Spring 2020

控制系統
Control Systems

Unit 14
Motivating Example of Feedback and Control

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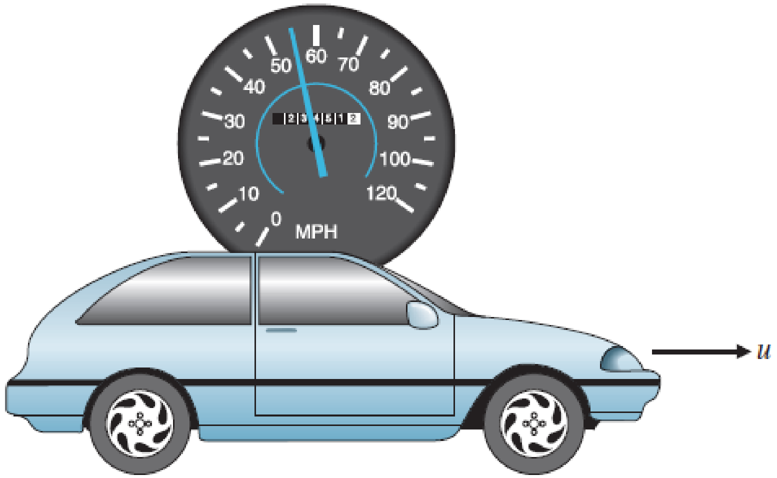
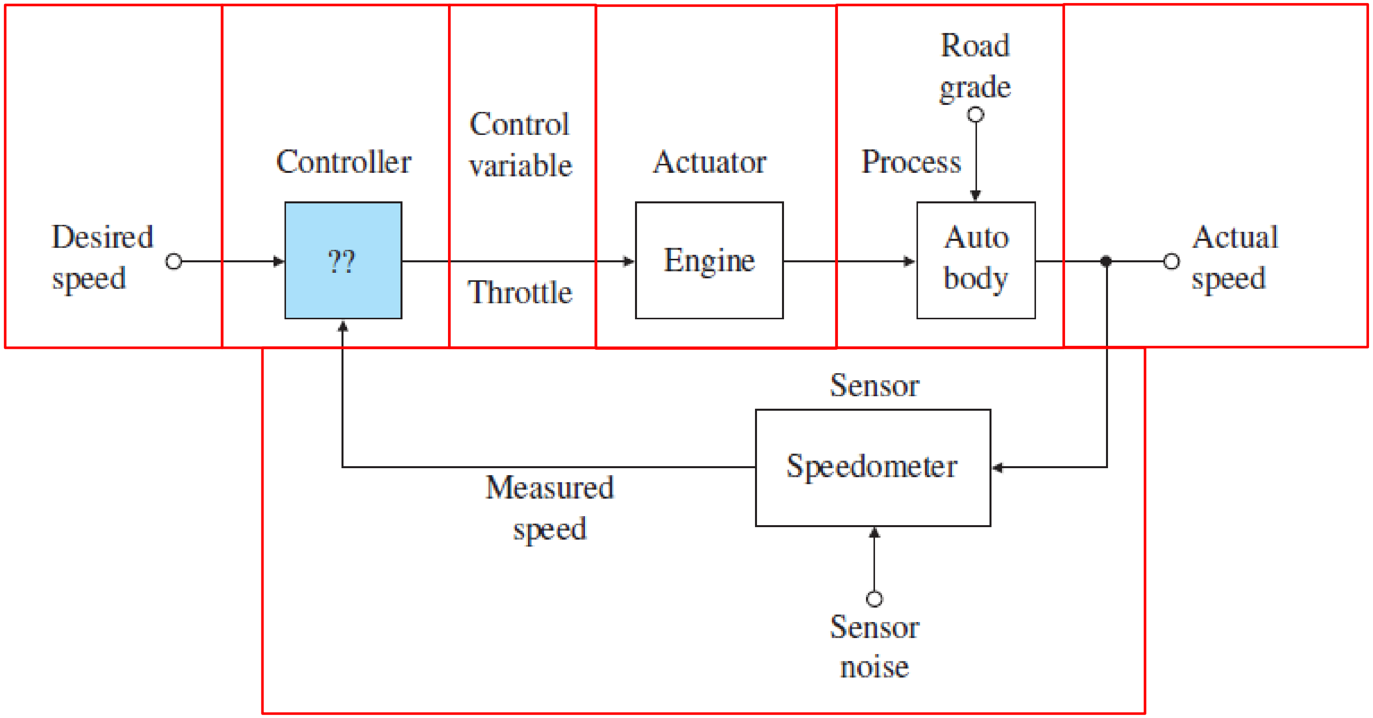
Motivating Example: Cruise Control of An Automobile





