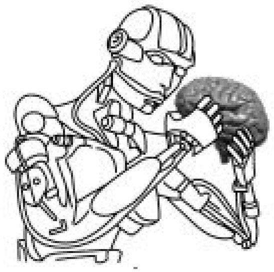
# CS 545 Lecture 7
# Case Study:
# An Artificial Eye System

- Introduction to Oculomotor Control
- Model of dynamics
- Gaze Stabilization
- Vestibulo-ocular reflex (VOR)
- Optokinetic reflex (OKR)
- Control

http://robotics.usc.edu/~aatrash/cs545

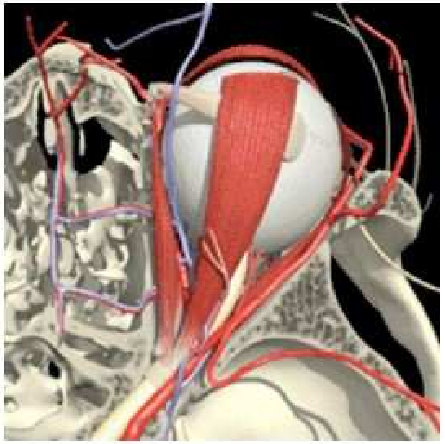
# Oculomotor Control

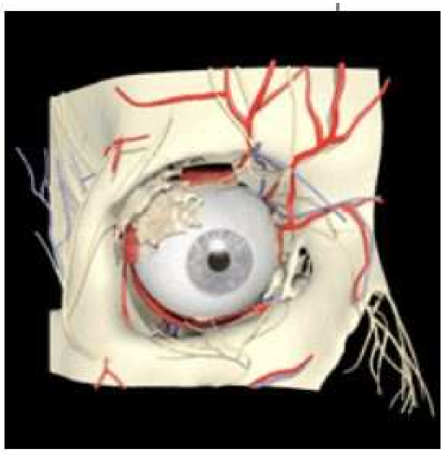


- Goals
  - Get visual input from the entire world with high resolution foveal vision and low resolution peripheral vision
- Behaviors
  - Move fovea to interesting targets (saccades)
  - Stabilize target on retina (VOR, OKR)
  - Adjust focal length (accommodation)
  - Enable stereo vision (vergence)
  - Avoid wordspace boundaries (nystagmus)
- Problems
  - Delays from visual processing are about 100 ms in humans and about 30-100 ms in artificial systems

