CCRMA Stanford University

Music 250 - Physical Interaction Design for Music

Lab 6: HAPTICS

home
schedule
homework
project
labs
materials
resources

The goal of this lab is to introduce three-dimensional active force feedback. Each haptic effect can easily be coupled to a sound because the feedback loop is controlled directly Pd. Different haptic effects suggest different sounds; different sounds suggest different effects. What are the most interesting mappings? Which are appropriate, controllable, even "expressive". Try each sound control with and without the motor turned on. Are there some that simply cannot be played without haptics?

Part 0: Setup

a. Add the following line to your ~/.bashrc file:

```
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/usr/ccrma/courses/250a/pd/externs
```

For example, your entire .bashrc file might look like this:

```
# .bashrc

# User specific aliases and functions
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/usr/ccrma/courses/250a/pd/externs

# Source global definitions
if [ -f /etc/bashrc ]; then
        . /etc/bashrc
fi
```

b. Connect the Falcon to the USB port of your machine by way of a powered USB hub.
c. Connect the power supply to the Falcon.
d. load lab6 on to your 250a directory

Save lab6.tar.gz into your 250a directory.

```
~> cd ~/250a
~> tar -xzf lab6.tar.gz
```

e. Type "bash" to load the bash shell. We recommend using bash because it knows how to find all of the dynamically linked libraries used by the Falcon driver. **If Pd reports that it cannot find some library necessary to load the Falcon driver patch, then it is probably because you are running some shell like tcsh or csh and not bash.**

f. Please be nice to the Falcon! It can be damaged if jolted around too much.

Part 1: Motor Test - spring centering

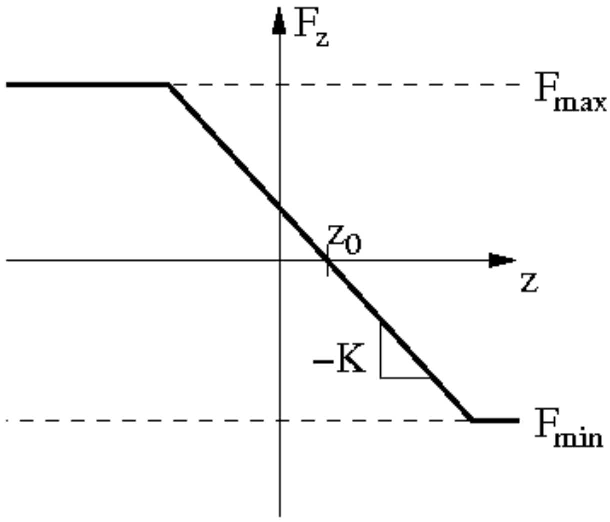
a. run "1D-spring.pd"

```
~>cd ~/250a/lab6/spring
~>pd -open 1D-spring.pd&
```

b. Test the spring governed by $F_z = K(z_0 - z)$. F_z is the force exerted by the motors in the z-axis, z is the position of the Falcon grip in the z-axis, K is the spring stiffness, and z_0 is the rest position of the spring. In this example, we choose $z_0 = 0$.

1. Check the messages in the Pd window to ensure that the Falcon has been initialized properly.
2. Hold down the center button of the Falcon grip to enable haptics.
3. Increase the stiffness of the spring from zero by dragging the number box.
4. Make sure that you understand how the "expr" object works.

In practice, the motors exert forces that are limited in magnitude, i.e. the Falcon limits the maximum force in both extremes, so the actual force as a function of position is slightly different from the idealized spring:



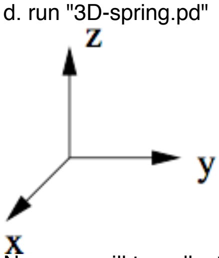
c. run "1D-wall.pd"

```
~>cd ~/250a/lab6/spring
~>pd -open 1D-wall.pd&
```

A wall is just like a spring that engages right as the user starts pushing into the virtual wall. The spring's rest position is the position of the virtual wall.

