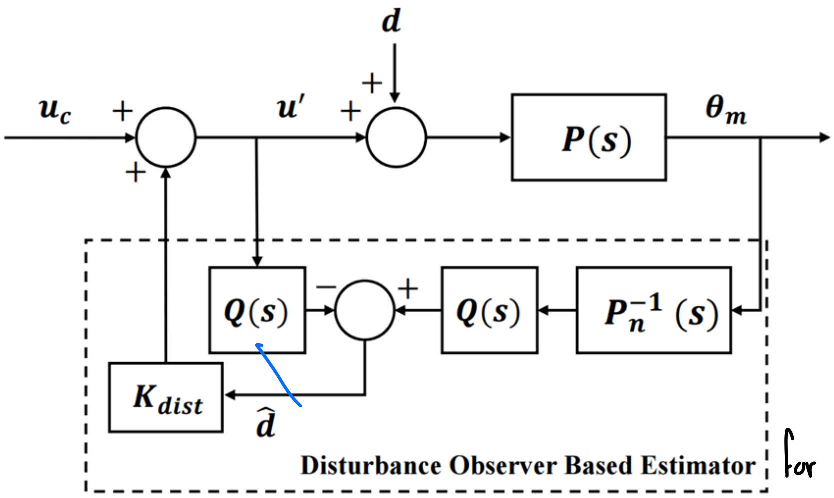
Theory and Practice of Humanoid Walking Control

2022 Fall semester

Homework # 5

Problem 5 Compliant control using disturbance observer

※ The first supporting foot is the left foot.



$K_{dist} = mx+b$
$m>0$
$=3x$
K_{dist}

for (int i, i?

DSP

temp_cx=0

- ✓ For walking in place, generate the trajectory of the X direction CoM as zero.
- ✓ Implement compliant control using DOB
  1) Refer to Reference materials for HW#5 and implement DOB code.
     - Cut off freq. of Q filter (1st order LPF) is set to 10Hz
     - In $P_n(s)$, K_p is set to 30.

faster

(Kp, motion Controller, ↑ better tracking)

  2) Using calculated $\hat{d}(k)$ and equation $u'(k) = u_c(k) + K_{dist}\hat{d}(k-1)$, perform the compliant control (u_c : Reference joint angle calculated by I.K, u': Joint angle command)
     - K_{dist} should be 0~1.
     - 0.1 seconds before the end of SSP, increase K_{dist} from 0 to 1 for compliant joint control when landing, and decrease K_{dist} from 1 to 0 when last DSP starts.

if Contact @0.1 or before DOB X

how to decrease? use linear function

- ✓ Run it after programming
  1) rosrun dyros_jet_gui dyros_jet_gui → X: 0m, Step length : 0m → START walking button click!!
  2) Placing obstacles under the robot's feet while the robot is walking in place.
  3) Plot the $\hat{d}$ graph in the 12 joints of the lower body.
  4) Record the walking simulation video in the presence of disturbances.

SSP DSP SSP

Step change

.. DSP → SSP → DSP → DSP → SSP → DSP

SSP DSP

Coord. change

Support foot

2) SSP

Supp

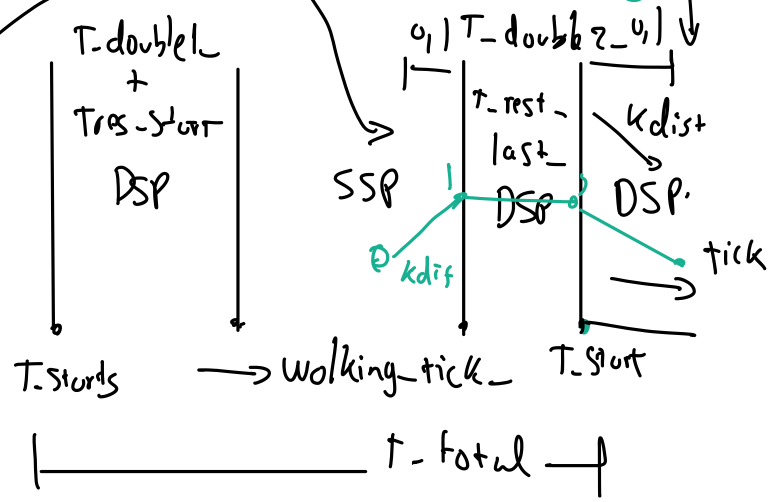
0.1

last DSP

symmetry

$y = mx$

$y = \frac{1}{9142}(tick - y_0)$



* Hint

Simulation time → walking_tick_ (1 tick : 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 → com_support_init_(0), com_support_init_(1), com_support_init_(2)

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)

Z transform

$H(z) = \sum_n h[n] z^{-n} \wedge X(z) = \sum_{n=-\infty}^{\infty} x[n] z^{-n}$

Con show decrease/inc.

sinusoidal impulse

fof discrete time $n \to f(z)$ $(s \to z)$

for $x[n] = \delta[n]$ $X(z) = \sum_{n=-\infty}^{\infty} x[n] z^{-n} = X(0) z^0 = 1$

$\delta(0) = 1$

ex $x(n) = \left(\frac{7}{8}\right)^n u[n]$

$x[n] = \delta[n-1]$ $X(1) z^1 = z$

$X(z) = \sum_0^{\infty} \left(\frac{7}{8}\right)^n z^{-n} = \frac{1}{1 - \frac{7}{8} z^{-1}}$

inf: $\frac{1}{1-r}$

series should converge.

$\sum_{n=0}^{\infty} a^n, |a| < 1$

$\left|\frac{7}{8z}\right| < 1$

work for all n, not all z. Convergence region linearity! $y[n] = x_1[n] + x_2[n]$

$Y(z) = X_1(z) + X_2(z)$, $z \subset$ both convergence regions

if $X(z) = \sum_{n=-\infty}^{\infty} x[n] z^{-n}$ $\quad$ $y[n] = x[n-1]$ then $Y(z) = \sum_{n=-\infty}^{\infty} y[n] z^{-n} = \sum_{-\infty}^{\infty} x[m] z^{-m-1}$

$Y(z) = z^{-1} X(z)$