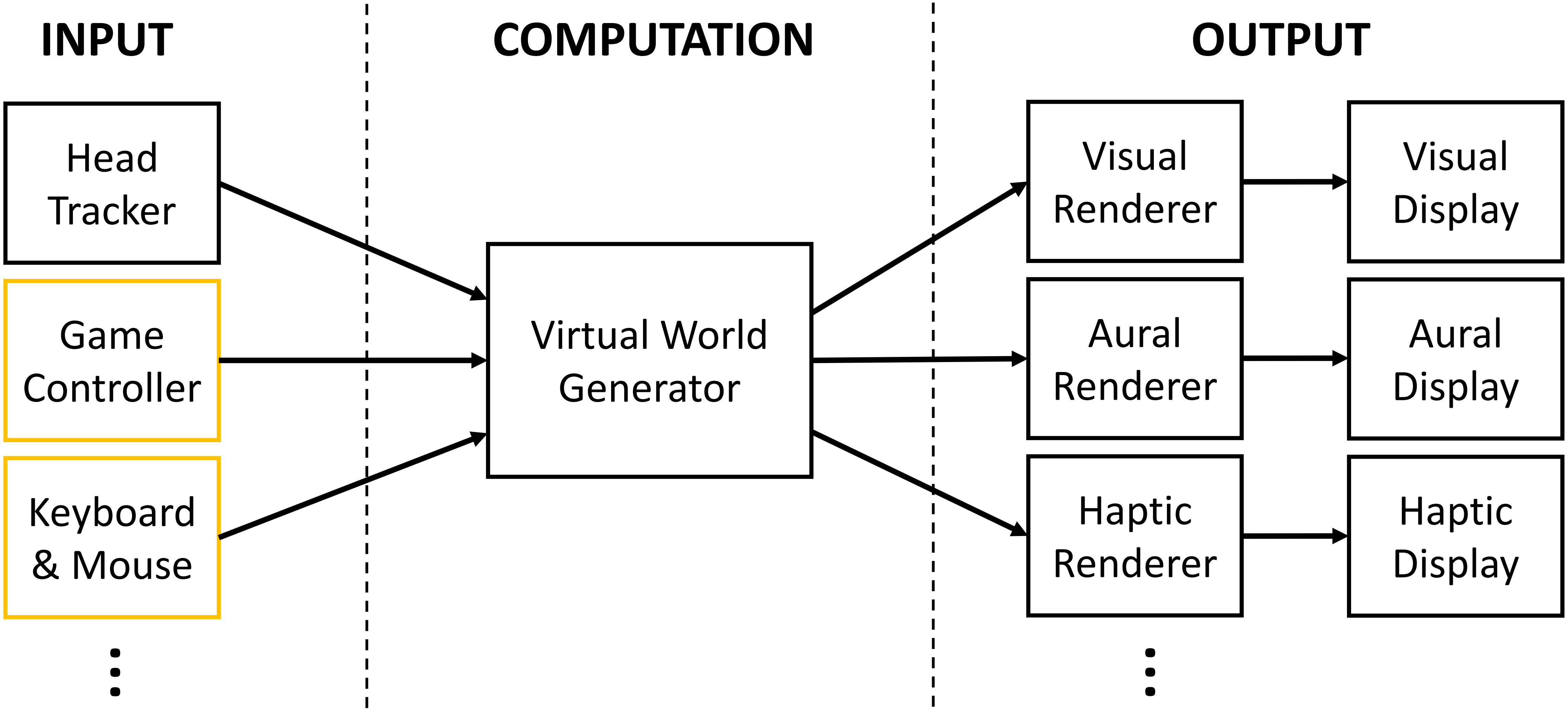
Interaction: Motor Programs and Remapping

