LOCOMOTION: PRINCIPLES AND FUNCTIONAL MORPHOLOGY

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Introduction

The ability to move from one place to another i.e. to locomote is considered to be one of the typical properties of animals. Internal forces are used to deform the animal's body in order to be able to interact with the environment, to generate external forces and impulses. Biomechanical modelling and experimental investigations help to understand this process. Using examples of ongoing research at Jena some aspects of this transformation will be illustrated.

Legged locomotion as quasi elastic oscillations

In a first approximation the general dynamics of legged locomotion can be described by simple lumped parameter models. Such models possess "modes" of oscillation which seem to be explored by the animals. The modes are defined by (close to) attractive operation points of a finite state system with nonlinear interaction. In dependence of the distribution of quasi-elastic constitutes in appendages and trunk different combinations and preferences of gait might be possible.

Leg segmentation

Animals (and humans) must deal with a traded segmented system. The human leg segmentation can be predicted assuming a typical compression of the quasi-elastic leg and a minimization of moments. Furthermore, the resulting configuration enhances structural stability of the system [Blickhan *et al*, 2010]. Stability and cost are both general factors strongly affecting design and operation. In small animals especially in arthropods, size, proportion, modes of operation (incline), and actuators shift preferred points of operation.

Actuation

Although elastic tissues are rather common the forces/moments and displacements/rotations of system and legs must be generated by the available actuator, the muscle. To understand an animal's or an athletes' performance it is necessary to quantify their respective muscle properties. The Hill-model has been most successfully used. In the estimation process suitable protocols are crucial and can help to estimate series elasticity. The influence of the contraction history [Rode *et al*, J Theor Biol 2010] is still awaiting a general description at the "Hill-level". Consideration in dynamic models together with tendon interaction may further help to understand specific muscle properties (layout) and/or their optimal use.
Numerical tools will help us to understand the influence of shape, mass distribution, and interaction with surrounding tissues. We know that wobbling masses help to reduce impacts.
Looking at adaptations we must consider the span of required tasks. For swimming numerical calculations may allow us to pin down the dynamic conditions imposed by the fluid in future [Hochstein *et al*, 2011].

Control

Controls must take the global task and its requirements but also the local properties of the system into account. While driving the system within an attractive mode neuronal networks can be used to command a template with minimum effort. In principle it would be possible to handle steps in the ground without adjusting the control step by step to new conditions [Müller *et al*, 2010]. Muscular actuators may even facilitate this adaptability. Due to physical constraints elderly may have problems to explore such advantages overloading an already hampered neuronal system.

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References

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