

Towards robust hexapedal running with serial elastic actuation: A 3D simulation study

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1 Motivation

The legs of a future generation of hexapedal robots should enable highly articulated walking as well as robust running within the same platform. Following a hypothesis from biology [2], robustness and stability of walking mainly result from feedback control while being anchored in self-stabilizing properties of the feedforward driven mechanical structure in case of running. The advantage of this shift from feedback to feedforward control with increasing velocity is, that it allows careful and highly adaptive locomotion at low speeds while the complexity of control is reduced at high speeds. In order to embed a fast locomotion mode within the structure of an articulated leg its individual functional behavior during running needs to be understood, first.

2 State of the Art

Several planar models have been investigated which are either completely passive or have a single actuated degree of freedom per leg. A good overview can be found in [4]. Only few attempts have been made towards 3D models, such as the multi-body dynamics based analysis of Clark [1] or the simplified hexapedal runner with actuated hips presented by Saranlı [5].

3 Approach

In order to identify the necessary functional properties of the mechanical structure for spatial hexapedal running, our sagittal plane model [3] is extended to 3D. Hereby, the body has mass m and a mass moment of inertia I , which is given by a symmetric 3×3 matrix. The legs are modeled to be mass less and each of them has two serial elastically actuated degrees of freedom. Those are, one telescoping degree of freedom along the leg and one rotating degree of freedom at the hip, which moves the leg in the fore-aft direction. In addition, each hip has one compliant, passive degree of freedom that allows lateral leg movements. The hexapod has a sprawled posture in the sagittal as well as in the frontal plane. As in the planar case, the actuation is modeled as feedforward driven sinusoidal change of the force free length of leg and hip springs. Hereby, the hip and leg actuation show a 90° phase shift. Fur-

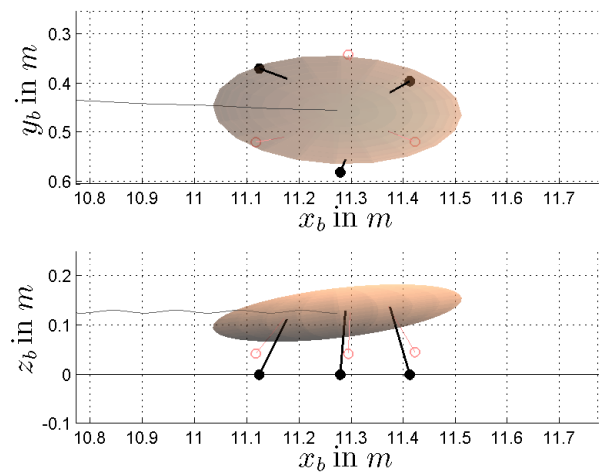


Figure 1: 3D hexapedal running with serial elastic actuation

ther, each leg is assigned to one of two tripods which are actuated 180° out of phase.

4 Results

Based on the modeling assumptions, parameter sets are identified that result in stable open loop running. The forward velocity is proportional to the actuation frequency. All legs equally support the body weight but specialize in their function in the fore-aft direction. The front legs mainly decelerate the body while the hind legs accelerate it and the middle legs do both. The laterally sprawled posture results in significant lateral forces. Hereby, only a small range of sprawl angles was found to produce stable open loop running. Further, for the lateral direction and the yaw angle we see neutral stability which already has been shown for different horizontal plane models. This means a disturbance results in a permanent displacement but oscillations settle around this new value. As for the sagittal plane model, the introduction of inter leg actuation phase shifts within a tripod results in different foot touch down sequences. Hereby, the ground reaction force patterns of the legs remain similar but the differences in timing strongly influences the overall dynamics. On the

one hand, an actuation phase shift that leads to a hind - middle - front touch down sequence results in a motion without flight phases and very small pitch oscillations. On the other hand, an actuation phase shift that causes nearly simultaneous touch downs results in body dynamics with flight phases and total ground reaction forces that show similarities to the spring loaded inverted pendulum model. Following up those preliminary results a more detailed analysis will give insight into the domain of attraction of the limit cycle, the robustness with respect to parameter variations and the power flow within the system.

References

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