Whole-body Cooperative COG Control through ZMP Manipulation for Humanoid Robots : Long Abstract

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1. Introduction

Strong non-linearity in dynamics of legged robots makes control of them quite hard. A lower-level modelization of robots based on the COG has been confirmed to be effective. However, the large gap between such lower-level model and precise model often causes the difficulty. This paper proposes COG Jacobian, which relates the whole-body motion to COG motion explicitly, to handle the legged robot. ZMP manipulation as a key for stable and responsive motion is also realized. Two applications, motion stabilization method based on DTAD(Dual Term Absorption of Disturbance) and VIIP(Variable Impedant Inverted Pendulum) model control, are introduced.

2. Derivation of COG Jacobian

A structure-invariant calculation method of COG Jacobian for the legged system is shown. COG Jacobian can be calculated from the relative motion of a temporarily fixed link in the inertia frame to the root. Thanks to it, the COG velocity can be related explicitly to the whole joint angle velocity, apparently as the linear summation of it. This fact helps to treat it as a simple linear equational constraint.

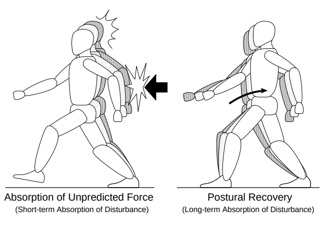

Figure 1: two schemes for DTAD

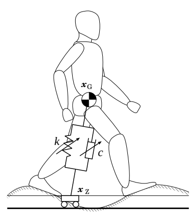

Figure 2: VIIP model

3. A Pattern-based Motion Control with DTAD method [1]

A pattern-based approach reduces the difficulty on the control. It requires stabilization in addition to pattern designing, to cope with various unpredictable factors. Previous works had limitation problems of applicability. We propose an applicable method for a variety of motion, which consists of two schemes figured in Fig.1; The former is absorption of unpredicted force to avoid short-term crisis, while the latter is recovery of postural pattern. We named it DTAD(Dual Term Absorption of Disturbance) method.

4. Motion Control based on VIIP [2]

Much more responsive motion is required in the real environment filled with unknowns. Previous trials suffer from the complexity of the problem. VIIP(Variable Impedant Inverted Pendulum) model control illustrated in Fig.2 can be a solution. Legged robots have similar dynamics with an inverted pendulum whose supporting point is equivalently located at the ZMP. Thus, the COG can be controlled through ZMP manipulation. Vertical force is also manipulated based on variable impedance model, which enables more adaptive and responsive motion, or even to transit seamlessly between contact and aerial phase. The whold-body cooperative COG control is synergetically achieved.

5. Conclusion

COG Jacobian to evade dynamical complexity of the legged systems and handle them is derived. DTAD method and VIIP model control are introduced as its applications. They are achieved through ZMP manipulation, which is also enabled with COG Jacobian.

References

[1] T.Sugihara and Y.Nakamura. Whole-body Cooperative Balancing of Humanoid Robot using COG Jacobian. In *Proc. of the 2002 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, 2002.

[2] Tomomichi Sugihara et al. Realtime Humanoid Motion Generation through ZMP Manipulation based on Inverted Pendulum Control. In *Proc. of the 2002 IEEE Int. Conf. on Robotics & Automation*, pages 1404–1409, 2002.