Interaction: Motor Programs and Remapping

CS 6334 Virtual Reality
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Review of VR Systems

INPUT

- Head Tracker
- Game Controller
- Keyboard & Mouse

COMPUTATION

- Virtual World Generator

OUTPUT

- Visual Renderer
- Aural Renderer
- Haptic Renderer

- Visual Display
- Aural Display
- Haptic Display
Interactions in the Virtual World

• Looking around

• Waking, running, flying, etc.

• Grab and place objects

• Interacting with other users in the same virtual world

https://blog.prototypr.io/how-to-design-common-basic-interactions-in-vr-f958cf160cfc
Universal Simulation Principle

• Any interaction mechanism from the real world can be simulated in VR.

• Make the interaction **better than reality**

• Realism is not the goal

• Remapping: map motion in the real world to different motion in the virtual world
Motor Programs

- Motor skills to accomplish specific tasks
  - Writing text, tying shoelaces, throwing a ball, riding a bicycle, etc.

- Learned through repetitive trials

- Some skills are hard to learn than another
  - Using mouses is easier than typing with keyboards
Considerations for Interaction Mechanisms

• Effectiveness for the task in terms of achieving the required speed, accuracy, and motion range, if applicable

• Difficulty of learning the new motor programs

• Ease of use in terms of cognitive load

• Overall comfort during use over extended periods
The Neurophysiology of Movement

- **Primary motor cortex**, main source of neural signals that control movement

- **Premotor cortex** and **supplementary motor area**, preparing and planning of movement

- **Cerebellum** (little brain), special processing unit mostly for motion, but also involves attention and language
Neuroplasticity

• How long it takes to learn a motor program?

• Neuroplasticity: the potential of the brain to reorganize its neural structures and form new pathways to adapt to new stimuli

• Synaptic pruning
  • Causes healthy adults to have about half as many synapses per neuron than a child of age two or three

Learning Motor Programs

- **Learning input**
  - Visual perception
  - Proprioception signals from turning the knob

- **Output**
  - Sensorimotor relationships
  - One dimension mapping, knob orientation to line position

- **Other input device**
  - Keyboards
  - Touch screens

Atari 2600 Paddle controller

The Atari Breakout game
The 2D position of the mouse is mapped to a 2D position on the screen:
- The screen is rotated 90 degrees
- The motion is scaled
Motor Programs for VR

• Different input devices can be used in VR
  • Keyboards, mice, joysticks, pen, touch screens, etc.

• Tracking
  • Position and orientation of body parts or controllers

• Sensorimotor mapping (remapping)
  • Produces different results in the virtual world
  • E.g., press a button to open a door in VR
Sensorimotor Relationship

• Using feedback from sensors

• Feedback control

![Diagram of sensorimotor relationship with feedback control loop](image)
Feedback Control Basics

- Cruise Control of an automobile

Feedback Control of Dynamic Systems. Franklin, Powell, Emami-Naeini
Feedback Control Basics

- A mathematical model of cruise control
  - Assume 1 degree change in the throttle angle, 10 mph change in speed
  - 1% change in road grade, 5 mph change in speed
Feedback Control Basics

• Open-loop cruise control

\[
y_{ol} = 10(u - 0.5w) = 10\left(\frac{r}{10} - 0.5w\right) = r - 5w
\]

\[
e_{ol} = r - y_{ol} = 5w
\]

\[
\%error = 50 \frac{w}{r}
\]

Feedback Control of Dynamic Systems. Franklin, Powell, Emami-Naeini

\[u = \frac{r}{10}\]
Feedback Control Basics

• Closed-loop cruise control
Feedback Control Basics

• Closed-loop cruise control

\[ y_{cl} = 10u - 5w \]
\[ u = 10(r - y_{cl}) \]

\[ y_{cl} = 100r - 100y_{cl} - 5w \]
\[ 101y_{cl} = 100r - 5w \]
\[ y_{cl} = \frac{100}{101}r - \frac{5}{101}w \]

\[ e_{cl} = \frac{r}{101} + \frac{5w}{101} \]

\[ e_{ol} = 5w \]
Further Reading

• Section 10.1, Virtual Reality, Steven LaValle

• Feedback Control of Dynamic Systems. Franklin, Powell, Emami-Naeini