Bio-inspired Control Framework for Legged Locomotion

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1 Motivation

For legged robots, both abilities of compliant locomotion and precise movements are crucial when traversing challenging terrain. Therefore, the demands require that the low controller follows the desired foot-end trajectory and trunk pose. At the same time, ground reaction forces need to be modified due to unknown disturbances [1]. But accurate control remains an enormous challenge for physical prototypes. In nature, the amazing locomotion of biological systems brings us more inspiration. In this paper, the bio-inspired control framework is designed based on the Equilibrium Point Hypothesis (EPH) [2].

2 State of the Art

The inverse dynamic model is a direct method to calculate the joint torques. Unfortunately, obtaining the accurate dynamic parameters is extremely impossible for physics prototypes. Through analysis on the simplified model, the mechanical and electrical leg system and control algorithm are developed to imitate the spring-like behavior of neuromuscular system [3] [4]. The Equilibrium Point Hypothesis (EPH) reveals the basic mechanism of biological movement, which is simplified the requisite computations for multi-joint movements and mechanical interactions with complex dynamic objects [2]. Based on EPH, a hierarchical controller is proposed for MIT Cheetah [5]. Nevertheless, the trot-running gait is achieved just in 2D sagittal plane with a tunable amplitude sinusoidal wave, which is hard to reject unknown disturbances.

3 Our Approach

As fig.1 showed, a simple and generic force control framework based on the EPH is presented for 3D dynamic trot-walking in rough terrain. In consistent with the CNS, the high controller generates the reference EP trajectory. Then the requisite force in operation space is obtained via spring-damper model, which is similar with muscle behavior. Meanwhile, tactile sensory feedback for handling large distribution brings us more inspiration. The reference EP trajectory is on-line modified for simultaneously tracking the desired position and force during dynamic locomotion. In other words, a stability goal for maintaining trunk posture can be achieved using the virtual model control to generate desired force deviation. Then the difference between the actual force acquired by sensor and the specified force by the high controller, as well as the force deviation can modify reference EP trajectory by the admittance controller, avoiding the complex "inverse dynamic" problem of computing the torques at the joints.

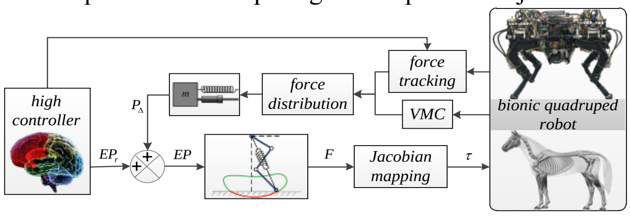

Figure 1: Bio-inspired control framework

4 Current Results

We have designed a bio-inspired control framework and a novel force distribution algorithm by solving linear optimization. Moreover, a hydraulic quadruped robot prototype has been constructed shown in fig.1. Then the simulations have successfully been achieved by means of dynamic trot gait travelling over the rough terrain with 1.2m/s. Finally, some experiments of robust performance against unknown disturbances have been carried out for verifying the feasibility of the proposed method.

5 Best Possible Outcome

In order to accomplish dynamic balance like biological behavior in challenging terrain, we are presently still refining the proposed framework carefully. And the different compliance parameters are set for stance and swing phase. In addition, the hydraulic servo level system is studied for better realizing the compliance properties.

References

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