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AMBULATORY SYSTEMS FOR ENHANCED HUMAN MOTOR CONTROL

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Abstract

People with impaired human motor control may be disabled in the performance of daily activities. Their motor control performance may be supported by ambulatory artificial motor control systems that are body-worn and exchange information with the human body. Exchange of information can be achieved at the level of the neural system, muscles activation, interface forces with the environment and body movements. Such motor support systems may not only be relevant in the case of impaired motor control but can also assist healthy people in performing tasks under high loading. This paper describes the general concept of these systems and several examples of applications which are investigated.

1 Introduction

People with impaired human motor control may be disabled in the performance of daily activities. Their motor control performance can be supported by ambulatory artificial motor control systems that are body-worn and exchange information with the human body. Such motor support systems may not only be relevant in the case of impaired motor control but can also assist healthy people in performing tasks under high loading.

2 Concept

The primary issue in the design of systems for support of human motor control concerns concepts of assisting impaired human motor function (Veltink et al. 2001). The secondary, derived, issue concerns methods of interfacing with the human body (figure 1).

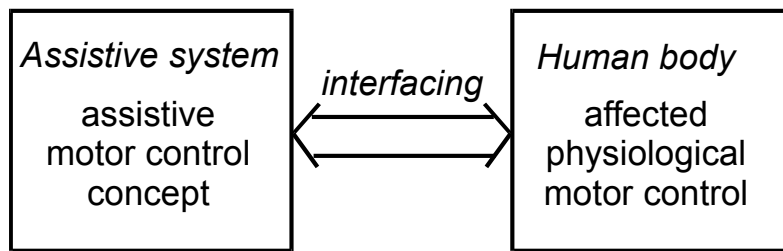


Figure 1. The two essential aspects of assistive motor system are the concept of motor support and the interfacing with the human body (Veltink et al. 2001).

The application of motor assist systems may serve several goals:

- It can take over part of the affected motor control. Examples are Functional Electrical Stimulation systems for activation of paralyzed muscles (Bajd et al. 1983; Franken et al. 1994), controlled prosthetic systems (Popovic et al. 1995; Taylor et al. 1996).
- It can tune the neural control to perform the desired function. Example are deep brain stimulation for improving motor control performance in Parkinson patients (Limousin et al. 1995), influencing sensation and reduce pain by spinal cord stimulation (Holsheimer 1997; Holsheimer 1998), or reducing hypersensitive stretch reflexes by stimulation of antagonistic muscles (Veltink et al. 2000).
- It can aid in training the impaired physiological system. Examples of are robot training systems for upper and lower extremities in stroke and incomplete paraplegics (Dietz et al. 1998; Krebs et al. 1998; Hesse et al. 1999) and training by electrical stimulation (Ladouceur et al. 2000).

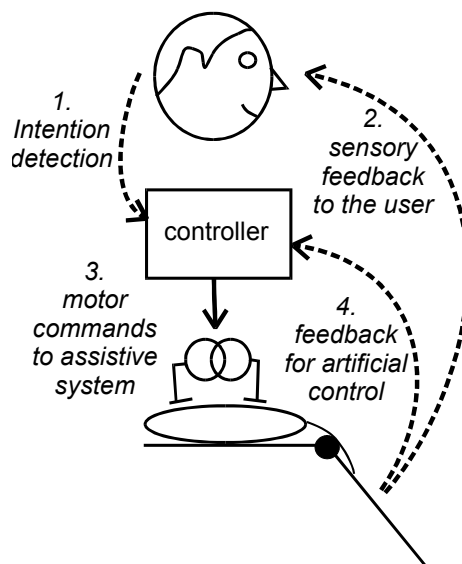
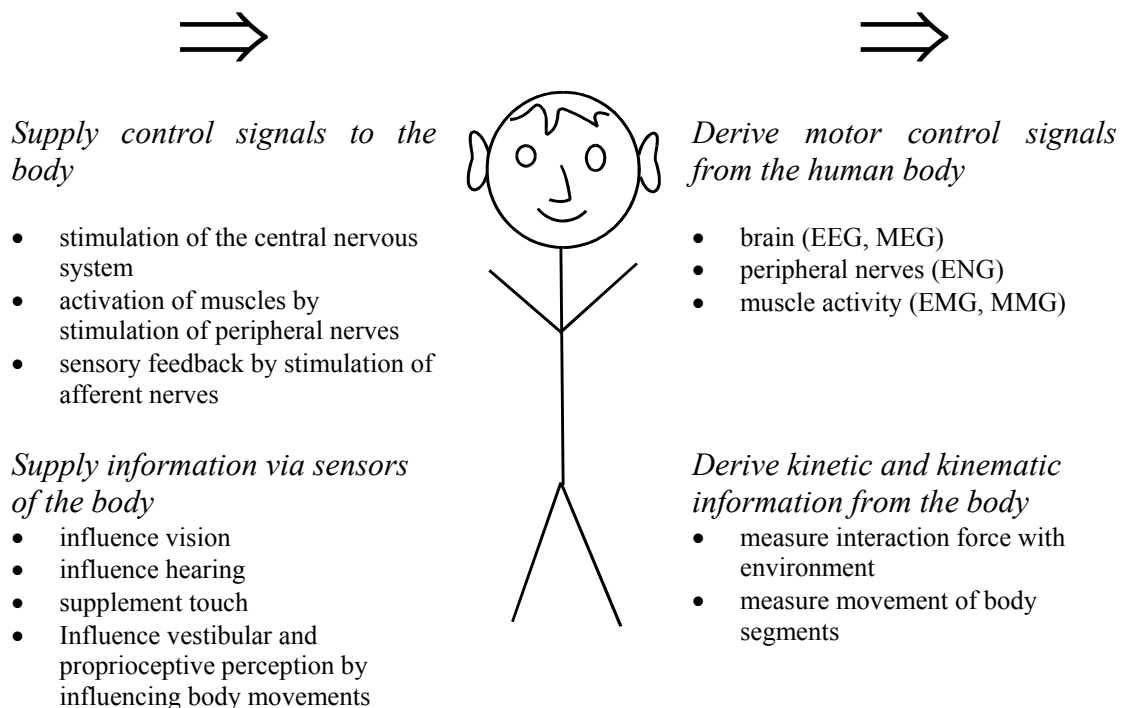