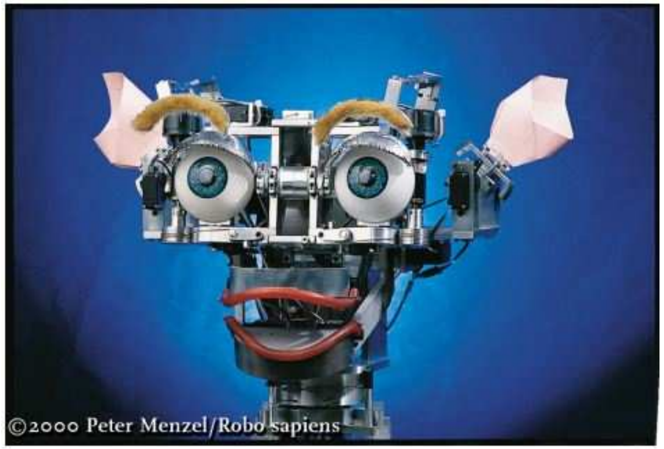
# Example Oculomotor Systems

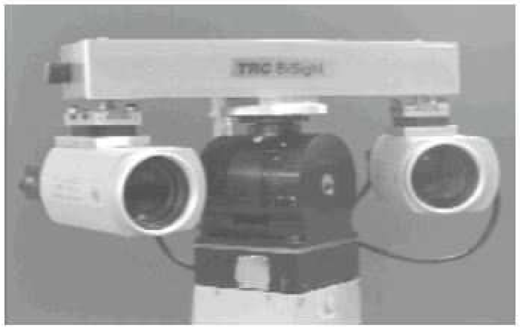
- Human Eye

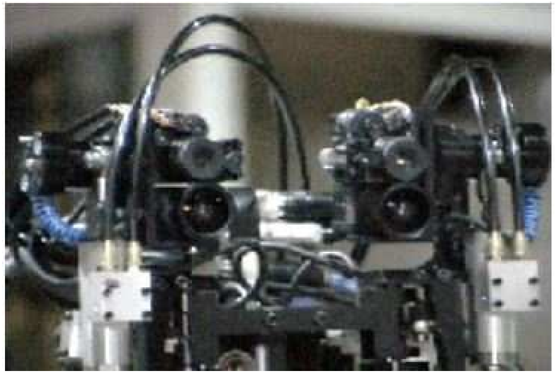




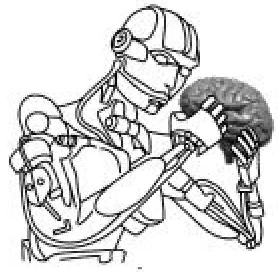
- Vision Heads



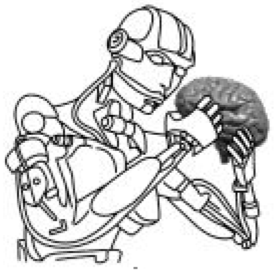



# VOR and VKR



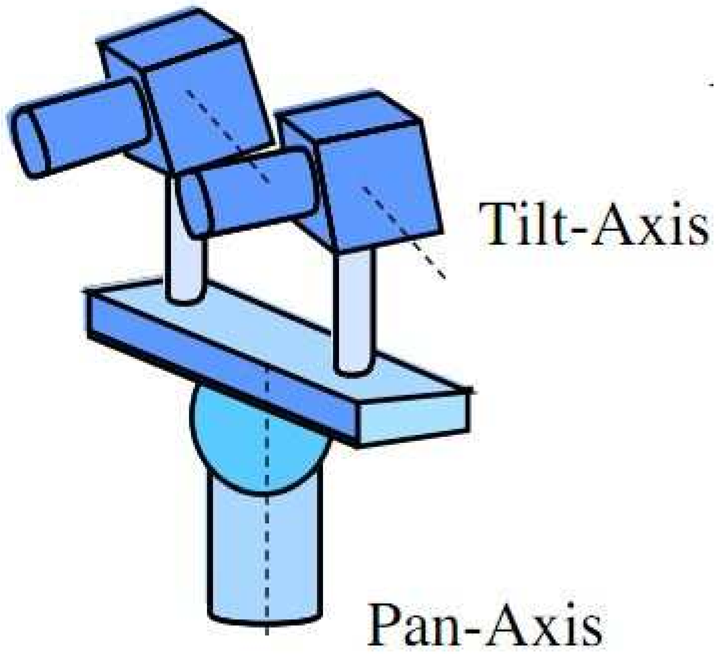
- Vestibulo-ocular reflex (VOR)
  - Stabilize image on retina as head moves
  - Human head is constantly moving
    - Rotational and translational
