論 文 の 内 容 の 要 旨

論文題目　Computational Foundation for Planner-in-the-Loop Multi-Contact Whole-Body Control of Humanoid Robots
（運動計画をフィードバックループに含むヒューマノイドロボットの多点接触全身制御のための計算基盤）

氏　　名　カロン　ステファン

In this thesis, we explore the questions of motion planning and control for humanoid robots with the aim to integrate motion planning in a fast control loop. Our contributions towards this goal revolve around three axes: kinodynamic decoupling, force-space curtailment, and dimensional reduction of the control space. In the first one, we decouple the kinematic and dynamic components of the planning problem by an original integration with time-optimal control methods. This approach allows us to keep planning in a geometric space, the benefits of which we demonstrate both empirically and through theoretical proofs. In the second axis, we focus on the contact aspects of planning. To avoid slippage or other contact losses, planners usually consider a large number of contact forces and their associated Coulomb friction cones. We show how this redundant representation can be reduced to contact wrenches, unique to each contacting articulation, and propose the first analytical derivation of the associated frictional wrench cone for rectangular contact surfaces. We then connect these developments to the gravito-inertial wrench for whole-body motion planning. However, we note that using wrenches for planning leads to diffult open questions such as the interpolation of the non-holonomic angular momentum. We attack this problem with a paradigm shift: rather than controlling wrenches, we generalize the notion of ZMP (point where the tangential component of the gravitoinertial moment vanishes) to that of "ZMP of a wrench". We then propose efficient algorithms to compute the associated support areas, and show how to use these tools to generate locomoting trajectories from simplified dynamics model such as the Linear Pendulum, even in arbitrary multi-contact scenarios. This reduction of the control space rounds the third and last axis of the computational foundations advanced by this thesis. We demnonstrate the applicability of each by simulations and empirical experiments on the HRP-4 humanoid robot.