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Converting constrained whole-body human motions to humanoid using smoothing

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This paper presents a method for generating a whole-body squat motion for humanoid robot HRP-4 from human motion data. We convert joint angle trajectories into linear combination of base functions which are cubic B splines. In order to take into account the interactions with the environment and the stability conditions, we added appropriate kinematics constraints to the trajectory optimization to perform smoothing of whole-body motion. We investigated the validity of this method by using dynamical simulator and we succeeded in simulating squat motion with this method.

1 Introduction

In this paper, our objective is generating whole-body motion for humanoid robots using fewer parameters, by introducing smoothing method that estimates joint angles with linear combination of base functions. This smoothing process has two advantages: first, when we try to expand the framework of motion generation, we can classify different motions, tuning or blending motions in the lower dimensional space, for instance by using Functional PCA which is a statistical method. J. Aleotti et al. used Functional PCA and classified different motions in lower dimension and obtain representative motions to input the humanoid robot [1]. However, they applied the method to upper body motion, but not to whole body, without considering stability conditions. It is necessary to integrate appropriate kinematic constraints in order to ensure stability of the humanoid robot with generated motions. The second advantage is the reduction of complexity of the optimization problem. Since the proposed smoothing method allows expressing the whole-body motion with fewer parameters, the size of optimization problem with kinematic constraints is smaller, than directly using joint angles as parameters. We investigated the validity of this method by dynamic simulator and whole-body squat motion has been successfully executed with HRP-4 [2], a humanoid robot which has 37 DOF.

2 Smoothing with stability conditions

Let $\boldsymbol{q}_t$ be the observed joint angles at time instance $t\,(= 1, 2, \cdots, \mathrm{T})$. We represent $\boldsymbol{q}_t$ by the following nonlinear regression model:

$$\hat{\boldsymbol{q}}_t = C\boldsymbol{b}_t \qquad (1)$$

where, vector $\boldsymbol{b}_t$ is base cubic B spline functions at time instance t and C is a coefficient matrix. This process is called smoothing. We solve the following optimization problem in order to add stability constraints.

$$\min_{C,\boldsymbol{p}_t,\boldsymbol{r}_t} \sum_t \|\boldsymbol{q}_t - \hat{\boldsymbol{q}}_t\|^2$$

subject to

$$\forall t \quad f_t(\boldsymbol{p}_t, \boldsymbol{r}_t, C) = 0$$

where, $\boldsymbol{p}_t$ and $\boldsymbol{r}_t$ are position and attitude of robot base (waist) at time instance t respectively. These parameters are not smoothed. This optimization problem with nonlinear constraints is solved using the penalized method.

3 Simulation

In order to investigate the validity of our method, we simulated generated motion which was whole-body squat motion with humanoid robot HRP-4. HRP-4 has 37 DOF and we added the kinematic constraints as follows.

- Make both sole of feet are attached on the ground.
- All joint angles do not exceed the range of motion of HRP-4.
- The waist attitude is identity matrix.
- The CoM is near the center of static.

In this motion, since the joint angles of both arms scarcely varied we make both arms fixed in order to avoid self-collision by hand. The simulation result is shown in Fig. 1. The humanoid motion was executed with a half speed of the original human motion by considering the mechanical capacity of the robot. We could smooth the robot motion and add kinematic constraints as expected.

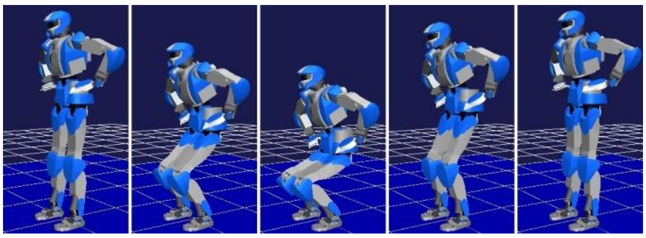

Fig. 1 Generated whole-body squat motion

4 Conclusion

We proposed retargeting method using nonlinear regression model considering stability constraint. Future work includes experiments with real robot hardware and expansion of motion generation such as blending motions in lower dimensional space.

References

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[2] K. Kaneko et al., “Humanoid Robot HRP-4 – Humanoid Robotics Platform with Lightweight and Slim Body –”, *IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS)*, pp. 4400-4407, 2011.