1. Try changing the stiffness of the virtual wall.
2. How stiff is a real wall?
3. Notice that the wall is implemented using a subpatch instead of expr. Look inside the subpatch to see how it is implemented.
4. Rigid virtual objects can be represented using significantly stiff walls with complex geometries. This is how haptics can be used to help CAD designers study the shape of complex objects.

d. run "3D-spring.pd"



Now you will try adjusting springs in three dimensions, labeled as shown above. Using one stiff spring, you can restrict the motion of the Falcon grip to a plane. Using two stiff springs, you can restrict the motion of the Falcon grip to a line. Using three stiff springs, you can restrict Falcon grip to lie near a point.

```
~>cd ~/250a/lab6/spring
~>pd -open 3D-spring.pd&
```

1. Try restricting the Falcon grip's motion to lie in a plane, a line, etc.
2. What is the rest position for the spring in the X direction?
3. Why is this rest position not equal to zero?

e. OPTIONAL: run "3D-damper.pd"
To implement damping, we need to control the Falcon according to $F = -Rv$, where v is the velocity

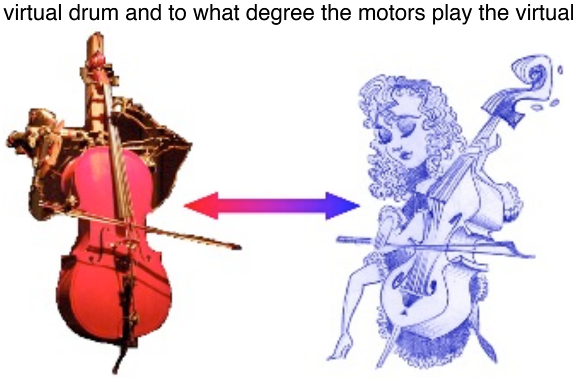
of the Falcon grip, and R adjusts the amount of damping. In other words, when the falcon grip is moving in a particular direction, the motors exert a force to try to make the grip stop moving. Since the Falcon does not measure velocity, the Pd patch obtains an estimate of the velocity by differentiating the position measurement.

```
~>cd ~/250a/lab6/spring
~>pd -open 3D-damper.pd&
```

1. Adjust the amount of damping by increasing the slider. You should feel like you are moving your hand through a bowl of thin molasses or jelly.
2. Try enabling the "damping strobe" which turns the damping on and off over time.
3. Turn off the damping strobe, open the properties dialog for the number box feeding the "s frictcoef" object, and edit the lower limit so that it is -1.
4. **Now be very careful because the following step can cause the haptic device to move very quickly. Try to avoid banging the grips against the limits of the haptic workspace.** Adjust the number box so that it reads -1 so that the damping is negative. Now you will find that the Falcon grip moves about in a strange manner, which doesn't occur in nature. If you have the grip moving an any direction, then the motors push the Falcon grip in that same direction.

Part 2: Haptic Drumming

In this section, we investigate how the haptic interface can enable us to make certain kinds of gestures which would otherwise be difficult or impossible. Consider to what degree you can play the virtual drum and to what degree the motors play the virtual drum.



(On the left we have a robot from Carlos Corpa's Automatic Noise Ensemble.)

1. ***Be careful in this patch as it is possible make the Falcon become unstable and jump around wildly. Hold on to the Falcon grip tightly.***

