Chapter 1

Biomechatronics - Introduction

INTRODUCTION

The human motor system can be conceived as a dynamic system, consisting of mechanics, actuation, sensing and control. In the case of motor impairements this system can be supported by an assistive system, which interacts with the human motor system mechanically and by exchanging information. This interaction with the physiological motor system with the goal of improving motor function is the topic of this course on Biomechatronics.

OBJECTIVES
This chapter
- will introduce the human motor system, conceived as a dynamic system, incorporating mechanics, actuation, sensing and control
- will introduce the concept of assistive systems for the impaired human motor system, which can be conceived as a control system parallel to the human motor control system.

CONTENTS

1.1 Human Motor Control

An essential capability of the human body is its ability to move itself and its extremities in a controlled manner. This motor control capacity enables a person to be mobile and handle objects.
The human body has several systems that contribute to human motor control (figure 1-1). The Central Nervous System (CNS) can be conceived as a complex hierarchically structured controller. The muscles are the motors of the human body and the skeleton and external load the mechanical plant to be moved and controlled. The muscles and the skeleton-load system are dynamically coupled and exchange energy. This is indicated by the “power bond” arrow connecting both subsystems. All other connections between the subsystems of the scheme concern the exchange of information without energy exchange, which is indicated by regular thin arrows in the scheme. The body has several sensory systems for feedback. The CNS controller is connected with the sensors and muscular actuators via the peripheral nerves. These subsystems together form a complex motor control system with nonlinear and time variant characteristics (Sinkjaer 1997).

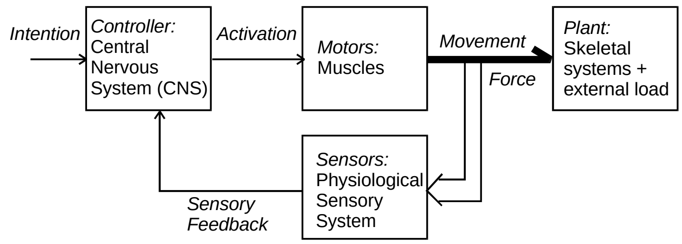

Figure 1-1 *Schematic block diagram of the human motor control system, consisting of a controller (Central Nervous System), motors (muscles), plant (skeleton – external load and sensors). The muscles and the skeleton-load system exchange energy, which is indicated with the thick "power bond" arrow, all other links between subsystems merely concern exchange of information. The double arrow indicates that many quantities of the muscle – skeleton system are sensed by the physiological sensors in the body.*

1.2. Affected Human Motor Control

Disease or a traumatic accident may affect the human motor control system. Impairments may concern the CNS controller (in case of spinal cord injury, Central Vascular Accident (CVA), Cerebral Palsy (CP)), the 'wiring' (Multiple Sclerosis (MS)) the muscular actuators (muscular dystrophy), or sensory system. Impairments may lead to disabilities (not being able to perform certain tasks), which may impose handicaps to a person (the disabilities are experienced as a restriction in daily life) (World Health Organization, 1980).

1.3. Assistive motor control systems

Orthotic and prosthetic systems may help a person to overcome disabilities in order to reduce a handicap. The systems will only be used if the user experienced an effective reduction of a handicap.
Orthotic and prosthetic systems assist the affected human motor control system. In general, these systems can be conceived as an artificial control system including a controller, actuators, mechanics (orthotic or prosthetic components) and sensors (figure 1-2). This system operates in parallel to the affected physiological motor control system. Both systems can interact in many ways, depending on the impairment that needs support:

- *In case the function of the CNS is affected*, the muscles, which are the motors of the body, may not receive adequate input. An inadequate central drive of the motor system may result in missing or incomplete voluntary drive of the muscles and/or non-optimal setting of the low-level reflex loops at a spinal level, which results in involuntary and non-functional spastic muscle activation. An artificial control system may supply the inadequately controlled muscles of adequate inputs by stimulating the peripheral nervous system (Kralj et al. 1989) (Functional Electrical Stimulation: FES). Also, it may interact with the spinal reflex system in order to improve the tuning of this low level control system (Veltink et al. 2000) and/or to use the sometimes complex neural network interactions in the spine to generate complex movements (e.g. control of flexion withdrawal reflex (Bajd et al. 1983)). In some cases of affected CNS, mechanical supports are added to the body. They support the body and limit the number of degrees of freedom, thus stabilizing the body and simplifying the requirments for the artificial control

