# Towards an Integrated Approach to Multimodal Assistance of Stroke Patients Based on the Promotion of Intentionality*

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**Abstract.** Different techniques for the rehabilitation of stroke patients have been developed so far mostly in isolation, namely robot therapy and functional electrical therapy. In many systems, assistance (either haptic or electrical) is provided without taking into account the intentionality of the patient. In this paper we review some general issues and advocate the need of an integrated approach to multimodal assistance, based on the evaluation of intentionality.

## 1 Introduction

Animal models of stroke and correlated human studies demonstrate that functional recovery of motor patterns after stroke is obtained through use-dependent reorganization of neural mechanisms, exploiting basic properties of neural plasticity. However, it is not movement per se, obtained for example by means of passive mobilization, which is effective in recruiting plastic adaptation. The key is movement associated with a *task* [1,2,3] and *volitional effort* [4,5,6]. In fact, task oriented training has emerged as a leading concept in clinical practice. In other words, in order to promote plasticity, there must be a causal relationship between intended actions and the corresponding feedback reafference.

In subjects with a high degree of motor impairment the execution of the intended action is impossible without external assistance, thus the key problem is how to integrate, in an effective way, assistance and intentionality detection.

The question then is: How can volitional effort be evaluated? How can it be enhanced? These issues are analyzed with reference to three important implementation

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aspects: 1) level of stiffness of robot assistance; 2) modulation of the patient's stiffness during functional recovery; 3) enhancing proprioceptive awareness.

There are two general ways to detect motor intentions of a subject: 1) via physiological signals or 2) via modulated haptic interaction.

The research carried out in my lab in the last few years has been focused mainly on robot therapy [7-11]. What is outlined here is a more general framework, which goes beyond pure robot therapy, borrowing ideas from intention detection and BMI, and more generally emphasizing the role of bidirectional interaction between man and machine which characterizes other application domains such as humanoid or service robotics.

## 2 A General Framework

Figure 1 illustrates a general view on an integrated approach to multimodal assistance of stroke patients based on promotion of intentionality. Recently, a lot of activities have been aimed at detecting motor intentions in impaired subjects by using physiological signals such as EMG, EEG, ERD/ERS, and generally movement related cortical signals [12-15]. These studies mostly use FES (functional electrical stimulation) for assisting patients in the contraction of muscles that are instrumental for carrying out planned actions. Although the results are promising, the technique is only applicable to small muscle groups that typically affect a single degree of freedom.

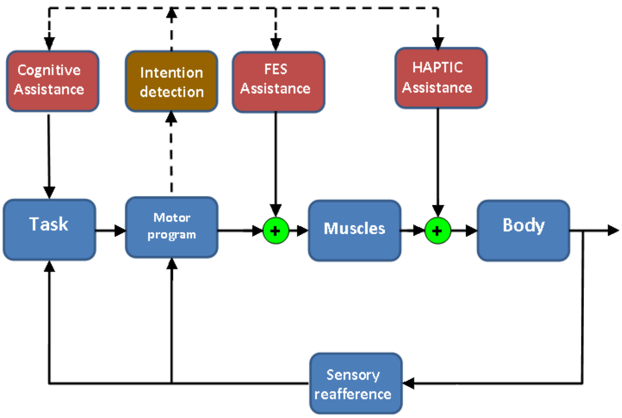


**Fig. 1** General block diagram of task-oriented, intentionality-sensitive assistance system of stroke patients

The alternative to *electrical assistance* (namely, FES) is *haptic assistance*, typically provided by a robotic arm. While the former method addresses directly the muscles of the subject, the latter operates in parallel, by providing assistive forces in a manner that simulates the interaction of a physical therapist with the patient (fig. 2). The key element, in order to provide effective haptic assistance, is that it supplements what has already been decided in the brain of the subject and initiated by producing some kind of efferent signals. This requires that there is a bidirectional flow of energy/information between the therapist and the patient, as is graphically emphasized in the figure.

**Fig. 2** Bidirectional haptic interaction between the patient and a (human or robotic) therapist

It is worth mentioning that the same kind of problems occur in industrial ergonomics [16,17] where haptic robots assist workers at the assembly line by a combination of force amplification and partial unloading of manipulated heavy parts. Moreover, bidirectional interaction is considered crucial also in recent developments of BMI, either intended in the classical meaning of *Brain Machine Interface* [18] or the extended meaning of *Body Machine Interface* [19], which includes assistive devices aimed at mapping/remap-ping residual motor skills of impaired users into efficient patterns of control.

## 3 Haptic Assistance

In order to allow bidirectional haptic interaction between the robot and the patient, the robot controller must be characterized by very low levels of mechanical impedance (in the limit zero-impedance if direct force control can be applied, as in [7]). Moreover, we suggest that the following design principles should be applied:

- To apply the lowest possible level of assistive force with the minimum value of stiffness (*anti-slacking strategy*) [20];
- To apply *task-oriented constraints*, while avoiding over-constraining;
- To monitor patient's *compliance* and *limb position sense* as indexes of receptiveness to detect/accept therapist's aiding intentions [21,22];
- To *personalize assistance* patterns in order to enhance receptiveness;
- To integrate *sensory training* with *motor training*.

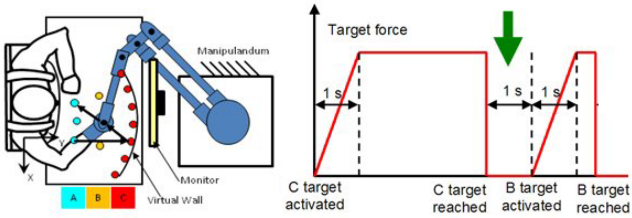


**Fig. 3.** Using a haptic robot for integrating assistance with evaluation of stiffness and limb position sense

Figure 3 illustrates some of the points: constant assistive force = null robot stiffness; disactivation of the force (green arrow) for evaluating the arm stiffness [21].

## 4 Conclusions

The main point of the paper is that in order to obtain real advances in the rehabilitation of stroke patients beyond what has been obtained so far by means of isolated technological systems, an integration of different techniques developed separately must be attempted (namely electrical and haptic/mechanical assistance, with a due attention to cognitive/motivational assistance). Moreover, assistance mechanisms must include measurement mechanisms of the volitional aspects and bodily properties, crucial for carrying out task-oriented actions, such as arm stiffness and limb position sense. This is in line with attempts to use virtual reality and multimodal scenarios [23].

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