RoboFrog? Explosive Power from Elastic Tendons Without Escapements

Peter G. Adamczyk[1*], Matthew Robertson[1], and Arthur D. Kuo[2]

[1]Intelligent Prosthetic Systems, LLC, Ann Arbor, MI USA; [2]University of Michigan, Ann Arbor, MI USA. **p.g.adamczyk@gmail.com*

Motivation

Frogs have the ability to propel themselves several body lengths in a single explosive jump. This performance is remarkable because the frog's leg muscle mass is insufficient to achieve the observed peak power output directly. Use of energy storage and release in elastic tendon structures has long been suspected, but the detailed characteristics of this mechanism are still unclear.

State of the Art

Recent research has shown that the output performance of the frog's leg is enhanced by an elastic "catapult" mechanism, which allows the muscle to perform work slowly, with no leg motion, to store energy in a compliant tendon. The tendon then recoils at a high rate to launch the animal [1]. However, the mechanism by which the frog decouples muscle force generation from leg motion to load the tendon is unclear, as there is no obvious escapement mechanism.

Approach

We explore the concept of escapement-free explosive motion in series-elastic artificial systems through theory, simulation and hardware. We show that certain architectures of a contractile actuator and leg joints can produce similar explosive behavior. Careful selection of compliance and angle-dependent joint moment arms can effectively decouple actuator displacement from leg motion to store elastic energy up to some limit, and then release this energy explosively through the leg.

Discussion

The decoupling of muscle action from leg motion depends on having a wide range of moment arm values at the joint a modest force opposing motion of the body externally. Exploiting very small moment arms when the leg is fully flexed allows this opposing force to control the moment of release, replacing a mechanical escapement.

Because this mechanism requires an extreme kinematic configuration, it need not severely compromise the control gained from closer coupling of muscle motion to leg motion in more extended postures. Future research should explore the extent to which the same leg could be used under position control or for explosive leaps in different circumstances.

The architecture described in this project is appropriate for artificial systems, but it is unclear whether it is responsible for the effect observed in frogs.

Format

This topic would be best presented in (a) a 5-minute lightning talk. We may have a hardware demo available as well; it should need only a table.

Keywords

Series elasticity, jumping, leg architecture

References

1. Astley HC and Roberts TJ (2011) *Biol. Lett*. Evidence for a vertebrate catapult - elastic energy storage in the plantaris tendon during frog jumping.