  - Extremely fast
  - Not visual
- Optokinetic reflex (OKR)
  - Allows eye to track an object as head remains still
  - Works together with VOR

# Model of Eye System

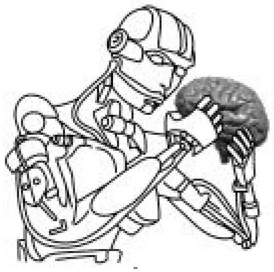


- Assumptions:
  - System is linear second order system
  - Eye motors are very strong (inertial loads are small)
  - Independent control of pan and tilt
  - Dynamics:

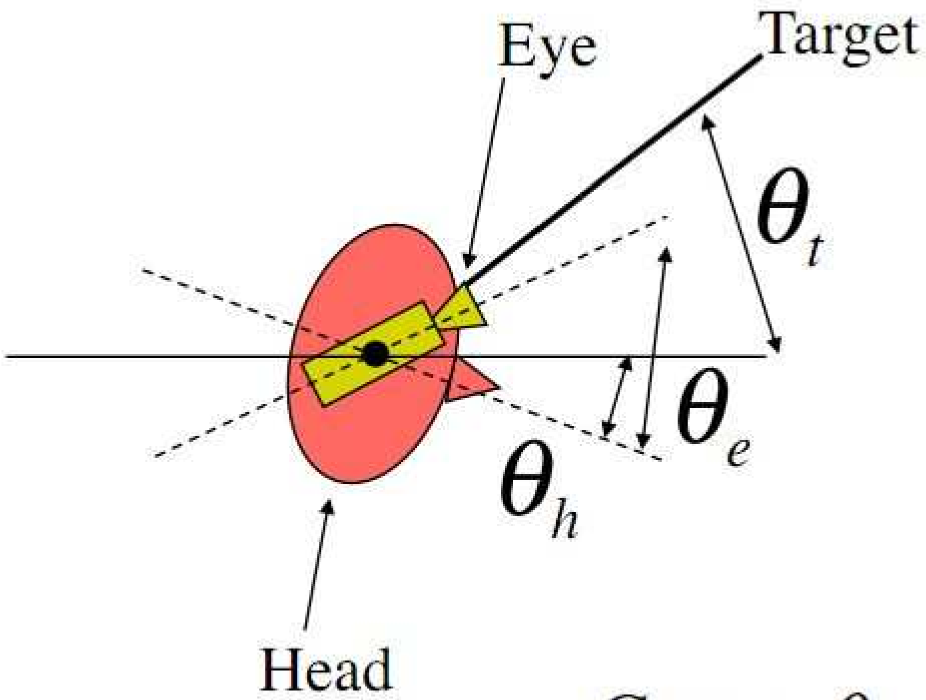
$$I\ddot{\theta} = -b\dot{\theta} - k\theta + \tau$$



