Case Study: An Artificial Eye System

- Introduction to Oculomotor Control
- The model of the dynamics
- Gaze stabilization
- The vestibulo-ocular reflex (VOR)
- The optokinetic reflex (OKR)
- Delays
- Controlling the VOR and OKR

Reading Assignment for Next Class

- See http://www-clmc.usc.edu/~cs545
Introduction to Oculomotor Control

- Goals
  - Get visual input from the entire world with high resolution foveal vision and low resolution peripheral vision

- Behaviors
  - Move the fovea to interesting targets (saccades)
  - Stabilize target on retina (VOR, OKR)
  - Adjust focal length (accommodation)
  - Enable stereo vision (vergence)
  - Avoid workspace boundaries (nystagmus)

- Problems
  - Delays from visual processing are about 100ms in humans, about 30-100ms in artificial systems
Example Oculomotor Systems

- The human eye
- Vision Heads
Example Oculomotor Systems

- Vision Heads
Case Study:
The VOR and OKR
A model of the eye system

- Assumptions:
  - System is a linear second order system
  - Eye motors are very strong (inertial loads are small)
  - Independent control of pan and tilt degree-of-freedom, thus:

\[ I \ddot{\theta} = -b \dot{\theta} - k \theta + \tau \]
Gaze Stabilization

Gaze = $\theta_e + \theta_h$

Goal: keep the eye on the target in case of visual and head perturbations!
Simulink Model of Oculomotor System

2-eye dynamics

Left Eye

\[ \frac{1}{m} \frac{1}{s^2 + \frac{b}{m} s + \frac{k}{m}} \]

th_left

th-right

u_left

u_right

focal length

delayed retinal slip

retinal slip velocity

retinal slip

Animation function

du/dt

th-target

th-head

u (4)-(u(3)+u(1))

Mux

Mux

OculomotorAnimationSimp
PD Control for the VOR & OKR
Performance of PD Control

- Step Input:

- Sinusoidal Input
How to Improve Performance?

- Integrator
- Feedforward Control
- Delay Compensation