Ecole doctorale SMAER

Sciences **M**écaniques, **A**coustique, **E**lectronique, **R**obotique

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Thesis subject 2017

Laboratory : **Institut des Systèmes Intelligents et de Robotiques (ISIR) CNRS UMR 7222**

University: **Université Pierre et Marie Curie**

Title of the thesis: **Development of a "Body-Machine-Interface" for the control of a gravity balancing lower limb exoskeleton.**

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Collaborations within the thesis: **WANDERCRAFT (French exoskeleton company)**

Program affiliation:

Cotutelle:

University :

This subject can be published on the doctoral school's web site: **NO**

Thesis's summary (abstract):

As more research is conducted around the design of lower-limb assistive devices, the question of how they are to be controlled and commanded in a natural and efficient way remains largely open – which is particularly important in the case of neurologically affected individuals with impaired control. Previous research has shown that the upper body provides effective cues regarding the planning of walking motions and turns. **The aim of the thesis is to study and use such cues as an intuitive way to control a lower-limb exoskeleton, yielding good reaction capabilities.**

Subject

Context:

Exoskeletal lower-limb devices present an alternative to wheelchairs through which neurologically impaired individuals – stroke patients, spinal cord injuries, etc. – are assisted with gait motions in an upright position. While current industrials mainly focus on the design of such devices, and work towards making them lighter and less bulky [1], the question of which control strategies are to be adopted when dealing with an exoskeleton remains a challenging one. Not only should the control interface be safe, robust and efficient, but it should also be intuitive and natural; as most patients perceive assistive and rehabilitation devices as an extension of their own body [2].

Figure 1 : Left: 4 DoF exoskeleton from Rewalk Robotic. Middle: 10 DoF exoskeleton from Rex Bionics. Right: exoskeleton Atalante from Wandercraft

Considering the case of assistance to paraplegic patients, which is the first market target of lower limb exoskeletons companies, there is a growing gap between the complexity and possibilities offered by the hardware of these robotic structures on one side and the control approaches yet available [3,4]. While research is conducted in research facilities on control approaches relying on the decoding of human motor intentions from physiological signals (like surface electromyograms, sEMG, or electroencephalograms, EEG) to control assistive devices [5], such control approaches remain hardly transferred because of the lack of robustness of the machine learning methods used, associated with the important variability of these physiological signals when they are used alone [6]. Therefore, commercially available exoskeletons are controlled through simplified approaches. The Rewalk [7] from Rewalk Robotics (see Fig.1 left) is for example controlled through a wrist watch (to indicate the type of action, like standing up or walking) and a simple accelerometer placed in the back vest worn by the user which is used to give a on/off signal to the exoskeleton (bending the trunk will start the walking pattern, while straightening the back will stop it). With such platforms, the overall stability, along with the turning actions, have to be managed by the user him/herself through the use of traditional canes. Recently, more complex mechatronics structure have been developed, like the Rex [8] from Rex Bionics (see Fig.1 Middle) with extra motorized degrees-of-freedom (at the hips and ankles levels) to ensure balance of the user without requiring him/her to use the canes which were constraining a lot his/her freedom. Unfortunately no simple and robust control methods are yet available to capture and decode user's motor intention and offer him/her a natural and intuitive control: an exoskeleton like the Rex with numerous motions capabilities (assuring balance and able to perform turning actions) remains controlled through a simple hand joystick by its user, constraining, again, the precious upper-limb motor capabilities.

Objectives:

The aim of this thesis is to investigate the potential of a body-machine interface for patient using a lower limb exoskeleton, which could provide for a highly stable and intuitive controller, as well as improve the human-machine interaction. A body-machine interface performs the mapping between different body signals into specific control commands for the device [9]. In the particular context of exoskeletons for neurologically impaired individuals, such signals can be extracted from the kinematics and dynamics of the upper body.

The first step of the thesis is to study and assess which upper body motions could be used to provide with a robust and reactive control strategy. Previous research has already shown the effectiveness of anticipatory head, trunk and eye movements in predicting the walking direction of healthy subjects [10]. However, further studies are to be led in order to assess the range of relevant body motions in neurologically impaired subjects. The recording of various upper body measures – such as sEMGs, head and elbow movements and accelerations, etc. – in patients enrolled in a virtual walking experiment will help acquire a large data set of upper body signals.

The high dimensional space formed by the signals from the data set will then be analyzed in order to extract the relevant features and parameters to be used within the mapping interface. Performing a dimensionality reduction, and restricting the data set to a sub-space of patterns that are the most natural and intuitive, a continuous map between body signals and control commands can be constructed. Typically, the control space would be a 2-dimensional one, comprised of forward and angular velocities, which are enough to translate a walking intention into the corresponding exoskeleton movements.

Finally, the control framework developed as part of this thesis will be tested by interfacing it to the Atalante exoskeleton (see Fig.1 Right) developed by the Paris-based company Wandercraft, and performing experimental sessions with both healthy and impaired subjects.

Expected results:

- An innovative, non-invasive and intuitive control approach dedicated to paraplegic patients using a gravity balancer lower limb exoskeleton, which would fully free their upper-limbs and extend their autonomy, transferable to a commercial product.
- A wearable interface exploiting different sensor technologies able to capture upper-body movements.
- Some knowledge on human motor control, on lower and upper body parts synergies and on the learning phenomenon of new sensorimotor skills.

References:

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