1DOF Rendering:
Simulating Physical Interactions on Hapkit
Due Thursday, Feb 13 End of Day

Objective

Haptic rendering describes the process of conveying touch sensations to a user via a haptic device. In this lab, you will be programming the Hapkit haptic paddle to simulate a set of physical interactions. You will be presented a set of visualizations, interactive animations of some end effector interacting with a surface or terrain. Your task is to design the impedance rules to generate an appropriate force response for each of the visualizations.

Procedure

Code

You are provided code (Python) that generates the visualizations and a scaffold of an arduino sketch that you will complete; you may edit any code as you see fit.
`Hapkitviz.py` contains some helper functions and classes for generating the environments and creating visual simulations.

`E399_Lab01.py` establishes communication between the Hapkit arduino and the Python code, generates a set of visual environments (using the pygame package), and starts the simulatio
`hapkit_IU_E399_Lab01.ino` is the Arduino sketch that controls the Hapkit. After the variable declarations and before `setup()`, you'll see a set of (currently empty) functions named `mode1`-mode5. In these blocks, you will add code to implement your impedance rules for each of the visualizations. Additionally, in the body of `loop()`, you will add code to estimate the angular velocity and acceleration of the haptic paddle.

Simulations

Currently, you are presented six visual interactions: Flat, The Wall, Valley, Hillock, Notch, Bumpity.

Flat: The user should be able to move the handle without impedance. No force output should be coded.

The Wall: The user should be able to move the cursor unimpeded until the cursor collides with the wall. Try to make the wall feel as rigid as possible.

Valley: The user should have to exert effort pushing the cursor up the edges of the valley. If the user lets go of the paddle, the cursor should slide down the valley walls and settle at the bottom. How does the cursor settle? Will the cursor glide down slowly or will it shoot down and oscillate at the bottom before coming to rest?

Hillock: The user should have to exert effort pushing the cursor up to the top of the Hillock. At the top, the cursor should be at rest, but perturbed in either direction, it should slide down the side of the hill. What happens when the cursor hits the edge? Does it land with a dull thud or a bounce?

Notch: When the user runs over the divot, the cursor should fall in and get a bit stuck. The user should have to exert a bit of extra force to unstick the cursor.

Bumpity: A sequence of notches. The user should feel like they're pushing over a rumble strip. Each force bump should be aligned with the visual representation.

E599 Required - E399 Extra Credit

Do one (or both) of the following:

The Wall 2: Okamura et al. [2001] measured forces while tapping a stylus on different surfaces. They observed high frequency vibrations at impact. While most haptic devices do not have the bandwidth to recreate such vibrations, the authors found that adding a vibratory mode at the onset of contact increased the percept of rigidness. Add a decaying vibration at first impact with the wall. What frequency and decay rate do you use? How does this feel in comparison to your original simulation for The Wall?

I have not tried this with our Hapkit. I just thought it would be cool to try.

Dealer's choice: Create a new terrain and haptic rendering. Perhaps simulate a button press, a pinball launcher (that launches the cursor), a sloshy liquid. Be creative.

Methods and Results

Document (and explain) your code implementation for estimating the velocity (and acceleration?).

For each simultion above, present any physics-based equations that describe your simulation, code snippets of your implementation, and any force and position traces that might be informative.

Discussion

For the simulations above, discuss your process and rationale for the impedance laws you used. Did you use physical principles to derive impedance laws? Did you deviate or make exceptions to improve your rendering? Did the haptic renderings feel how you expected or wanted? Were some effects more convincing than others? Were there any unexpected or undesired system behaviors?

Demonstration and report

In class, on the day the assignment is due, you will be asked to demonstrate your haptic paddles. I may ask questions probing your design decisions or implementation. Every member of the lab group should be able to answer these questions.
Reports can be submitted after class until the end of day (11:59p EST on Canvas). Each lab group member should prepare and submit their own report.

References

Allison M Okamura, Mark R Cutkosky, and Jack T Dennerlein. Reality-based models for vibration feedback in virtual environments. *IEEE/ASME transactions on mechatronics*, 6(3):245–252, 2001.