CS 6334 Virtual Reality

Professor Yu Xiang

The University of Texas at Dallas

Review of VR Systems



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

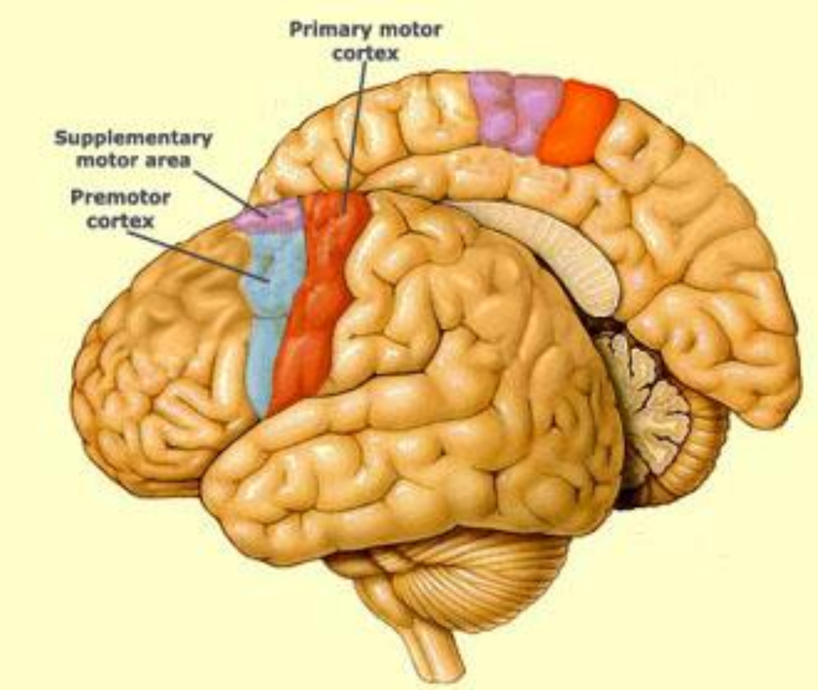
Motor Programs

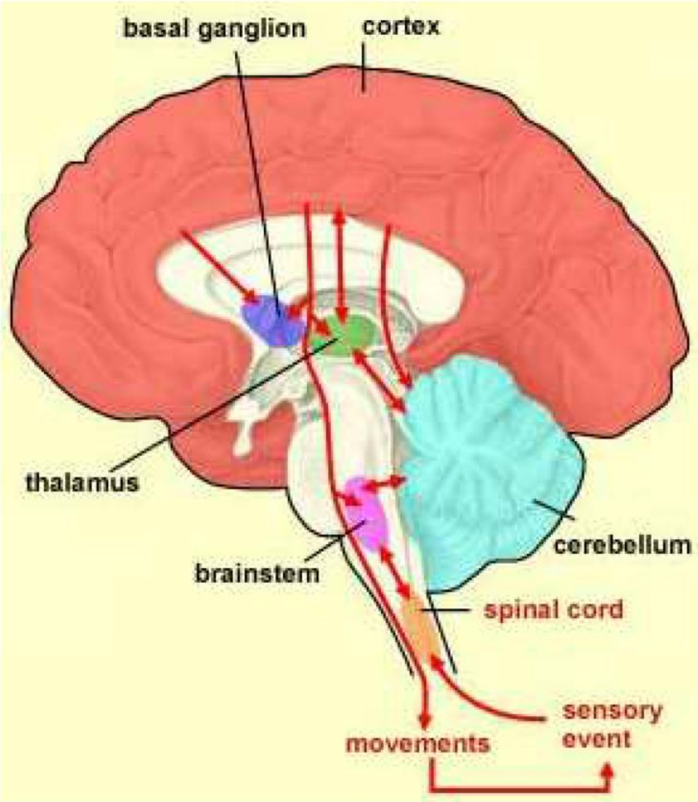
- Motor skills to accomplish specific tasks
  - Writing text, tying shoelaces, throwing a ball, riding a bicycle, etc.
- Learned through repetitive trials
- Some skills are hard to learn than another
  - Using mouses is easier than typing with keyboards

