for the adoption of an adaptive approach. The TetraNauta smart wheelchair interface design is used to illustrate the design of user, context, and task models. In addition, it describes some mechanisms to enhance the communication rate when a single-switch-scanning input device is used (scanning rate dynamic adaptation and word prediction). The chapter finishes with a discussion of the influence of new navigation models, such as the behaviour-based one, in the design of the user interface.
INTRODUCTION

From the technological point of view, smart wheelchairs are very similar to autonomous vehicles or mobile robots. They have actuators (electric motors), sensors (mainly for localise and distance measuring), and a real-time controller that performs the mapping, planning, and driving tasks. Similarly, to other autonomous vehicles, they are designed to transport individuals, but smart wheelchairs present some interesting differences: due to the special features of the user, they require the necessary interaction between the system and the person to be performed with the minimum physical and cognitive effort.

The intense relationship between the user and the wheelchair raises interesting challenges to the designers of the user interface. The user must be in control, while leaving many navigational tasks to the system. The dialogue must be designed in a way that allows the user to give commands quickly enough to efficiently interact with a mobile system, with the minimum physical and cognitive effort.

The following sections present the technological context for which smart wheelchairs are designed, and the constraints and challenges that the wheelchair-user interface design must face, illustrated by details of the design of the TetraNauta smart wheelchair interface (Abascal, Cagigas, Garay, & Gardeazabal, 1999).

WHAT IS A SMART WHEELCHAIR?

Electric-powered wheelchairs are prescribed to people with lower-limb motor disabilities who have difficulties using manual wheelchairs due to upper-limb motor disabilities, such as arm, hand, shoulder, or more general movement restrictions. The user of an electric wheelchair typically controls its speed and direction by operating a joystick on a controller. If the user lacks coordination or strength in the hands or fingers, a number of other input devices can be used, such as chin controls or puff/suck scanners. However, due to severe physical or cognitive restrictions, several users find it extremely difficult to control powered wheelchairs by means of conventional methods, especially when they must perform complex steering or manoeuvring tasks. Smart wheelchairs are mainly devoted to avoiding these problems (Fehr, Langbein, & Skaar, 2000).

Therefore, smart wheelchairs are designed to improve the autonomous mobility of users with severe motor impairments (e.g., quadriplegia or multiple sclerosis) who experience difficulties in driving traditional electric wheelchairs. Individuals in this population can also experience low vision, visual field reduction, spasticity, tremors, or cognitive deficits.

Even though smart wheelchairs have occasionally been used for training and evaluation of traditional and electrically powered wheelchairs (Simpson, 2005), their main purpose is to assist the user with navigation tasks in real time. Since the remaining capabilities of the users are very diverse, and they can change with time due to fatigue, disease evolution, changes in motivation, and so forth, the type of assistance required is also very diverse. Some people may only require help to traverse narrow places, such as doors, or to get out from difficult places, such as small toilets, while others may require complete navigation help, including location and mapping, path planning, and accurate driving to a selected destination. Therefore, smart wheelchairs should be able to perform navigational tasks autonomously, though always taking into account the user’s needs, capabilities and desires.

Smart Wheelchair Structure

A smart wheelchair typically consists of either a standard powered wheelchair to which a computer and a collection of sensors have been added, or a mobile robot platform to which a seat has been attached (Simpson, 2005). The majority of smart wheelchairs developed nowadays are based on commercially available powered wheelchairs. Some models are even designed as independent units that can be attached to and removed from the commercial wheelchair. Several relevant examples of smart wheelchairs can be found in the literature,
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