Position-Force Coordination is the Key of Advanced Humanoid Control

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Focus: "Humanoid robot" is necessarily a highly integrative system of versatile cutting-edge technologies. Particularly, understand and control of its dynamics are the bases of them, which provides deep insights about how its body should be designed, what information should be processed, how behaviors should be planned, how decisions should be made, and so forth.

Dynamics investigation: Conventional industrial manipulators form pure chains from the inertia frame to the endpoint with less than ten fully-actuated joints. On the other hand, the humanoid system has the following dynamical properties (Fig.1): 1) hyper multi-DOFs with tens of joints, 2) unactuated coordinates with floating base link, 3) passivity actuated through the interaction with the environment, and 4) variation of structure with frequent collision and contact. Due to them, its kinematics and dynamics – in other words, problems about position and force – are strongly linked.

Position-force coordination: The main concern of kinematics is the transition of the whole-body to the desired position, while dynamics relates to the manipulation of contact states and reaction forces so as to be physically consistent. Since the force is in the same dimension with acceleration, the latter poses severer constraints in general, while the former most often accepts a certain duration. We've found that it works to utilize this difference and coordinate the both in multiply-layered time frame for the motor control. Based on this idea, an online gait planning method[1], a stabilization method to absorb sudden impacts[2], and a controller which doesn't require detailed motion planning[3] have been proposed.

Open problems: So far, we've developed small humanoid robots, UT-μ series [4] (Fig.2), and have achieved stepping, fast walking (Fig.3), jumping, some fighting actions and tap-dancing with toe-heel kicking (Fig.4). In the cource of development, remaining problems have been clarified: 1) reliable joint controllers which robustly compensate nonlinear effects such as friction and gravity in order to support the macroscopic whole-body controller, 2) state measurement of robots with respect to the inertia frame in spite of a lack of rooted link, and 3) self-identification of dynamical model with varying structure. It's no surprising that they sound old-fashioned since conventional robots are not so complicated that drastic solutions have been required!

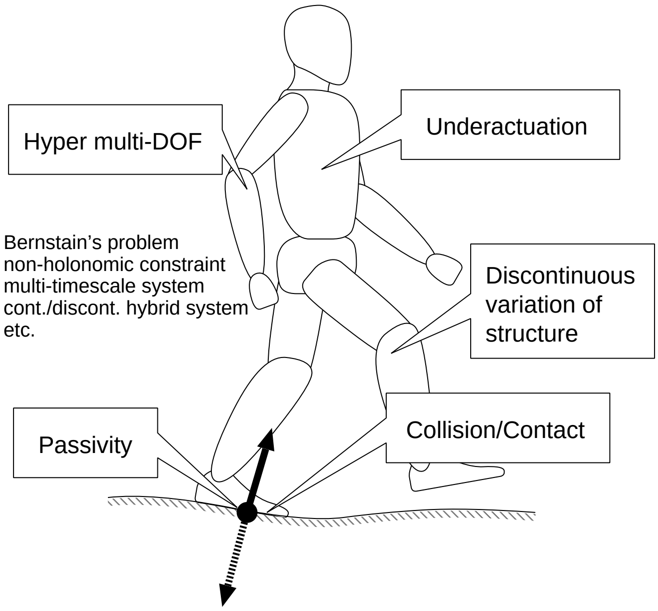
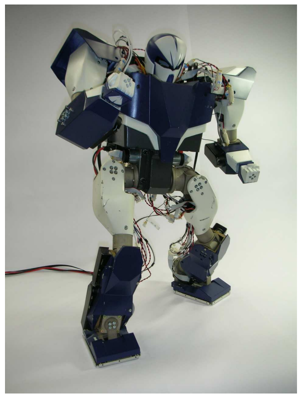


Fig. 1. Dynamical properties of humanoid systems

(a) UT-μ:mighty



(b) UT-μ2:magnum

Fig. 2. UT-μ:mighty and UT-μ2:magnum

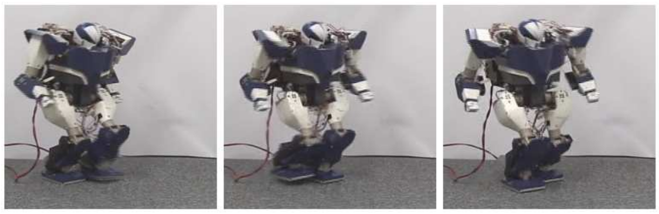


Fig. 3. Walking (0.3[s/step]) by UT-μ2

Fig. 4. Tap-dancing by UT-μ2

References

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