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





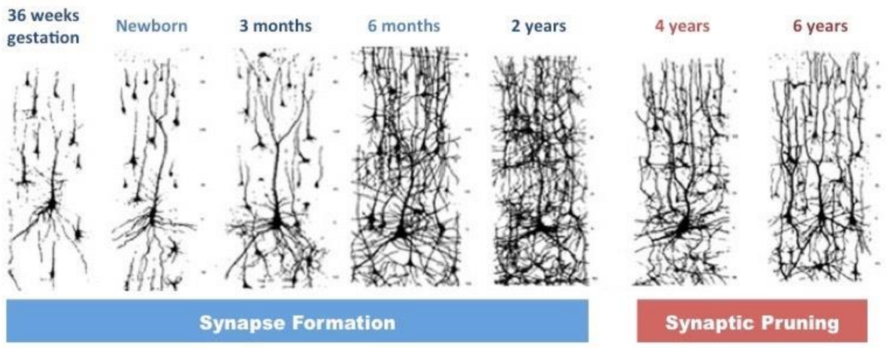
- **Primary motor cortex**, main source of neural signals that control movement
- **Premotor cortex** and **supplementary motor area**, preparing and planning of movement
- **Cerebellum** (little brain), special processing unit mostly for motion, but also involves attention and language

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



https://ib.bioninja.com.au/options/option-a-neurobiology-and/a1-neural-development/synaptic-formation.html

