Part I
Locomotion

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Locomotion remains a fundamental challenge in developing robots that can do useful work in the real world, outside of office, factory, and laboratory environments. Even today, as self-driving cars and autonomous quadrotors seem teasingly close to transforming our daily lives, robots clearly fall far short of the incredible capabilities of animal locomotion. In particular, it is difficult to achieve a balanced combination of speed and agility, low energy use, and high reliability. The four papers in this session all focus on legged robot morphologies, toward providing unique mobility across rough and/or discontinuous terrain, and they each consider some combination of trade-offs between agility, energetics and stability. Two of the papers (Duperret et al. and Miller et al.) study highly dynamic systems with an aerial phase during locomotion, while the other two (Satzinger et al. and Grand et al.) focus on trajectory planning for redundant limbs to produce quasi-static motions to negotiate extreme terrain.

The first paper in this session, Towards a Comparative Measure of Legged Agility by J.M. Duperret, G.D. Kenneally, J.L. Pusey, and D.E. Koditschek, introduces a new metric for specific agility and uses it to quantify agility versus endurance for two different legged robots during leaping trials: the four-legged Canid robot, which has a flexible spine, and the six-legged XRL robot, which has a rigid body. Their experimental data support two hypotheses. First, the robot with the spine achieves greater agility, and second, both active and passive dynamics of the spine improve agility.

The second paper, On Prismatic and Torsional Actuation for Running Legged Robots by Bruce Miller, Jason Brown and Jonathan Clark, studies hybrid mechanisms for robots with spring-loaded inverted pendulum (SLIP) dynamics to exploit both prismatic and torsional actuation together to achieve speed, stability, and efficiency. Specifically, they investigate the coupled interplay of these actuation sources and discover near-optimal gait characteristics that simultaneously achieve each of these three performance goals in idealized models, and they also demonstrate similar characteristics in experiments with a hexapedal robot with a design similar to iSprawl.
**Experimental Results for Dexterous Quadruped Locomotion Planning with RoboSimian** by Brian Satzinger, Chelsea Lau, Marten Byl, and Katie Byl presents a practical solution for resolving kinematic redundancy for a dexterous, four-limbed robot. Their approach combines rapidly-exploring random tree (RRT) searches over the degrees of freedom of either one or two of the legs with heuristic solutions for inverse kinematics to constrain the \((x,y,z)\) positions of the remaining end effectors to remain in place on the ground during locomotion. They explore the planning time required and quantify dexterity in terms of the additional feasible workspace reachable by the robot by allowing body motion during a swing leg trajectory, and they test the approach through experimental trials with RoboSimian, demonstrating both agile and highly reliable walking on terrain designed for the DARPA Robotics Challenge (DRC).

The final paper in this group, **Experimental Evaluation of Obstacle Clearance by a Hybrid Wheel-Legged Robot** by Christophe Grand, Pierre Jarrault, Faiz BenAmar, and Philippe Bidaud, presents a control approach that allows a redundantly actuated vehicle with four wheel-legs to cross a step that is taller than the wheel diameter. Their approach optimizes for the center of mass position and distribution of internal forces such that torque and friction constraints are met using a minimax optimization approach, toward maximizing robustness while simultaneously achieving highly agile mobility, and they demonstrate the approach in experimental trials on steep, step-like terrain.