# Gaze Stabilization

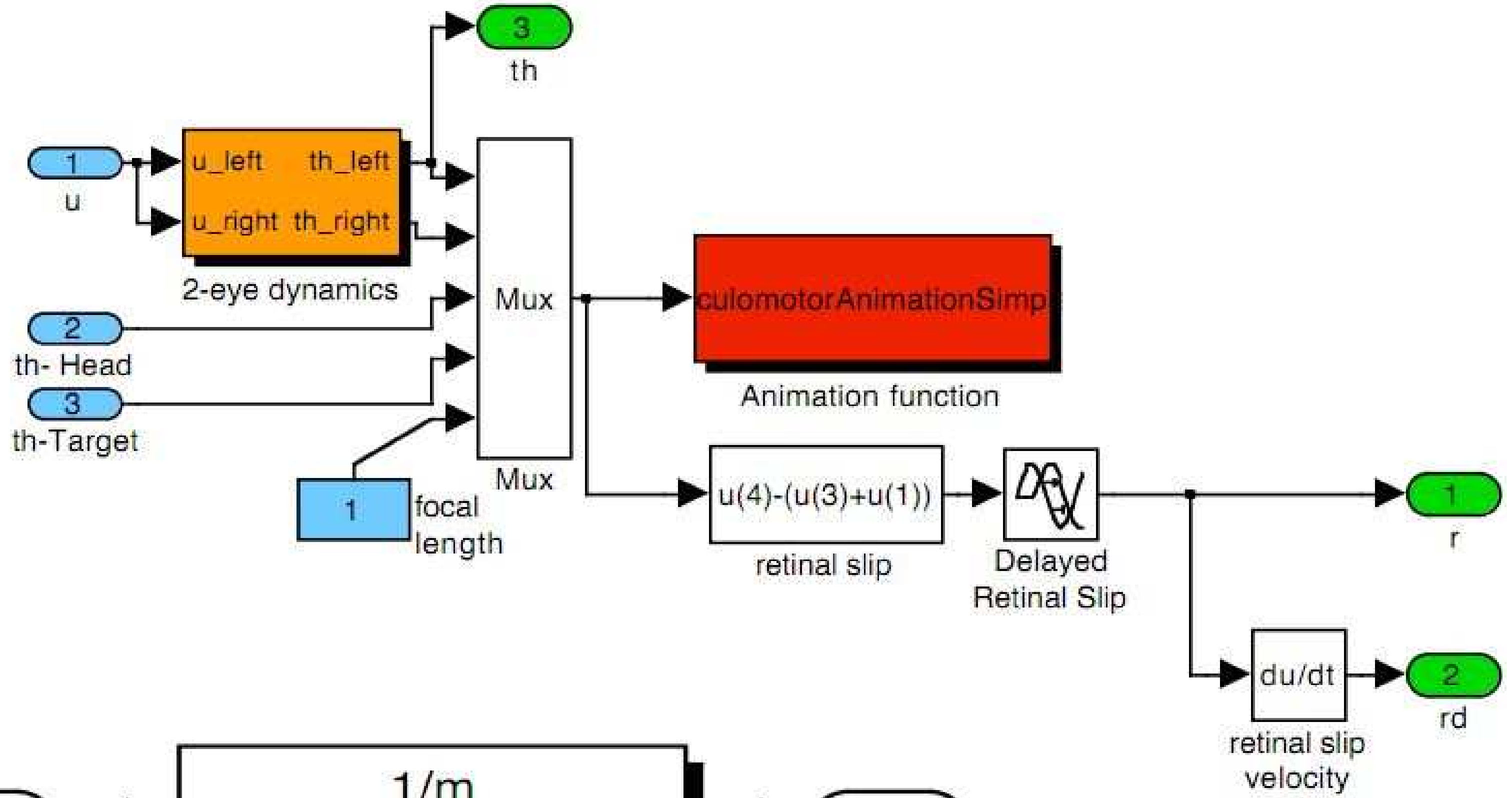


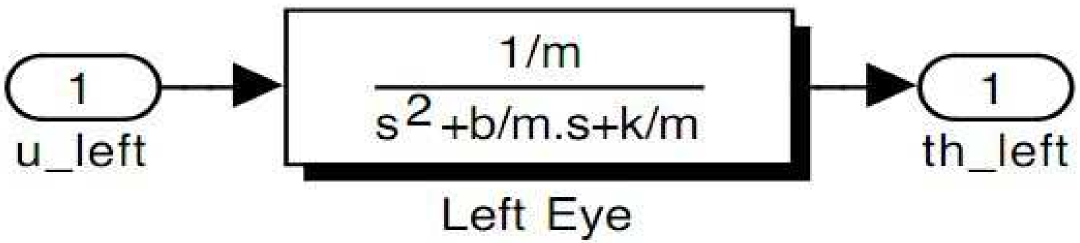
- Goal: Keep the eye on the target in case of visual and head perturbations