Learning Motor Programs

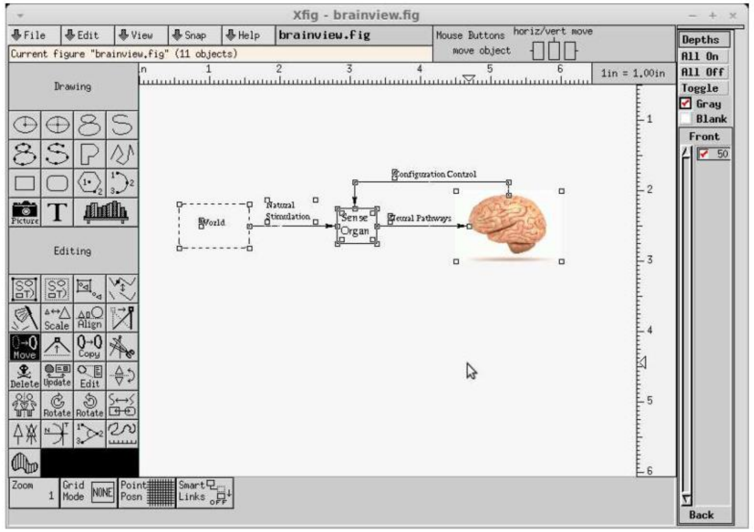
Atari 2600 Paddle controller

The Atari Breakout game

- 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

Learning Motor Programs

The Apple Macintosh mouse



- 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

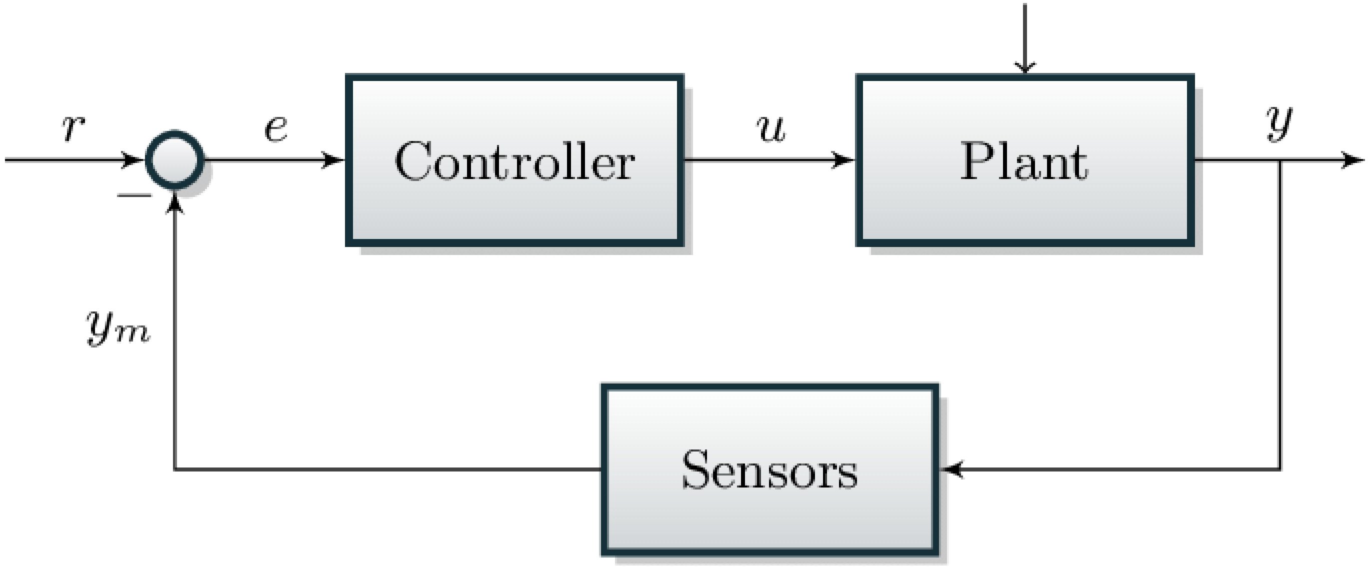
- Different input devices can be used in VR
  - Keyboards, mice, joysticks, pen, touch screens, etc.
- Tracking
  - Position and orientation of body parts or controllers
- Sensorimotor mapping (remapping)
  - Produces different results in the virtual world
  - E.g., press a button to open a door in VR

