# HIP CONTROL IN LOCOMOTION

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## INTRODUCTION

In walking and running the leg retracts during stance phase and protracts during flight phase. Proper timing of retraction and protraction seems to be crucial to obtain stable locomotion [1]. Therefore, we ask whether the difference in duty factor (ratio between stance and cycle time) between walking and running requires gait-specific timing of protraction and retraction in running and walking. Furthermore, we investigate to what extend passive joint mechanisms could help to simplify hip control.

## METHODS

*1) Hopping Robot.* A two-segmented leg is constructed with an elastic joint between the two leg segments and a kinematically driven upper joint (servo motor with sinusoidal control function). For the given joint stiffness, stable hopping patterns exist for certain combinations of hip frequency f and offset angle φ of the servo motor control function.

*2) Human Locomotion.* In an experimental study on treadmill locomotion, subjects were asked to switch between walking and running every 9 seconds at a given speed. Leg kinematics (QUALISYS) and ground reaction forces (instrumented ADAL3D treadmill) are recorded for later analysis.

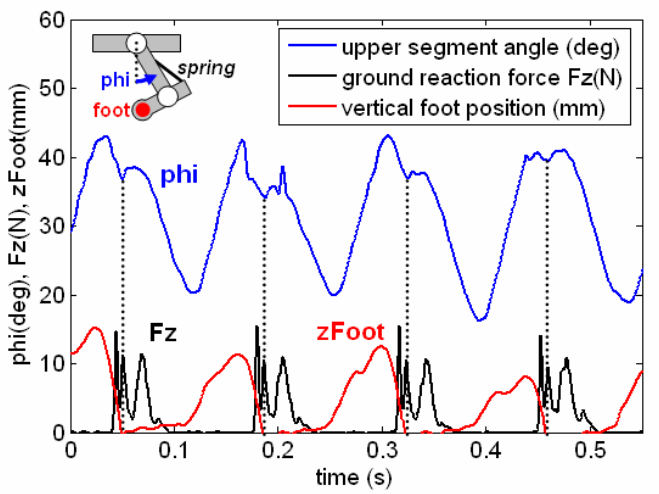


**Figure 1**: Kinetics and kinematics of the hopping robot.

## RESULTS AND DISCUSSION

*1) Robot Locomotion.* Stable hopping exists in different regions in the control space (f, φ) of the servo motor (details in: Rummel et al., this conference). During the fastest configuration, stable hopping is observed with the leg joint pointing to the forward direction. Although the motor is controlled using a perfect sine function, the upper segment kinematics showed a reset (re-initiation of the sine wave) at touch-down during the retraction phase (dotted lines).

*2) Human Walking and Running.* The thigh kinematics during walking and running are similar to the robot kinematics. In both gaits, the thigh protracts during about 35% of the gait cycle. Leg retraction is briefly interrupted at touch-down.

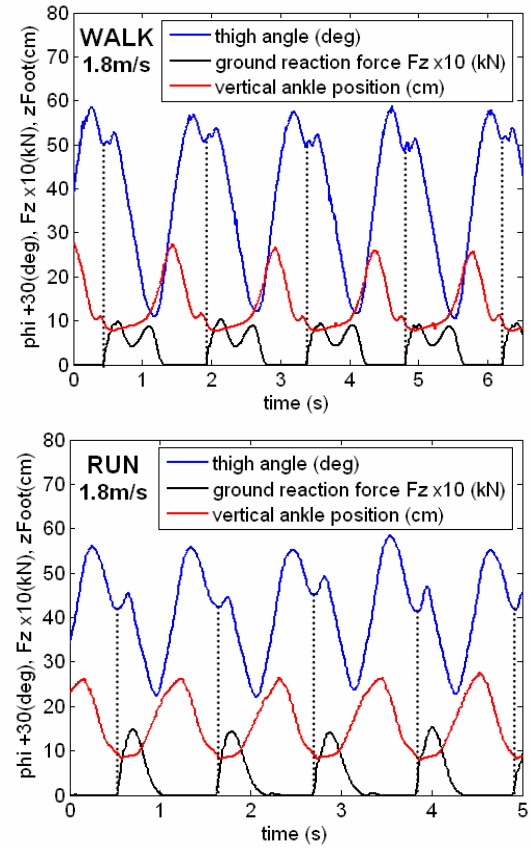


**Figure 2**: Kinetics and kinematics in human walking and running at 1.8m/s.

## CONCLUSIONS

The results indicate that hip control during locomotion could be very similar during walking and running. The duration of the stance phase with respect to the gait cycle could be modulated by the knee function depending on the gait.

The asymmetry in protraction and retraction does not imply that the biological hip controller (e.g. CPG) needs to work asymmetrically. The simple hopping robot demonstrates that joint play and compliant actuator properties could result in the experimentally observed acceleration of the protraction phase.

## REFERENCES

1. Seyfarth A, et al. *J Exp Biol* **206**, 2547-55, 2003.

## ACKNOWLEDGEMENTS

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