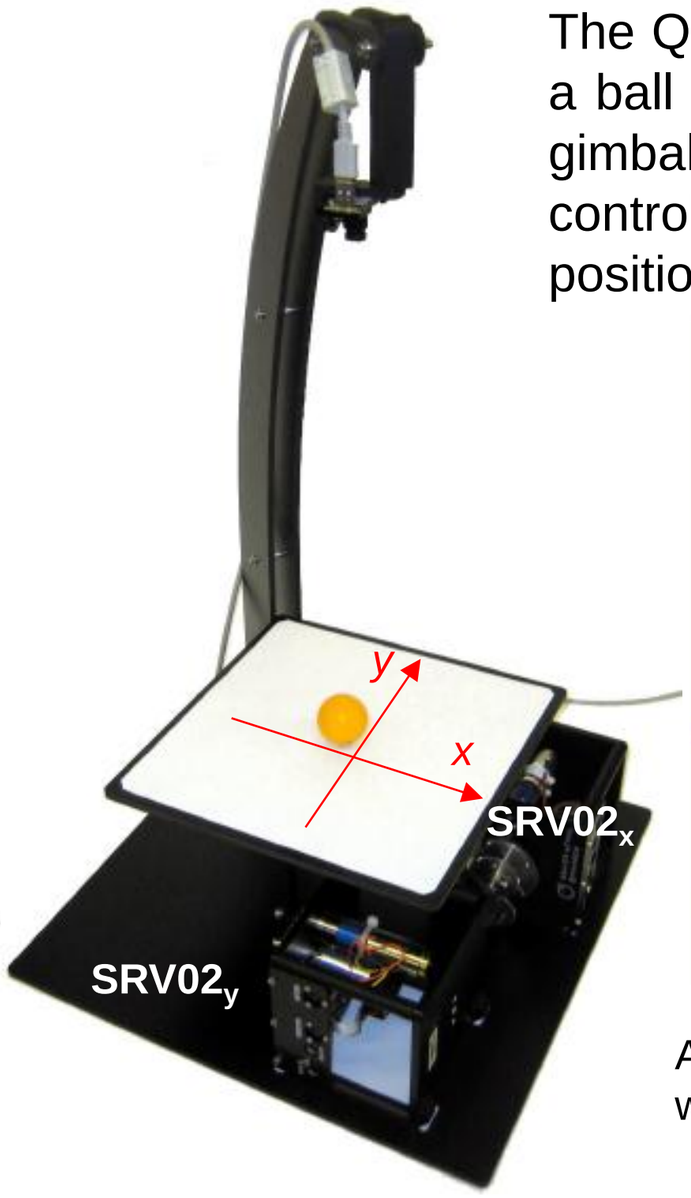
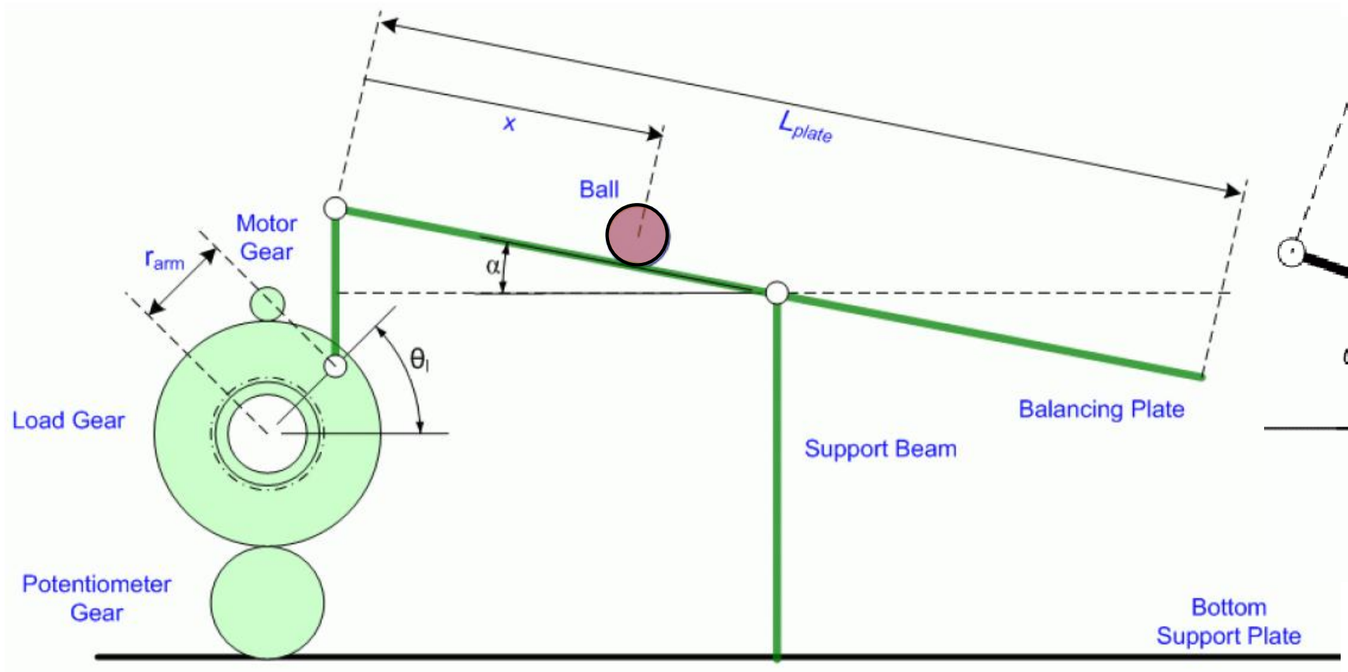
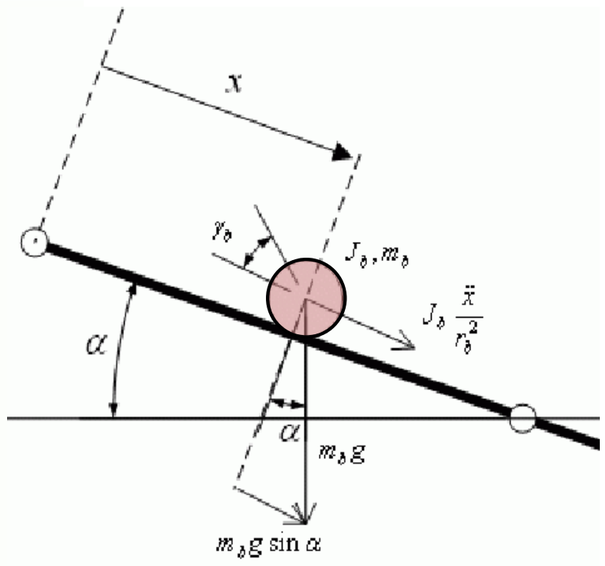
2D Ball Balancer



