Compliant Actuation for Biologically Inspired Bipedal Walking Robots

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Abstract

This thesis deals with compliant actuators and their use in energy efficient walking bipeds. Two types of actuators with adaptable compliance are discussed: *PPAM* (Pleated Pneumatic Artificial Muscles) and *MACCEPA* (Mechanically Adjustable Compliance and Controllable Equilibrium Position Actuator).

The PPAM is a design made to overcome shortcomings associated with the existing types of pneumatic muscles. The compressibility of air makes them inherently compliant, which can be employed to reduce shocks. Their main advantages are the high power to weight ratio, the adaptable compliance when used in an antagonistic setup and the fact that they can be directly coupled to the joint without a gearing mechanism. A second design of the PPAM concept, which resulted in an extended life time, is used in the biped *Lucy*. This planar biped is actuated with 12 PPAM's, giving the ability to control the six pin joints, both in equilibrium position and in compliance. The control strategy is based on the generation of trajectories for each joint out of the objective locomotion parameters. Ways to adapt the compliance in order to lower energy consumption are studied.

The second type of compliant actuator, the MACCEPA, is entirely developed during this thesis, and patented. It is an electrical actuator of which the compliance and equilibrium position are fully independent and both are set by a dedicated servo motor. The angle-torque characteristic is quasi linear up to 60 degrees, which makes the MACCEPA comparable to a torsion spring, which allows to modify equilibrium position and spring constant online. Moreover, the concept can be implemented using standard off-the-shelf components. This actuator was used to build the biped *Veronica*. This is a planar biped, with 6 MACCEPA actuators, each powering one pin joint. The strategy of using the compliance for energy efficient walking, as elaborated in this PhD, is based on the concept of passive walkers. The compliant actuators are used to modify the natural frequencies of the limbs online, in order to achieve a smooth and stable walking motion. Since the developed passive walking robot is not limited to one walking speed, but can be controlled while still using natural motions, this concept is entitled *Controlled Passive Walking*.