

# ASE 389: Homework 2: Balancing the Atlas Humanoid Junette Hsin

## Question 1:

$$\sum_{i=1}^n w_i \|J_i \ddot{q} + \dot{J}_i \dot{q}_m - \ddot{x}_i^d\|^2 + \lambda_q \|\ddot{q}\|^2 + \lambda_f \|f_r\|^2$$

$$\rightarrow \frac{1}{2} [\ddot{q} \ f_r] \begin{bmatrix} A & 0 \\ 0 & B \end{bmatrix} \begin{bmatrix} \ddot{q} \\ f_r \end{bmatrix} + \begin{bmatrix} a \\ 0 \end{bmatrix}^T \begin{bmatrix} \ddot{q} \\ f_r \end{bmatrix}$$

$$\rightarrow w_1 (J_1^T \ddot{q}^T + \dot{J}_1 \dot{q}_m^T - \ddot{x}_1^{dT})^T (J_1 \ddot{q} + \dot{J}_1 \dot{q}_m - \ddot{x}_1^d) + \dots$$

$$\rightarrow w_1 \ddot{q}^T J_1^T J_1 \ddot{q} + w_2 \ddot{q}^T J_2^T J_2 \ddot{q} + \dots$$

$$\rightarrow \ddot{q}^T (w_1 J_1^T J_1 + w_2 J_2^T J_2 + \dots) \ddot{q} = \ddot{q}^T \left( \frac{1}{2} A \right) \ddot{q}$$

$$A = w_1 J_1^T J_1 + w_2 J_2^T J_2 + \dots w_n J_n^T J_n + \lambda_q$$

$$2w_1 [(\ddot{q}_1^T J_1^T J_1 - \ddot{x}_1^{dT} J_1) + (\ddot{q}_2^T J_2^T J_2 - \ddot{x}_2^{dT} J_2) + \dots] \ddot{q}$$

$$a = 2w_1 [(\ddot{q}_1^T J_1^T J_1 - \ddot{x}_1^{dT} J_1) + (\ddot{q}_2^T J_2^T J_2 - \ddot{x}_2^{dT} J_2) + \dots \\ \dots + (\ddot{q}_n^T J_n^T J_n - \ddot{x}_n^{dT} J_n)]$$

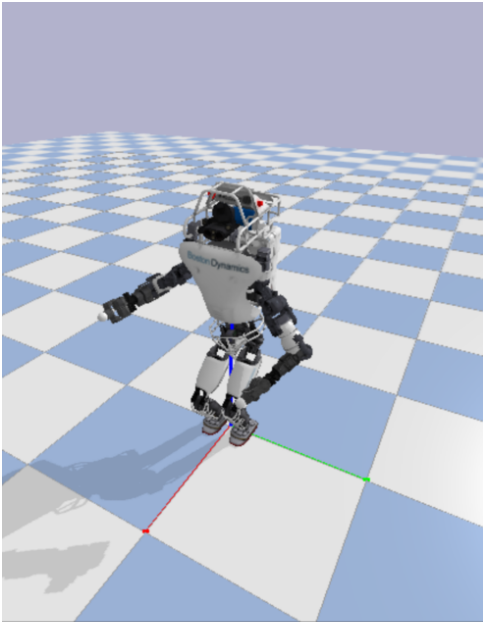
## Question 2:

$$A\ddot{q} + b + g = \begin{bmatrix} 0_{6 \times 1} \\ \tau_{cmd} \end{bmatrix} + J_c^T f_r \iff [C \ D] \begin{bmatrix} \ddot{q} \\ f_r \end{bmatrix} = c$$

$$A\ddot{q} - J_c^T f_r = \begin{bmatrix} 0_{6 \times 1} \\ \tau_{cmd} \end{bmatrix} - b - g \iff C\ddot{q} + Df_r = c$$

$$\begin{aligned} C &= A \\ D &= -J_c^T \\ c &= \begin{bmatrix} 0_{6 \times 1} \\ \tau_{cmd} \end{bmatrix} - b - g \end{aligned}$$

Running Atlas simulation in pybullet :



↩ Atlas remains standing and balanced

```
yaw=120.00      Status: OK
Vendor = VMware, Inc.
Renderer = llvmpipe (LLVM 10.0.0, 128 bits)
b3Printf: Selected demo: Physics Server
startThreads creating 1 threads.
starting thread 0
started thread 0
MotionThreadFunc thread started
ven = VMware, Inc.
=====
Initialize
=====
[WalkingState] STAND
ven = VMware, Inc.
[WalkingState] BALANCE
```