Motivating Example: Cruise Control of An Automobile

- On level road, at 65 mph,

  throttle angle = +1 (deg) ---> speed = +10 mph

- Driving up or down hills,

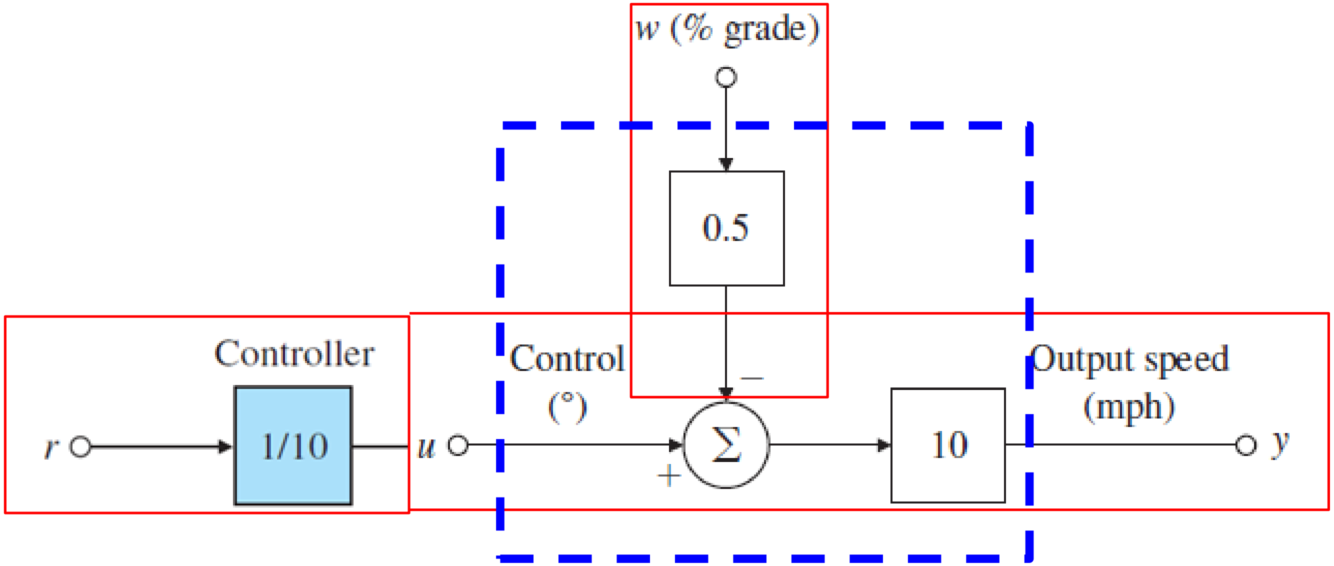
  grade = +1% ---> speed = -5 mph

- **Mathematical Model** & **Block Diagram** (Signal & System):

