Chapter 4
Mechatronic Design of Low-Cost Control Systems for Rehabilitation and Assisting Devices

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ABSTRACT

In this chapter, authors focus on mechatronic solutions for low-cost control devices for the homecare of elderly and people with reduced mobility, having the goal of assisting people in daily-life activities. The development of such systems can be exploited in the form of a toolkit to be flexible and applied either to rehabilitation or assistive systems, in order to aid movements with controlled position, force/torque, and acceleration, possibly introducing reliability, repetitiveness, and low cost in the related sector. In particular, the development of a low-cost control system design allows the applicability of the solution to a broad range of devices for the home-care. The authors aim to develop low-cost technologies for the homecare of elderly and people with motor impairments trying to reduce significantly the overall costs to facilitate wider use of assisting and rehabilitation systems. In particular, a Sit-To-Stand (STS) assisting device is considered as a paradigmatic example to illustrate design considerations.

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INTRODUCTION

Recent studies report that the number of elderly and people with motion disabilities that cannot perform Activities of Daily Life (ADL) without the help of other people is increasing. In order to face this problem, nurses, caregivers or relatives are involved for continuous aiding at home, alternatively, a number of commercial solutions have been developed to help the execution of some tasks. Among several ADL, such as walking, feeding, bathing, toileting, we are interested in the Sit-To-Stand (STS), which is one of the most frequent and, despite its apparent simplicity, it is a mechanically demanding functional task undertaken daily, requiring a strong coordination between posture and movement. Some commercial solutions were developed (Hari Krishnan & Pugazhenthi, 2014). Most of these devices act like end-effector robot, i.e. they provide assistive forces only at one body segment, while the trunk is either rigidly supported by a back support of a seat or through use of the arms. All these approaches may or surely result in unnatural kinematics. The purpose of this Chapter is to discuss solutions of mechatronic design for the control of the actuation of assisting devices designed for the STS, as evolution of the ones developed by the authors (Rea et al., 2013; Rea & Ottaviano 2018). They can be either used as rehabilitation devices, as the one proposed in (Rea et al., 2013). The mechatronic design is particularly important when the motion or force have to be controlled (Figliolini et al., 2010, Borras et al., 2009; Ottaviano et al, 2004). Simulation results are reported to show the feasibility of the proposed solution together an experimental test bed of the mechatronic design. This Chapter reports perspectives on mechatronics integrated in home environment and enhancements and of research activities presented in (Ottaviano et al., 2019) as a paradigmatic case of study.

One of the main challenges in the design of assisting and/or rehabilitation systems is their portability and cost, which are in most of the cases prohibitive, even for the solutions developed and commercially available.

Nevertheless, in the last decades, the cost of electronics and microcontrollers has been decreasing, but software in mechanical products have increased. In addition, trends in new products ranging from mechanical solutions with added functionality realized by electronics and software to electronic products with embedded software with the need of mechanical encapsulation. The multi-technological products pose a fundamental challenge for companies joining development processes, different in nature, into a synergistic process to produce successful products. While some companies see new market potentials in the joining of solutions from several engineering disciplines, other companies sees it as a necessity to stay competitive on already captured market segments. The added complexity caused by going from single- to multi-disciplinary development can have various consequences, bringing potential danger to the project. When designing a new mechatronic product or solution, these issues should be faced.

The engineering disciplines mainly considered in the mechatronic design are mechanical engineering, electronics engineering and software engineering. Thus, control engineering might be considered as an engineering discipline on the same level as mechanical, electronics and software engineering. The concept of mechatronics was born in Japan in 1969, (Fukuda et al., 2010). Research efforts continuously demand for fruitful and seamless integration between the involved engineering disciplines (Andreasen & McAloone, 2001, Gausemeier et al., 2009; Tomiyama et al., 2007) to create success in the development of mechatronic products. Mechatronics can be defined in several ways. A common consensus would be to describe mechatronics as an integrative discipline based on mechanics, electronics and information technology to provide enhanced products, processes and systems. It commonly integrates the classical fields of mechanical and electronic engineering, and computer science/information technology since the

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