Today’s Class

- Haptic Device Review (be sure to review kinematics and Jacobians from Lect. 3 if you are rusty) (We will discuss tactile devices in the next device design lecture)
- Impedance Device Design
- Case Study: Cheap haptics
  - Haptic Paddle
  - Falcon device design
- Readings: No readings – start on your lab

Physical Haptic Systems

- Basic Elements of a haptic system
  - Physical device (the plant of a control system)
    - Actuators and transmission
    - Sensors
  - High power (current) amplifier + power supply
  - Controller
    - Computer Controller
      - Control (DAQ) Card
      - Servo control loop (typically at ≥1kHz)


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Haptic System Diagram

Mechanisms

- Common mechanism for 2&3 dof: five-bar

Immersion 3GM Kinematics

Stringed Devices

Grounded kinesthetic devices

Admittance Type

Platform Devices

Stewart Platform
(parallel actuator robot)
(Uncommon haptic interface, but used in vehicle simulators and telesurgery)

Arm-based devices

Body-Based Devices

- Displays unilateral constraints, inertial forces, and slope
Design Principles for impedance devices

- Low inertia (should appear mass-less)
  - Note, transmissions can increase the reflected inertia of the motor (see below)
- Low friction/drag
  - Smooth mechanisms
  - Smooth bearings (typically ABEC-5 ball bearings or better, roller bearings tend to not be as smooth)
  - Smooth actuator (e.g. Maxon motors) and transmission (e.g. Capstan)
    - No cogging (e.g., torque ripple or gear meshing)
    - Some friction/damping can improve stability [Colgate, et al. 1994]
    - This can be partially cancelled using control (cogging or configuration dependent friction is usually undesirable)

Most common Impedance device design

DC Motors with capstan drives for rotary motion

- Pros
  - Cog-less “gear-ratio” transmission
- Cons
  - Issues with friction transmission of cable on capstan pulley
  - High cable tension \(\rightarrow\) high drag
  - Possibly high reflected \(N^2\) inertia

Low Cost impedance Device

The Haptic Paddle

- Its humble beginnings
  - Stanford University – used to teach system dynamics
  - $27 in parts, using a surplus motor, bronze bushings, laser cut acrylic and a hall-effect sensor
- Adopted and revised
  - Johns Hopkins University – used to teach system dynamics and haptics
  - Uses motor, bronze bushings, laser cut acrylic and a hall-effect sensor
  - Added PCB for parallel communication and amplifier

- http://haptics.lcsr.jhu.edu/Making_and_Using_a_Haptic_Paddle
Low Cost impedance Device
The Haptic Paddle

- Adopted and revised
  - Rice University – used to teach system dynamics and haptics
  - Uses motor, ball bearings, laser cut acrylic and a hall-effect sensor
  - Added higher end amp and Labview control interface.
  - Inverted capstan drive to be opposite the handle and lower the motor
  - Added grooved capstan pulley and shoulder bolt paddle axle

- From Stanford Haptic Paddle

Design Principles for impedance devices Reviewed

- Low inertia (should appear mass-less)
  - Note, transmissions can increase the reflected inertia of the motor (see below)

- Low friction/drag
  - Smooth mechanisms
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Developing a Mass Market Haptic Interface

- For further info see: EduHaptics.org (to be posted spring 2009)
Product Requirements

- what is the device for?
- define the workspace
- mechanical structure, stiffness
- position resolution
- sensors
- calibration
- force range, max torques, resolution
- motors
- friction
- update rate
- control
- interface

- mass market
- 12 x 12 x 12 cm
- parallel
- < 0.2 mm
- optical
- micro-switch
- up to 5 Newton
- high torque
- constant & low
- > 1000 Hz
- PIC microcontroller
- USB

Overview

- $10,000 $100

  - to convert a ROLEX into a SWATCH
  - divide the costs by 100

Low Cost Actuators

- $100 $1

  - going from high precision actuators to motors which are found in hair dryers
  - Can anything bad happen when you do this?

Low Cost Position Sensors

- $40 $2

  - usdigital.com
The Falcon available through Novint and slightly cheaper through major distributors such as Amazon and Walmart.