Extended summary (500 words)

Locomotor Sub-functions — An Model-based Approach for Describing Legged Locomotion

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In this talk we consider the concept of "locomotor sub-functions" as an approach to analyze and describe the modular organization and function of legged locomotor systems as found in humans, animals and robots. We aim to understand how the dynamics of locomotion can be represented based on a set of a few characteristic model parameters, which can be derived experimentally. Based on the model predictions and it movement behavior, we will investigate the mechanical design and control approaches for stable and adaptive locomotion.

During bipedal and polypedal locomotion, legs need to fulfill different functions: (1) During stance phase, legs provide the required axial leg force to support body weight by counteracting gravity. In running and to some extend also in human walking, a compliant axial leg function can be observed. (2) During swing phase, the leg needs to be rotated forward (protraction) and to be prepared for the next landing event. (3) Third, through appropriate hip torques acting on the upper body, postural balance of the trunk (including head and arms) needs to be guaranteed.

All three locomotor sub-functions can be described by simple mechanical models (e.g. prismatic leg spring of stance leg) with a few number of mechanical parameters (e.g. spring properties like stiffness and rest length/angles). These model parameters exhibit characteristic changes with locomotion conditions (e.g. gait, step length and speed). Based on model validation through comparison with experimental data and by transfer to technical systems (e.g. conceptual walking machines, assistive systems), the quality of the model can be assessed. As a consequence, simple model descriptions may not suffice and need to be reconsidered. Then, alternative and/or more detailed models may be required to better represent the observed behavior of the biological counterpart. Model extensions typically consider additional features representing the structure of the muscle-skeletal and neuronal system, such as segmentation of legs, muscle function and/or alignment, or reflex networks based on sensory pathways.

An important challenge in the future will be to further extend these models to represent adaptation mechanisms for changing conditions in the locomotor system (e.g. muscle dysfunction) or in the environment (e.g. uneven ground). With these model extensions adaptation strategies like those typically found in gait impairments could be better described and coping strategies (e.g. treatments) could be derived.