Title	支持脚接地点の滑り接触を考慮したコンパス型2脚ロボットの3自由度受動歩行
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3-DOF passive walking of compass like biped robot in consideration of sliding contact point of stance leg

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Practical robotic walkers must be able to adapt to various ground conditions without stepping or slowing down. One of the most difficult surface conditions for legged robots to walk stably is slipping. As the first phase of the study on adaptation to oily or snowy road surface, Asano et al. have proved that a stable limit cycle walking on a slippery floor can be achieved using simple models with suitable system parameters. In their previous works, however, they considered only limit cycle walkers that achieve constraint on impact posture to fall down as a 1-DOF rigid body in the same position. Such dynamic walkers can reproduce limit-cycle stability or the behavior of the hybrid zero dynamics (HZD) similar to that of a rimless wheel (RW). These limit-cycle walkers, especially RW walkers, can easily generate a stable walking gait on grippy or slippery road surfaces because of the low DOF.

We should note, however, that the essential difficulty and complexity inherent in passive bipedal walking are caused by the free motion of swing-leg and various impact postures. The stability principle underlying passive bipedal walking is still not fully explained even if the contact point does not slide during motion. Most of the previous works of the compass-like biped robot assumed that the contact point between the end position of the stance leg and ground is non-sliding. We still do not know, however, that this condition is essential or necessary for generation of a stable passive compass gait.

Understanding the minimum necessary requirement for stable gait generation involving free swing-leg motion is very important to explain the principle of passive bipedal walking. The condition of non-sliding would be not necessarily required if the compass-like biped robot can generate a stable gait while sliding along the slippery downhill, and we can consider that there is also a stabilizing controller for contact point inherent in natural bipedal locomotion.

Based on the observations, in this thesis I discuss the possibility of passive bipedal walking on a slippery downhill and its fundamental gait properties. First, I develop a 4-DOF model of the passive compass-like biped robot that walks sliding on a slippery downhill. The model has 1-DOF constraint at the contact position and the generated walking gait then becomes 3-DOF. The sliding friction dynamics is specified as the Coulomb model. Second, I discuss the possibility that non-instantaneous double-limb support motion emerges after impact based on the mathematical analysis of the collision dynamics. Third, I perform numerical simulations to observe the typical walking gait sliding on a slippery downhill, and show that period-doubling bifurcation occurs with the decrease of the coefficient of sliding friction. Furthermore, I investigate the effect of semicircular feet on the 3-DOF passive compass gait. Through this thesis, I show that the sliding contact is not a critical condition in achievement of walking motion, and that a stable and natural walking gait can be generated only with 1-DOF constraint condition.