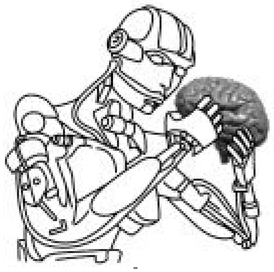

$$Gaze = \theta_e + \theta_h$$

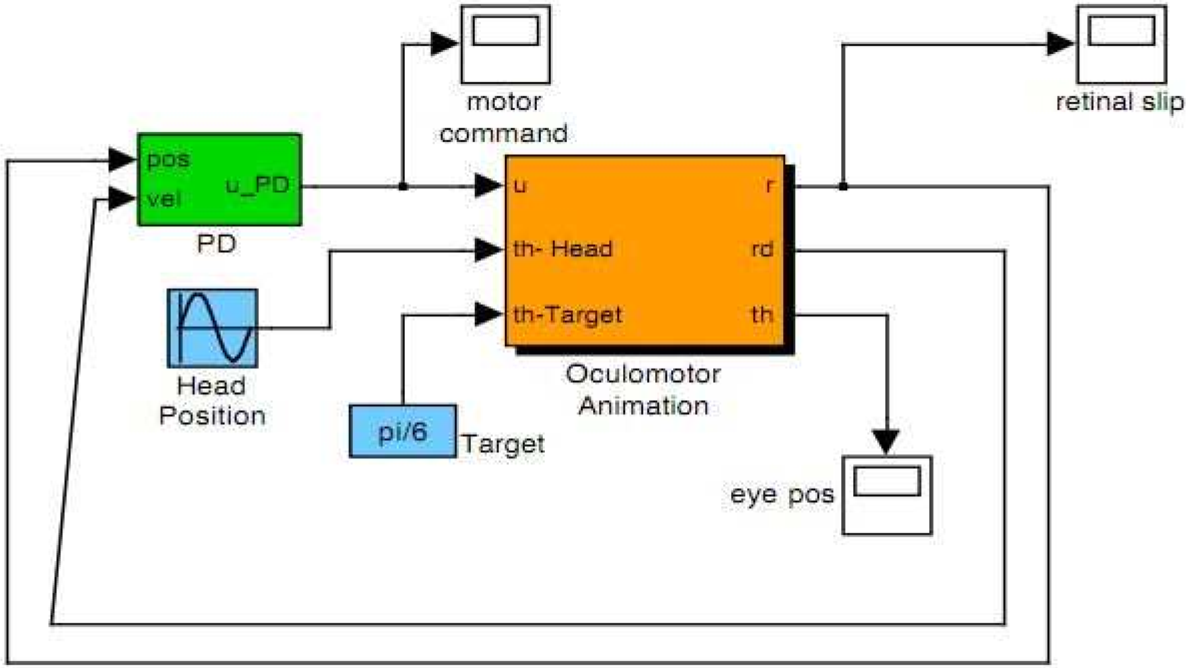
# Simulink Model of Oculomotor System

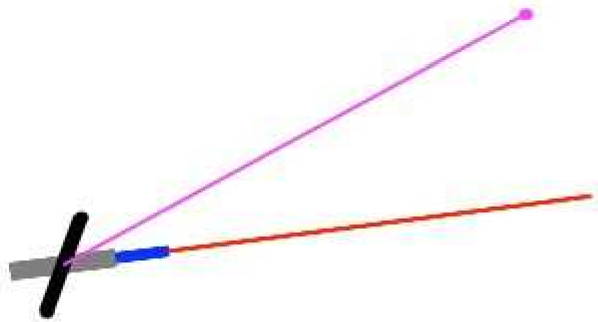


# PD Control for VOR and VKR

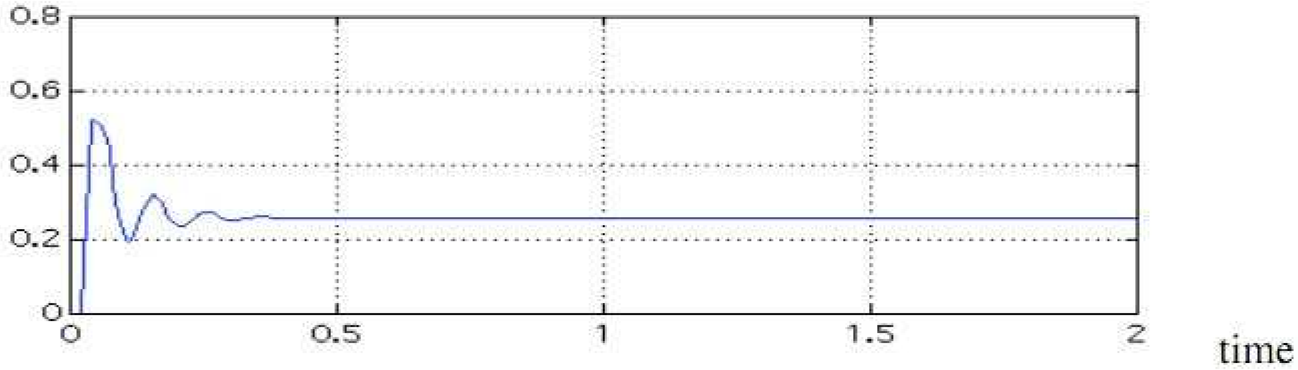




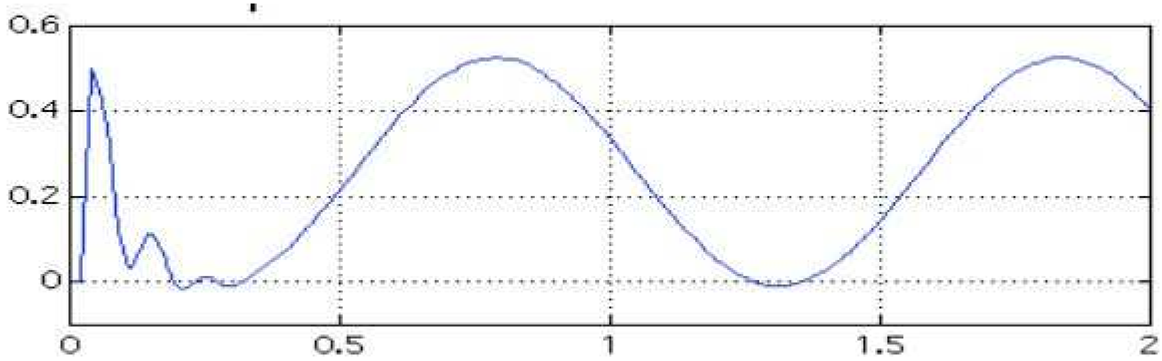



# Performance of PD Control

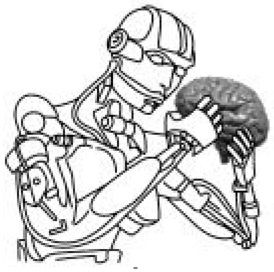
- Step Input:




- Sinusoidal Input:



# How to Improve Performance?



- Integrator (PID)
- Feedforward Control
- Delay Compensation