figure 2. The interface between the human body and an assistive device can provide signals from the user to derive motor intention (1), provide the user with lost sensory information (2), transfer motor commands to the assistive system (3) and provide feedback for the assistive motor control (4) (Veltink et al. 2001).

The interface can provide signals from the user to derive motor intention, provide the user with lost sensory information, transfer motor commands to the motor assist system and provide feedback for assistive motor control (figure 2)

Interfacing with the human motor system can be realised via several channel (figure 3). Sensory and control signals can be supplied to the body both mechanically and by electrical stimulation of nervous tissue, both peripherally and centrally. Sensory and control signals can be derived from the body by electrical and magnetic measurements of nervous and muscle activity or by use of artificial sensor systems (Veltink 1999).



Figuur 3 Channels for ambulatory information exchange with the human motor control system

3 Results

In Twente, ambulatory systems for enhanced human motor control are developed for several applications, for example:

1. Functional Electrical Stimulation (FES) of the paralysed neuromuscular system, after spinal cord injury and stroke. Control strategies have been developed and tested for control of cyclical movements like walking (Veltink 1991; Franken et al. 1995) and to detect the motor intention of the user (Veltink et al. 1996b). Hybrid mobility systems consisting of FES and orthoses have been developed and tested (Baardman et al. 1997; IJzerman et al. 1997) and the therapeutic effects of FES on motor control have been evaluated for the upper extremities (IJzerman et al. 1996).
2. The application of electrotactile stimulation is being investigated for sensory supplementation for transfemoral prostheses users. This method may provide transfemoral prosthesis users with information about kinematic quantities, like knee angle at the end of the swing phase of gait, which are currently lacking, avoiding uncertainty and fear in current prosthetic gait (De Vries 1999; Buma et al. 2000).
3. Ambulatory systems for monitoring back loading during labor task (Luinge et al. 1999; Baten et al. 2000), and EMG-based Biofeedback systems for avoiding work related chronic pain complaints like RSI, which are often associated with inadequate physiological motor control. Both approaches have applications in ergonomics.
4. Application of inertial sensor systems for measuring running velocity in sports (Slycke 2000). This application is related to experience of ambulatory measurement of body movements using inertial sensors as developed for rehabilitation purposes (Willemsen et al. 1990a; Willemsen et al. 1990b; Veltink et al. 1996a; Lötters et al. 1998)

4 Discussion

Concepts of enhanced human motor control by application of ambulatory sensory-control systems include artificial motor control, and tuning or training of the neuromuscular system. In many cases, tuning or training of the neuromuscular system is preferable because it enables the person's own neural control system to perform motor tasks in an improved way, providing natural user control and maximal flexibility.

As indicated in the application examples, the concept of enhanced human motor control by application of ambulatory sensory-control systems not only has applications in rehabilitation but also in ergonomics, sports and other non-medical fields where intelligent user-machine interaction is important.

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