- *If the mechanics of the body is affected*, the support system may consist mainly of orthotic or prosthetic components. Traditionally, they are purely mechanical, but lately, more flexible controllable mechanical support systems have been developed.
- *If the sensory system of the body is affected*, additional sensory feedback may be given using signals from artificial sensors (Smith 1990; Szeto et al. 1990; Matjacic et al. 1998). However, in many cases, mechanical support systems are used to increase stability of the body in order to enable the body to function with reduced sensory feedback.

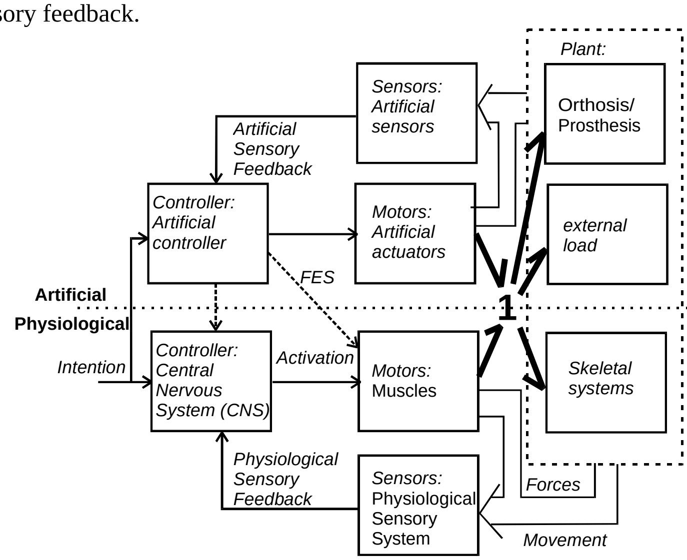

Figure 1-2 *Orthotic and Prosthetic systems that support the affected physiological control system may be conceived as a parallel control system, having many possible interactions with the physiological system. The interactions between subsystems which are associated with energy transfer are indicated by the thick "power bond" arrows, connected by a "1-junction", which means that all velocities are the same, and the forces balance (see course on Dynamic Systems: 1241650).*

1.4. Contents of this syllabus

The current course on Biomechatronics will present all components of the physiological motor control system, discuss impairments of this system and present the components and design of assistive motor control systems, which can contribute to reducing impairments, disabilities and handicaps.
The components of the physiological motor control system are the mechanical system (skeleton) (chapter 2), the actuation system (muscles) (chapter 3), the sensory system (chapter 4) and the motor control system (chapter 5). The components of the physiological motor control system will not be discussed in detail, because they are the topic of other related courses: the mechanical system in *Anatomy and Physiology I* (129353) and *Biomechanics* (115739), the physiological sensory and control system in *Motor Control* (115747), while the neurophysiological basis of this system is discussed in *Physiology II* (129351).
Impairments of the physiological motor control system and resulting disabilities and handicaps will be discussed in chapter 6.

The components of assistive motor control systems will be presented in the subsequent chapters: assistive mechanical systems like orthoses and prostheses (chapter 7), assistive actuator systems (chapter 8), assistive sensory systems (chapter 9), assistive motor control systems (chapter 10). These topics relate to several other courses: *Mechatronics* (124151), *Mechatronic measurement systems* (124163), *Dynamical Systems* (1241650), *Mechanics and Transduction technology* (1228160), *Measurement and Control* (124174), *System and control technology* (113143).
Finally, chapter 11 will present examples of motor prostheses. Knowledge of the physiological motor control system and possibilities of interaction with this system are required but not sufficient in the design of prosthetic systems that satisfy user demands. These systems need to be *cosmetic*, *comfortable* and well *controlled*. These aspects are discussed in the course *Design in Biomedical Technology* (114733).

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