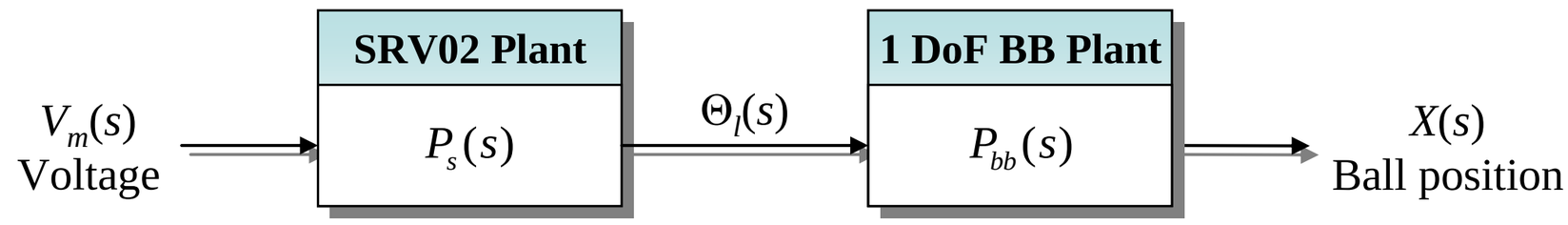
The Quanser 2D Ball Balancer (BB) experiment setup consists of a flat plate on which a ball is placed and is free to move. The plate rests on a 2-degree-of-freedom (DoF) gimbal which allows tilts in x- and y-direction. Two orthogonal servos under the plate control tilt (around x and y axes) which balances ball position and velocity. Balls position is measured with an overhead camera.





