MOTORE: a mobile robot for the upper limb neuro-rehabilitation

G. Cappiello¹, Z. Curto¹, A. Scoglio¹, P. Berna², F. Posteraro², E. Ruffaldi³, M. Satler³, C. A. Avizzano³, N. Canelli¹, G. Teti⁴, G. A. Di Lauro⁵

¹ Humanware Srl, Pisa, Italy  
² Auxilium Vitaevolterra - ASL S Pisa, Italy  
³ Percro, Pisa, Italy  
⁴ RoboTech Srl, Peccioli, Italy  
⁵ Dedalo Solutions Srl, Peccioli, Italy

Daily training in people with injuries caused by strokes or traumas can lead to continuous improvements in neuro-motor coordination. A small link-less robot (suitable for both home health care or hospital rehabilitation) has been developed to reach cost-effectiveness, to improve hospital time saving and to reduce patient travel time and costs. The robot is a haptic kinesthetic interface consisting of a mobile cart with three independent actuated omnidirectional wheels. It is in fact an omni-directional device which gives force feedback. The Motore interface with the patient hand is a handle with a load cell; Motore connects wirelessly with a remote PC.

When exercising the patient is requested to follow a virtual path as shown on the screen while the robot (according to the force interaction and the current position on the desk) can help the patient to start the movement or to avoid going in the wrong direction, just like a human therapist would do. While the patient is following this path on the screen he is also actually following a real path with his arm.

The peculiarity of this system is that in order to operate the robot the patient must be actively involved therefore he/she must exert a minimum amount of force. A passive mode is also implemented in which the robot carries the patient arm along the same path. Moreover the audio-visual feedback together with the force feedback are used to make the exercises more appealing, as in a videogame.

In fact this type of device:

- Enhances the patient motivation with fun and challenging exercises.
- Increases the therapy duration while reducing its cost.
- Allows precise measurement (in terms of positioning and force exerted) useful for functional assessment.
- Can be used for patients with mild or severe injuries.

The system is composed by three distinct units that communicate through Bluetooth interface:

- Absolute position processor – gives the robot absolute position information.
- Host Pc – provides the exchange of information between the absolute position processor and the robot, gives the visual feedback to the patient.
- Local control unit – reconstructs the robot position and provides the force feedback to the user handle.

The local control unit runs both the low level control (sensor measurement and motor control) and the high level control (logic control for phase detection and etc.). The control algorithm has to provide:

- Accurate position measurement
- Force and position control
- Fail safe criteria

The control algorithm is composed by three closed loops, i.e. the current control, the velocity control and the position update, and by two open loops, i.e. Inertia compensation and torsion compensation.

A pilot study on hemiparetic patients has been done. Each patient performed up to six 20 minutes sessions. The spasticity has been evaluated before and after treatment by Modified Ashworth Scale. All patients (mild and moderate impaired) have been able to use the device and after treatment muscle tone was not increased. Treatment was well accepted by patients. A wider experimentation will be performed for a full evaluation of effectiveness.

REFERENCES:

• Wheeled robot with force feedback moving on a desk.
• Low cost portable device
• Embedded actuation and control
• Omni-directional autonomous rehabilitation robot
• Exercises consist of virtual training trajectories. Target/trajectory size accorded to anthropometric measure (Full, Medium, Small size)
• Large workspace
• Voluntary movements are needed and they seem to be useful for upper limb motor recovery: a minimum amount of force (0.3N) is requested to activate the robot.
• Force feedback and audio-visual feedback are used to increase the patient motivation
• Force and position are recorded and can be used for functional assessment (and for evaluation of the therapy progress)