STABILIZING THE TRUNK IN HUMAN WALKING

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INTRODUCTION

Humans walk naturally in an upright posture. This posture is not inherently stable as the center of mass lies above the hip. Thus, the body corresponds to an inverted pendulum, mounted at the hip. Hip torques have to be applied to keep the body in an upright position. Here, we present a simple, biologically inspired hip torque control strategy to stabilize the body.

METHODS

A computer model consisting of two mass-less spring-legs and a rigid trunk was built (Figure 1). This is an extension of the bipedal spring-mass model (bipedal SLIP) which predicts both walking and running to be mechanically stable [1, 2]. During stance, a hip torque is applied for each leg to redirect the ground reaction force to a point on the body axis which we call the Virtual Pivot Point (VPP). This resembles the ground reaction force intersection observed in walking experiments. During swing, the legs are adjusted to a pre-defined angle of attack with respect to the ground.

For comparison, experimental hip torque patterns from 21 healthy subjects walking on an instrumented treadmill were calculated.

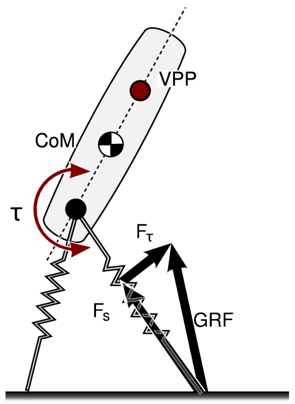

Figure 1: The VPP model consists of a rigid trunk with two massless spring legs. A hip torque is applied such that the ground reaction force (GRF) points to the VPP.

RESULTS AND DISCUSSION

The model shows stable steady-state walking for different positions of the VPP. These solutions resemble parts of the solutions previously identified with the underlying bipedal SLIP. Moderate disturbances like a small step downward are tolerated. Here, the simple hip-torque control scheme is sufficient to stabilize the posture while keeping the underlying gait dynamics intact.

By redirecting the ground reaction force to the VPP, the system acts as if it was mounted at this point. After a perturbation, oscillations in the trunk movement occur with a frequency according to the frequency of a corresponding physical pendulum.

The predicted hip torque patterns in steady-state walking are similar in shape and amplitude to those observed in experimental data, and show a phase delay (Figure 2). This phase delay might be explained by the need to position the legs during swing.

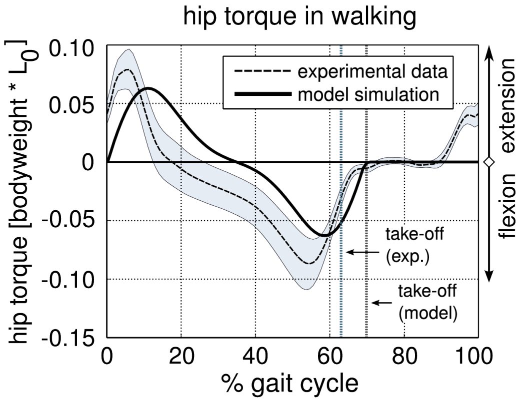

Figure 2: Hip torques predicted by the model for a stable walking pattern (VPP 25cm above CoM) are similar to experimental hip torques in human walking with approx. 1.1 ms^{-1}.

The model does not only resemble the hip torque patterns in human walking, but also has explanatory capabilities: e.g. by leaning forward or backward the model accelerates or decelerates, respectively. This is in line with typical human behaviour and shows a simple, intuitive method to control the system energy.

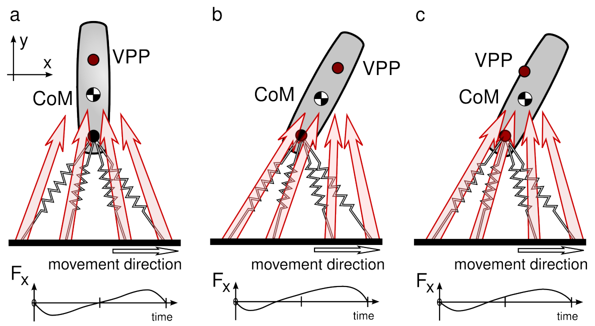

Figure 3: The force is always directed to the VPP (**a**), so the VPP location affects the acceleration, e.g when leant forward, the model accelerates (**b**). By shifting the VPP out of the body axis, the body can be continously tilted (**c**), which leads to a similar effect.

REFERENCES

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