2. ```
   ~> cd ~/250a/lab6/drum
   ~> pd -open drum.pd -alsa &
   ```

3. By default, the horizontally-placed virtual drumhead is modeled analogously to the walls in the previous sections. Whenever you push the Falcon end-effector into the drumhead, the sound synthesizer plays a recording of a drum sound.
4. The haptic assistance is designed to provide an upward exponentially-decaying force pulse every time that you strike the virtual drum. Turn on the toggle labeled "ASSISTANCE" and hold on tight!!
5. Do you find that the assistance makes it easier to play drum rolls?
6. Can you play especially fast drum rolls?

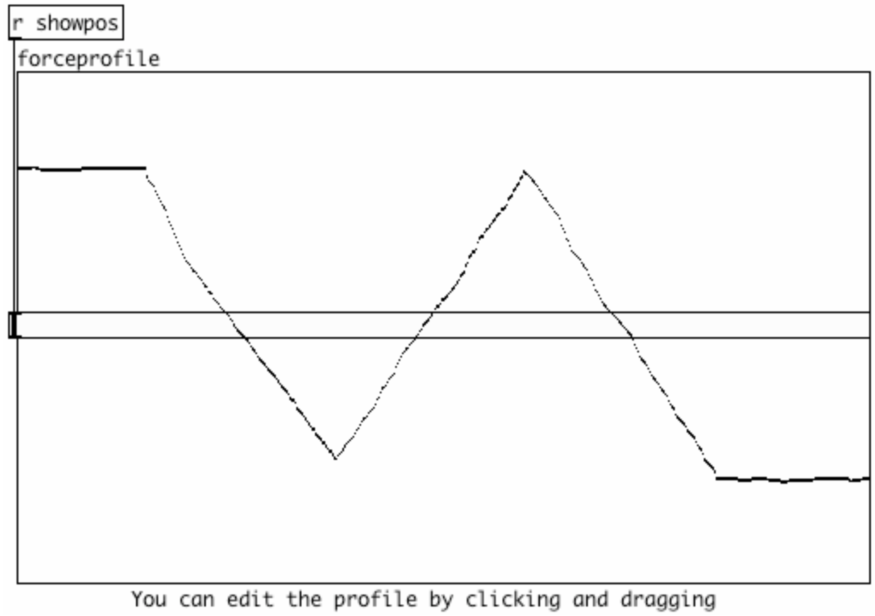
Part 3: Haptic landscapes

a. run "force-profile.pd"

```
~>cd ~/250a/lab6
~>pd -open force-profile.pd&
```

The patch restricts the motion of the Falcon grip to the Y-axis using springs in the X-axis and Z-axis.
```

The force in the Y-axis is a function of the Y-position. The function is specified by a user-editable graphical array. At the center of the array, a horizontal slider (hslider) shows the Y-position of the Falcon. The example below specifies two equilibrium points, toward which the Falcon grip is pushed by the motors.



1. On a separate sheet of paper, copy the graphical array and draw X's over the equilibrium points.
2. On the reverse of the separate sheet of paper, draw a force profile resulting in three equilibrium points, test it in Pd, and draw X's over the equilibrium points.
3. Experiment with some other force profiles.

b. run "surface.pd"

```
~>cd ~/250a/lab6
~>pd -open surface.pd&
```

The patch restricts the motion of the Falcon grip to the Y/Z-plane by way of a spring in the X-axis. The forces in the Y-axis and Z-axis are a function of the shape specified in the graphical array "height".

1. Increase the "SURFACE STIFFNESS" parameter so that the surface repells the Falcon grip when it is in contact with the surface.
2. Increase the "DAMPING" slider so that when in contact with the surface, the motion of the grip is damped.
3. Optional: Experiment with other surfaces by redrawing the contents of the graphical array "height".

Part 4: Bouncing ball

Now the Falcon grip is connected to a virtual mass by way of a spring.
a. run "bounce.pd"

```
~>cd ~/250a/lab6
~>pd -open bounce.pd&
```

```
1. Before enabling haptics, manipulate the motion of the virtual mass.
2. Now enable haptics by holding down the center button on the end of
   the Falcon grip. Is it easier to control the motion of the virtual
   mass with haptics enabled?
```

Part 5: Build Your Own

1. Make your very own musical controller using the Falcon and one of the above patches as a starting point. We suggest *3D-spring.pd*, *3D-damper.pd* or *surface.pd* but feel free to use any patch from the lab or build your own patch from scratch around the Falcon object.
2. Some ideas:
   Try to impart kinetic energy from your body into a physical model of an instrument.
   Try to use a haptic surface to control something with your eyes closed.
3. Make us proud. (And be ready show off your controller at the next lab session)