3DConnexion SpaceMouseCompact

Sensorimotor Relationship

- Using feedback from sensors

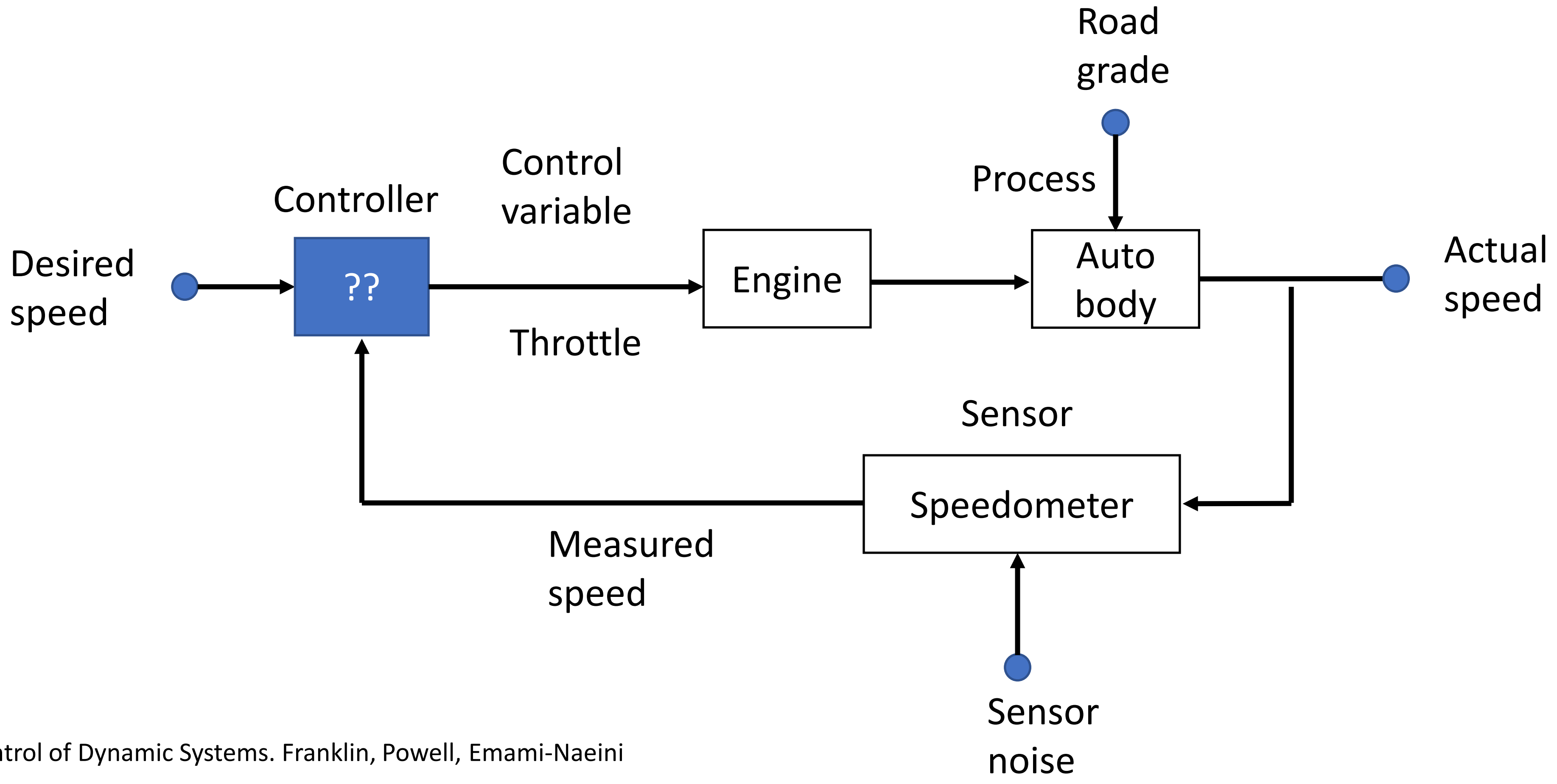
- Feedback control



Closed-loop

Feedback Control Basics

- Cruise Control of an automobile

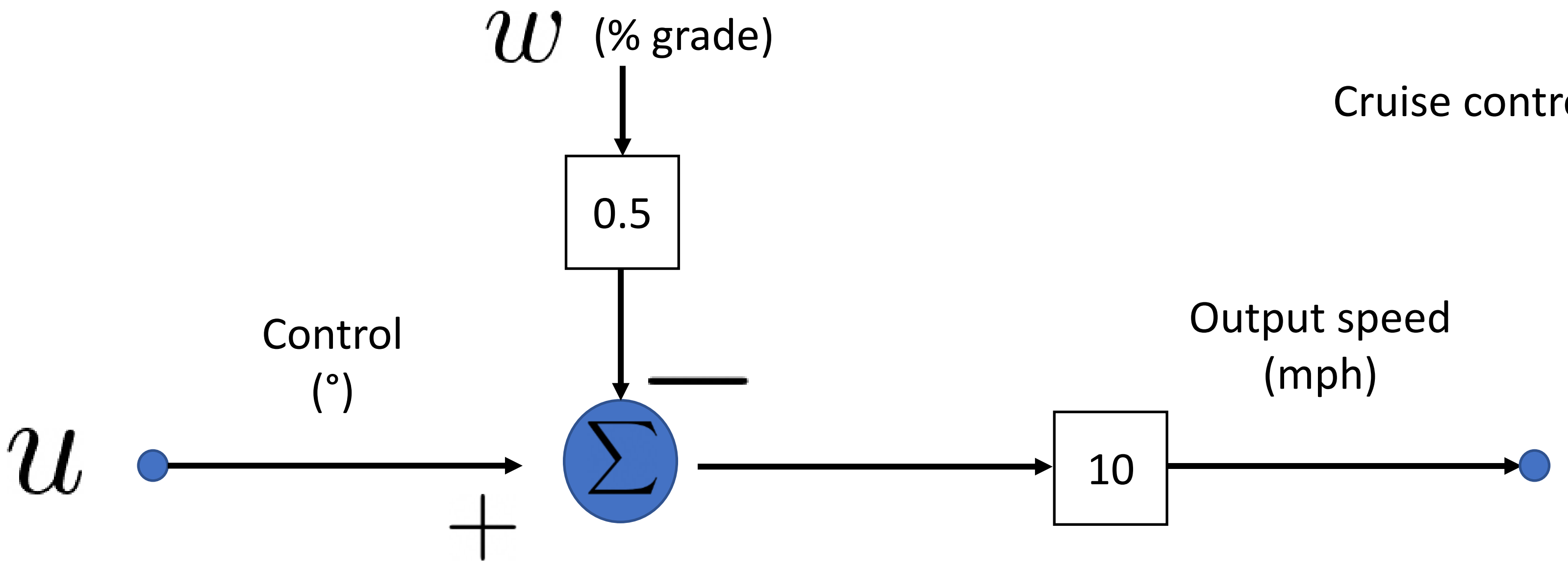


Feedback Control of Dynamic Systems. Franklin, Powell, Emami-Naeini

