Characterization of leg function in human and humanoid locomotion

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Abstract

During human and animal locomotion, leg function can be described with simplified leg models, such a the bipedal spring-mass model. Here, it is assumed that the force produced by the leg during stance phase resembles that of a linear prismatic spring. This is a reasonable assumption for bouncing gaits like running and hopping and holds with some limitations also for human walking (at moderate speeds).

There are several systematic deviations from the linear leg spring-concept observed in human locomotion. For instance, leg forces may deviate from the leg axis (connecting line between centre of mass, COM, and centre of pressure, COP) or may not be proportional to the amount of leg compression (change in leg length) during stance.

In the first case, deviating leg forces to point above the COM may help to support balance, as suggested by the VPP concept (Maus et al., 2010). Furthermore, the COP may shift during ground contact as observed in human walking (Bullimore) to extend contact times and to reduce vertical body excursions and leg forces during locomotion.

In the second case, the conservative spring-like leg function is not exactly found in nature. This may be due to the dynamics of the neuro-muscle-skeletal system which may generate bouncing tasks only approximately like described in the spring-mass model. These deviations are most dominant in walking. At slow walking or standing, spring-like leg function is even absent and more rigid (pendulum-like) leg function is found.

There is an increasing interest to implement spring-like leg function also in humanoid robots, both by hardware design or software control. However, the segmented structure of the human body makes it difficult to achieve compliant leg function as found in biology. With novel actuator concepts (e.g. pneumatic actuators or serial elastic actuators), the leg function in robots can be tuned to more closely match the biological counterpart. Still, a matching, bio-inspired control approach needs to be developed to achieve robust and efficient locomotion modes in changing (body or environmental) conditions.

References

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