Theory and Practice of Humanoid Walking Control

2020 Fall semester

Homework # 7

Problem 7 Walking Pattern generation considering CoM control performance

※ The first supporting foot is the left foot.

※ References:

✱ 1) M. Kim, D. Lim and J. Park, "Online Walking Pattern Generation for Humanoid Robot with Compliant Motion Control," 2019 International Conference on Robotics and Automation (ICRA), Montreal, QC, Canada, 2019, pp. 1417-1422.

2) Katayama, T., Ohki, T., Inoue, T. and Kato, T., "Design of an Optimal Controller for a Discrete Time System Subject to Previewable Demand," Int. J. Control, Vo1.41, No.3, pp.677-699, 1985 (679 ~ 681p)

- ✓ Find the control input gain of the plant (CoM control performance model)

  HW 6 same diff plant

  1) Define the plant (CoM control performance model). (A, B, C, D Matrix / discrete time domain)
     - ✓ $k_p = 100,\ k_v = 10$ behaviour modeled, just use.
  2) Define $\tilde{A}, \tilde{B}$ using A, B, C, D Matrix to construct the state space equation for ZMP error and state variation.
  3) Calculate the Riccati equation using System matrix $\tilde{A}$, Input matrix $\tilde{B}$, Weighting matrix R and $\tilde{Q}$ to find $\tilde{K}$
     - ✓ R = 1.0, $\tilde{Q} = \begin{bmatrix} Q_e & 0 \\ 0 & Q_x \end{bmatrix}, Q_e = 1.0, Q_x = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$
     - ✓ In MATLAB : $\tilde{K}$ =dare($\tilde{A}, \tilde{B}, \tilde{Q}, R$)
  4) Calculate G_i, G_x, G_d using $\tilde{A}, \tilde{B}, R, \tilde{Q}$ and $\tilde{K}$

- ✓ Build the preview controller
  1) Set the preview time to 1.6 sec. (Preview the future reference ZMP trajectory after 1.6 seconds from the current point in time/ $N_L = 320$ (200Hz control frequency))
  2) The reference ZMP generated in HW#2 is used.
  3) Using the calculated control gain, the variation of control input is calculated in real time. (Use the actual CoM value)

     $$\Delta u(k) = -G_i e(k) - G_x \Delta x(k) - \sum_{l=1}^{N_L} G_d(l)\, \Delta p^{ref}(k+l)$$

  4) CoM is calculated in real time by integrating the variation of control input and putting it into the control input of the control performance model.

     $$u(k) = -G_i \sum_{i=0}^{k} e(k) - G_x x(k) - \sum_{l=1}^{N_L} G_d(l)\, p^{ref}(k+l)$$

     $$x(k+1) = Ax(k) + Bu(k), x(k) = \begin{bmatrix} x_c(k) \\ \dot{x}_c(k) \end{bmatrix}$$ (Use the actual CoM value.)

  5) The calculated $u(k)$ becomes the reference CoM position.

- ✓ Run it after programming
    1) rosrun dyros_jet_gui dyros_jet_gui → X: 1.0m, Step length : 0.2m → START walking button click!!
    2) Plot the reference ZMP, reference CoM and actual CoM trajectory
    3) Record the walking simulation video.

Some diff must be seen (better)

* Hint

Simulation time → walking_tick_ (1tick : 0.005sec)

1 step time (1.2sec) → t_total_

Start time of each step → t_start_

End time of each step → t_last_

First DSP and last DSP time in one step → t_double1_ (0.15 sec), t_double2_ (0.15 sec)

The total number of steps to reach the target point. (It is automatically calculated when you click the start walking button.) → total_step_num_

Current number of steps → current_step_num_

Initial X, Y, Z CoM position w.r.t the support foot → xi_, yi_, zc_

Real pelvis position w.r.t the supporting foot frame → pelv_support_current_.translation()(n), n = 0, 1, 2 (X, Y, Z respectively.)

Initial pelvis height w.r.t the supporting foot frame → pelv_support_start_.translation()(2)

Real CoM position w.r.t the supporting foot frame → com_support_current_(n), n = 0, 1, 2 (X, Y, Z respectively.)

Foot step position w.r.t the current support foot frame

→ foot_step_support_frame_(n,0), foot_step_support_frame_(n,1)

→ The first element n of the variable means sequence, and the second elements 0 and 1 mean the positions of X and Y, respectively.

Measured joint angle → current_motor_q_leg_ (Vector12d)