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

Cruise control plant



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

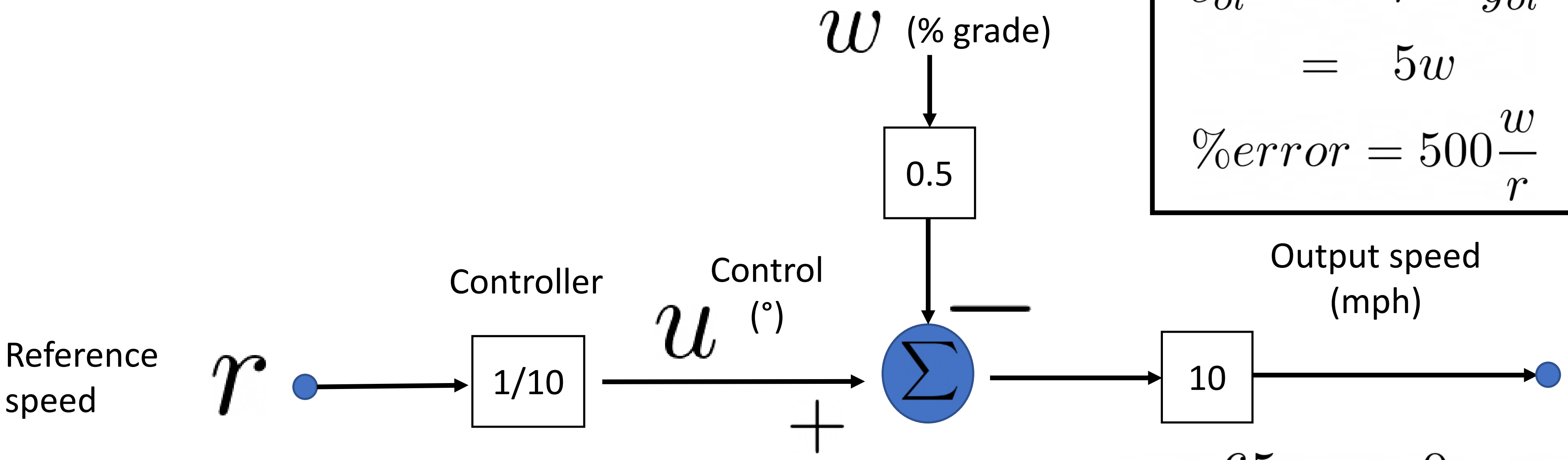
Feedback Control Basics

- Open-loop cruise control

$$
\begin{aligned}
y_{ol} &= 10(u - 0.5w) \\
&= 10(\frac{r}{10} - 0.5w) \\
&= r - 5w
\end{aligned}
$$

