Chair of Applied Mechanics
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Foot Models for a Bipedal Robot

Master's Thesis

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Introduction and Problem Description

Besides the progress we see in the last decades, modern humanoid robots, exoskeletons, gait rehabilitation training devices or lower limb prosthesis do still not reach human performance by far. For many aspects of bipedal locomotion, there is a fundamental lack of understanding of the underlying biomechanics principles and control schemes. One mechanism that is assumed to contribute to the high efficiency and natural leg dynamics in human walking is the *swing leg catapult*. This expression describes an effect in human walking arising shortly before the hind leg leaves the ground to swing forward. An impulsive power output at the ankle joint is observed propelling the leg forward into swing, similar to a catapult launching to fire its projectile [2, 4].

The project EcoWalk at our chair aims to find a functional description of this swing leg catapult in human walking and implement it on the child-sized bipedal robot EcoWalker, see fig. 1 and https://www.youtube.com/watch?v=gIWV9ih-awU.

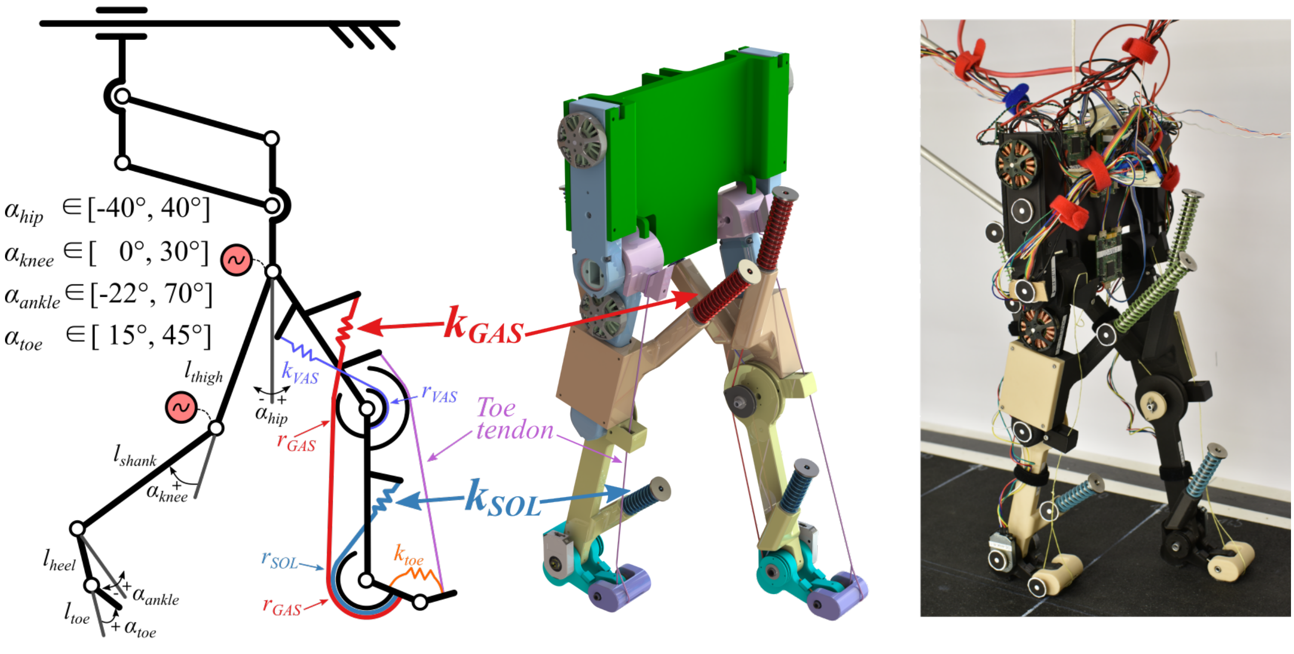

Figure 1: Schematic, CAD rendering, and image of the EcoWalker robot from MPI Stuttgart [3]. The schematic on the left shows the angle definitions, the joint angle limits, and the spring tendon routing. The toe tendon is mounted slack without a spring. The four-bar mechanism limits trunk motion to the sagittal plane and prevents trunk rotation. EcoWalker is a child-sized bipedal robot weighing 2.2 kg. The knee and hip joints are actuated by motors adapted from the SOLO robot modules [1]. The robot's ankle joints are purely passive elastic. Springs imitate calf muscles. The knee muscle spring tendon mimics the Vasti muscle group. A rotating toe spring reproduces the elasticity of the foot. The stiff toe tendon between the femur and toe segments increases ground clearance. It pulls the toes into dorsiflexion when the knee flexes more than 20°. Figure adapted from [3].

Task Description

In this thesis, we want to explore the role of different foot models on the robot's gait and the ankle push-off behavior. Your work will be to design and test different foot models for EcoWalker as illustrated in fig. 2.

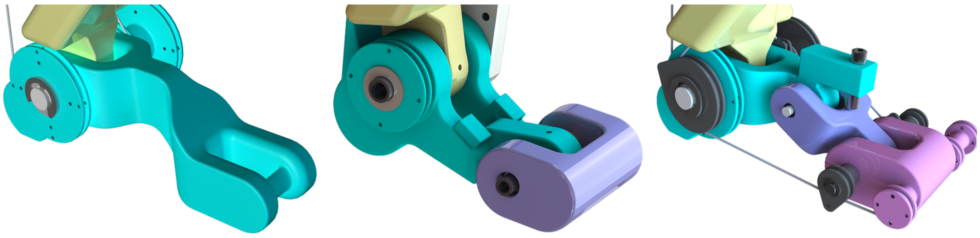

Figure 2: Ideas for different foot designs.

WP1: Familiarization with existing literature and robotic hardware

WP2: Foot Modeling and Manufacturing (Solid Works, 3D print)

WP3: Conduction of Experiments

WP4: Evaluation and Documentation

Requirements

- Project experience with multibody simulation in Matlab Simulink
- Strong theoretical background in engineering mechanics, dynamics and control theory
- Practical experience with electronic hardware, especially microcontrollers and sensors, ideally for robots
- Practical experience with CAD design, 3D printing, and metal manufacturing processes (turning, milling)
- Curious and highly motivated
- Independent, structured problem solving and documentation

References

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