Concept of a Novel Soft Wearable Robot for Gait Rehabilitation

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***Abstract*—Current lower-limb exoskeletons for gait assistance are still too bulky, too heavy and, thus, too inconvenient to use, which leads to unsatisfactory performance and discomfort. The goal of this project is to develop a novel wearable exoskeleton that is based on "soft actuator" and "soft control" principles in order to overcome the current disadvantages. The novel system is dedicated to the assistance of humans with limited leg torques, such as incomplete SCI patients, stroke patients, and elderly.**

I. INTRODUCTION

Lower-limb exoskeletons can be very useful to restore walking abilities in two ways. First, they can be used as assistive devices to support elders or patients with gait impairments in daily life situations. Second, they can promote neurorehabilitation as training devices after neurological injuries such as spinal cord injury (SCI), traumatic brain injury and stroke. However, current solutions are still too bulky, too heavy and, thus, too inconvenient to use. Furthermore, torque induction into the human body joints is tricky, and often leads to mechanical stress in the attachment points and/or in the human joints as well as unwanted movements of the exoskeleton with respect to the human limbs. These disadvantages result to unsatisfactory performance and discomfort. The goal of this project is to develop a novel wearable exoskeleton that is based on "soft actuator" and "soft control" principles.

II. CONCEPT

The novel concept will be inspired by the biomechanical structure and function of the human leg. Similar to the human musculo-tendon apparatus several thin cables integrated into a wearable suit that are spanned from their distal end, i.e. the foot/shoe, along the ankle, knee, and hip joints to a linear actuation mechanism attached to the pelvis or trunk (e.g. in a backpack). To keep the system lightweight and easy to handle, in a first version of the device, all cables should merge to only one actuator unit per leg. As the cables surround the joints on the anterior or posterior sides with a well-defined angle-dependent moment arm (see Fig. 1), they generate the torques that are required to support the human in a specific motion phase of a specific movement pattern, such as standing up, sitting down, walking, and ascending. Additionally, functional electrical stimulation (FES) electrodes will be integrated into the suit to increase joint torques to a sufficient level. A great challenge will be the design of the suit fabrics, which must on the one hand be very flexible to allow sufficient joint ranges of motion. On the other hand, the suit fabrics must provide very high stiffness in dedicated directions, to cope with the challenges of sagging and stretching and to prevent that the load transfer via the human limbs does not go beyond a certain limit. Furthermore, the cable conductions must have low friction to be energy efficient, and the entire suit must be comfortable to wear.

A similar system has been developed by the group of C. Walsh [1], [2]. In contrast, our system will be characterized by a different kind of cable guidance and different webbing to better deal with the problems of cable friction, longitudinal load transfer, shear forces and sagging. Furthermore, our system is dedicated for humans with limited leg torques, such as incomplete SCI patients, stroke patients, and elderly.

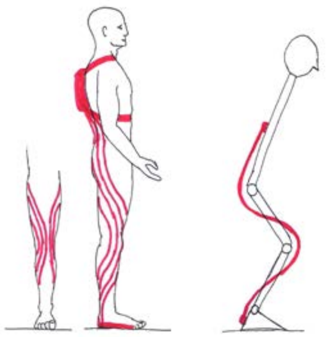

Fig. 1: Cable guidance along ankle, knee and hip joint.

III. EXPECTED RESULTS AND OUTLOOK

The limitation to only one type of movement, assisted by only one DOF actuation per leg, with only a unidirectional load transfer, will make the design simple, feasible, lightweight and comfortable for the user. Misalignment problems, as common with conventional "rigid" exoskeletons are not an issue, because the suit is working without mechanical joint restrictions. After first feasibility tests with healthy subjects, the exoskeleton will be evaluated on the dedicated patient groups. The experimental work will be performed in close collaboration with clinical partners. In a later stage, the soft exoskeletal suit will be used also to verify whether it could reduce the probability of falling in elders.

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