$$
\begin{aligned}
e_{ol} &= r - y_{ol} \\
&= 5w
\end{aligned}
$$

$$\%error = 500\frac{w}{r}$$



$$u = r/10$$

$$r = 65, w = 0, y_{ol} = 65$$

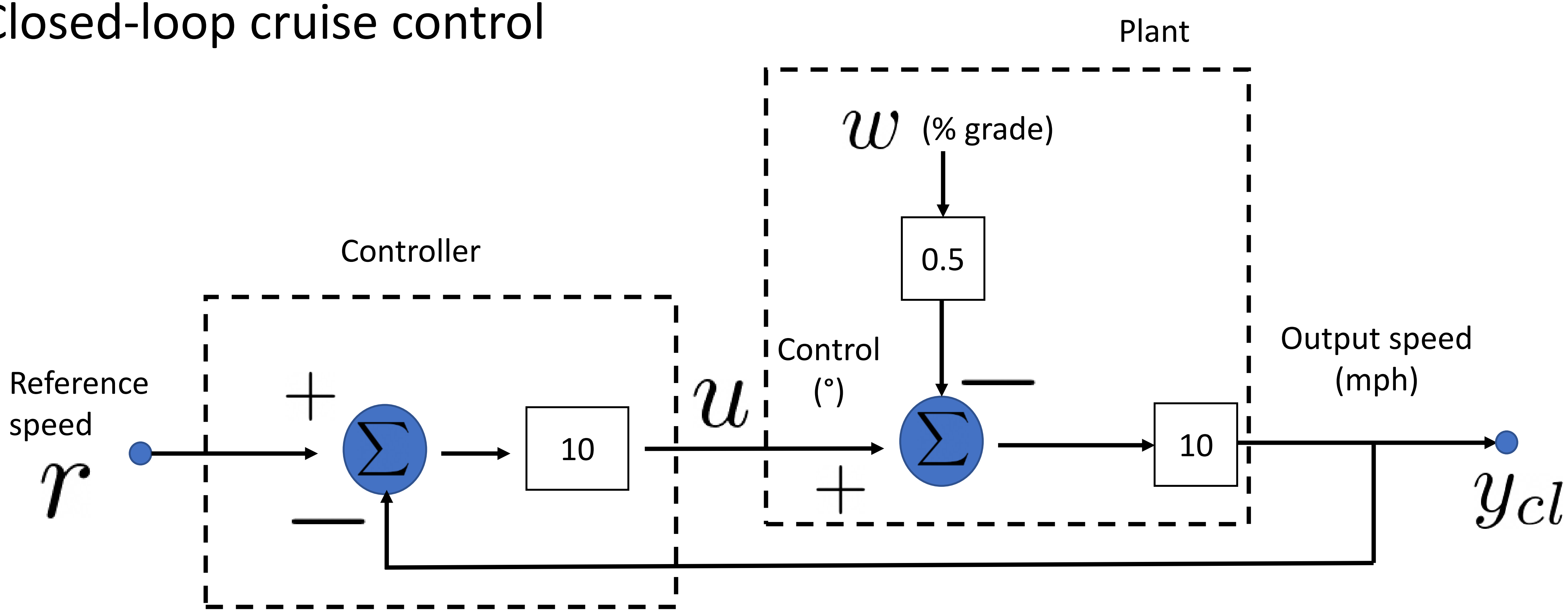
$$r = 65, w = 1, y_{ol} = 60$$

$$r = 65, w = 2, y_{ol} = 55$$

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

Feedback Control Basics

- Closed-loop cruise control



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

Feedback Control Basics

- Closed-loop cruise control

$$y_{cl} = 10u - 5w$$
$$u = 10(r - y_{cl})$$

$$y_{cl} = 100r - 100y_{cl} - 5w$$
$$101y_{cl} = 100r - 5w$$
$$y_{cl} = \frac{100}{101}r - \frac{5}{101}w$$
$$e_{cl} = \frac{r}{101} + \frac{5w}{101}$$
$$e_{ol} = 5w$$

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

Further Reading

- Section 10.1, Virtual Reality, Steven LaValle
- Feedback Control of Dynamic Systems. Franklin, Powell, Emami-Naeini