Intention reading and intuitive shared control for mobility assistive devices

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***Abstract*—My talk will first examine conditions for efficient and intuitive interfaces to control mobility assistive devices. How observation of human sensorimotor behaviour can be used to design such interfaces, will be then illustrated in two examples: (i) intuitive shared control, in a collaborative robotic wheelchair that has been tested on healthy and impaired individuals, and (ii) a system to detect turning intention for controlling the movement direction in a lower limb exoskeleton.**

I. Principles for the interaction with mobility assistive devices

Intelligent mobility assistive devices such as robotic wheelchairs and lower limb exoskeletons have been intensively developed in recent years. The mature mobile robots technology and the well developed field robotics promise robotic wheelchairs able to move safely in various terrains. However, to our knowledge there is no commercially available smart wheelchair, and only sparse literature describing experiments with end users. I claim that one major reason for the very limited use of robotic technology in wheelchairs lies in unsuitable human-machine interaction strategies to control them.

On the other hand, the mechatronic design of a light but powerful lower-limb exoskeleton to enable neurologically impaired individuals to walk involves various difficult problems, and it is not yet a mature technology. However extensive efforts, such as the recent European projects MINDWALKER, BETTER, BALANCE, SYMBITRON, BIOMOT, H2R, are producing rapid advances in this area. It is no longer fanciful to pretend that individuals affected by spinal cord injury will be able to walk again with an exoskeleton. However, a mechatronically perfect exoskeleton will not be a big help to impaired users if it is not able understand their intention.

So, what factors should be considered to design an interface that enables human users to control a mobility assistive device efficiently and comfortably? A *first principle is that the device should let the user as much as possible in charge of the control*. This is critical because impaired individuals, like able ones, want to decide and carry their actions independently. For instance, autonomous mobile robots used as wheelchairs are not appreciated by users, who do not want to be driven but only helped to drive themselves. Conversely, it is important to use minimal assistance as humans naturally tend to minimise effort, thus will tend to depend more and more on it [1].

As a consequence of this principle, assistance of able subjects will gradually decrease and eventually disappear. In fact, the device should be usable by various kinds of users and *it should not disturb healthy subjects*. In fact unimpaired users should not notice the device, i.e. it should be *transparent* to them. While this principle seems to be trivial, it is in fact difficult to obtain this from an assistive device: robotic wheelchairs often disturb users as they impose a command even when a user would be able to maneuver well without it, and current exoskeletons can hardly be controlled in a transparent way.

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A *second principle to control an assistive device is that it should obey natural motion intention*. This has two favourable consequences: Users will be able to use the device efficiently, because they can control their movements well, and they will need little cognitive effort. In order to implement this strategy, it is necessary to examine natural behaviours and identify how these could be used in order to elicits suitable commands of the assistive device.

II. Collaborative wheelchair

The concept at the heart of our *collaborative wheelchair assistant* (CWA) [2] is to rely on the users motion planning skills while assisting the maneuvering with flexible path guidance. The user decides where to go and controls the speed (including start and stop), while the system guides the wheelchair along software-defined guide paths. An intuitive path editor allows the user to avoid dangers or obstacles online and to modify the guide paths at will. By using the human sensory and planning systems, no complex sensor processing or artificial decision system is needed, making the system safe, simple, and low-cost.

This system fulfils the first principle as it will guide individuals who cannot control the wheelchair, while still letting them in charge of speed control. For instance, they can start to move when they want (not just when the robot starts) and stop to observe a butterfly or discuss with a friend along the way. Human-like [3], [4] adaptive guidance stiffness yields automatic adaptation of the path elasticity so that assistance disappears for able subjects. The second principle is fulfilled as the joystick command is not modified, just filtered on the lateral motion.

Trials on individuals affected by cerebral palsy or traumatic brain injury who could initially not use a motorised wheelchair demonstrated that the CWA enabled them to drive safely safely and efficiently in an environment with obstacles and narrow passageways. The CWA enabled these subjects to drastically reduce their effort and intervention level without compromising performance. Some subjects improved their control to the point that the guidance assistance automatically disappeared, and they did not notice the gradual change.

III. Detection of turning intention

Control systems of exoskeletons for walking assistance should provide sufficient performance, be safe for users and enable intuitive and natural human-machine interaction. In cases of neurological injury such as stroke and spinal cord injury, patients are unable to control their lower body but often have better control of the upper body including the head and trunk.

During locomotion in humans, upper body movements generally precede the actual turn: it has been shown that the head and gaze react first during locomotion and turning by steering the eyes and head towards the turning direction. We propose to use these natural synergies, and detect the intention to turn from the head and trunk in order to control a gait assistance exoskeleton.

An experiment with able bodied subjects showed that head and pelvis yaw measurements can be used to detect turning action before the movement actually occurs. This method may be used as an intuitive way of controlling the steering of exoskeletons by using the natural anticipatory behaviour of the upper body during locomotion. This method based on natural movements thus fulfils the second principle; in turn the system will assist minimally as is required by the first principle.

Future experiments with impaired individuals will test whether this modality can be used to command a mobility assistive device. We believe that even if impaired individuals may initially not use head movements during mobility with an exoskeleton, because they did not move for a long time, it will be relatively easy for them to learn using this modality based on natural synergies.

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