Assumption: Ball dynamics in *x*-direction and *y*-direction are decoupled (no interference), hence we could use the same control architecture in each channel (i.e. treat each dimension separately).

Open-loop block diagram



Linearized one-axis model

$$\ddot{x} = \frac{2 r_{arm} r_b^2 m_b g \sin\theta_l}{L(r_b^2 m_b + J_b)} \approx K_b \theta_l$$

Ball balancer transfer function

$$P_{bb}(s) = \frac{X(s)}{\Theta_l(s)} = \frac{K_b}{s^2} = \frac{1.3}{s^2}$$

SRV02 servo transfer function

$$P_s(s) = \frac{\Theta_l(s)}{V_m(s)} = \frac{K}{s(\tau s + 1)} = \frac{1.76}{s(0.0285 s + 1)}$$

Requirements

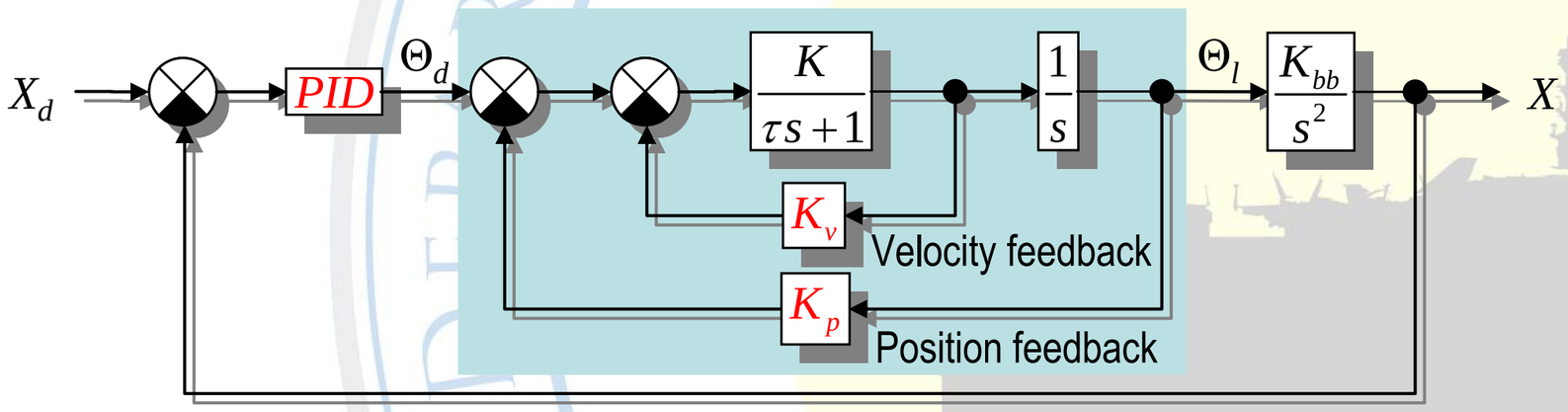
Servo: $e_{ss}^{step} = 0$ $\quad t_p \le 0.15s$ $\quad M_p \le 5\%$

Ball balancer: $e_{ss}^{step} \le 0.001m$ $\quad t_s^{2\%} \le 3s$ $\quad M_p \le 7.5\%$

$\Rightarrow$ $\zeta = 0.690$ $\quad \omega_n = 28.9 s^{-1}$

$\Rightarrow$ $\zeta = 0.635$ $\quad \omega_n = 2.19 s^{-1}$

One-axis control architecture



$K_p = 13.5$ $\quad K_v = 0.078$

$PID: \{k_p = 5.8,\ k_d = 2.9,\ k_i = 3.7\}$

Applications

PoC: Prof. **Oleg Yakimenko**, Bu-223
oayakime@nps.edu, (831) 656-2826

CRUSER
Consortium for Robotics and Unmanned Systems Education and Research

SYSTEMS ENGINEERING
ESTABLISHED 2002