$$y = 10\,u$$

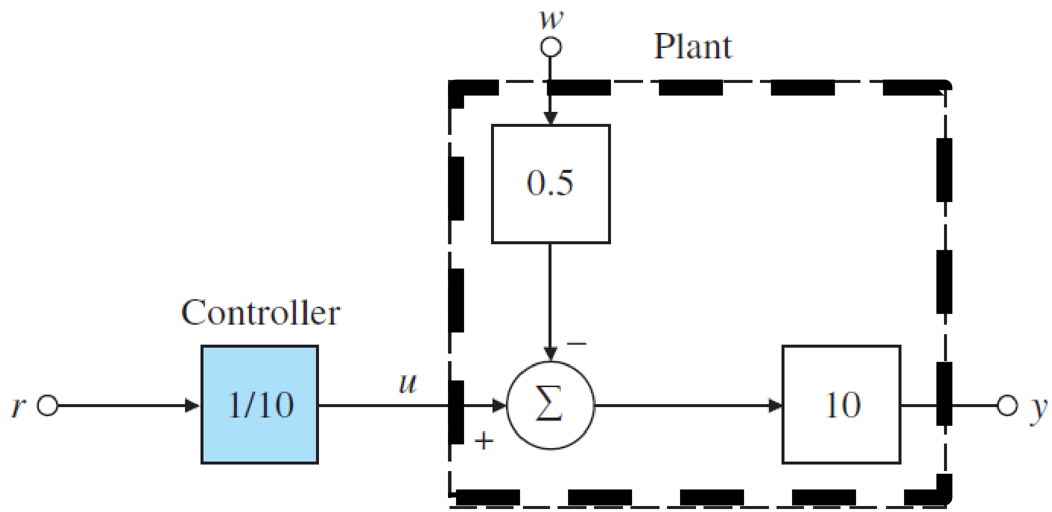
$$u = \frac{1}{10}\,r$$

$$y = r$$



Motivating Example: Cruise Control of An Automobile

- Open-Loop



$$y_{ol} = 10\,(\,u - 0.5\,w\,)$$

$$= 10\,(\,\frac{1}{10}\,r - 0.5\,w\,)$$

$$= r - 5\,w$$

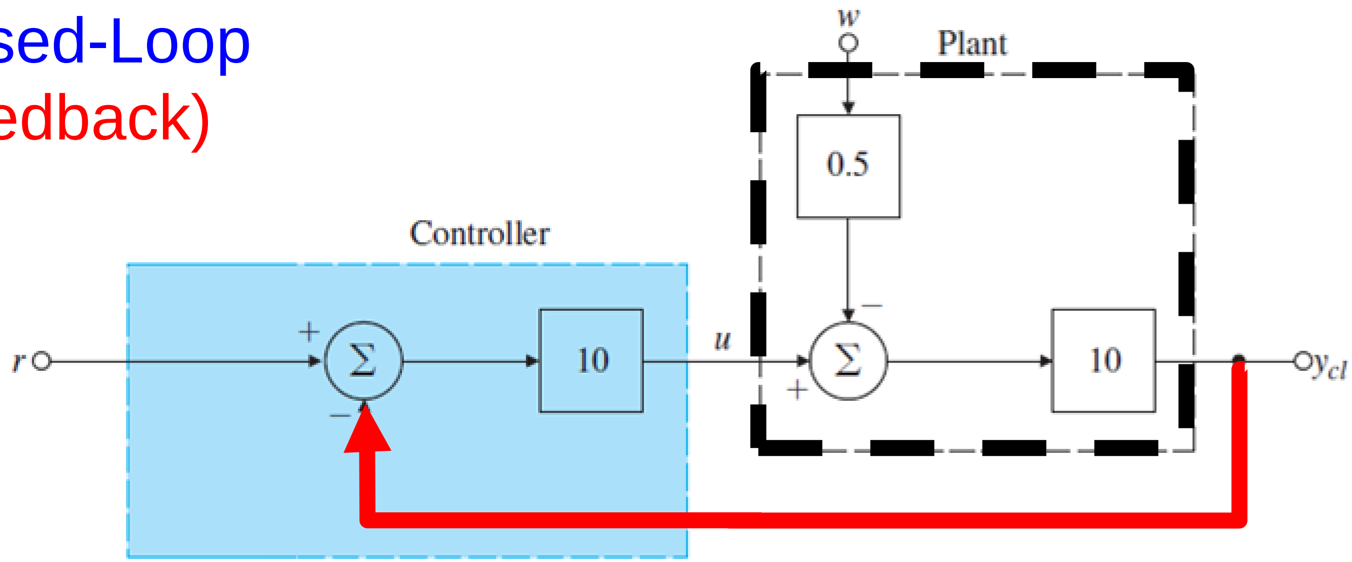
$$e_{ol} = r - y_{ol}$$

$$= 5\,w$$

$$\%\ \text{error} = \frac{5\,w}{r} \times 100$$

r = 65 w	error	% error	
0	0	0	
1	5	7.69%	
2	10	15.38%	

- Closed-Loop (Feedback)



$$u = 10\,(\,r - y_{cl}\,)$$

$$y_{cl} = 10\,(\,u - 0.5\,w\,)$$

$$= 100\,r - 100\,y_{cl} - 5\,w$$

$$e_{cl} = r - y_{cl}$$

$$101\,y_{cl} = 100\,r - 5\,w$$

$$= \frac{1}{101}\,r + \frac{5}{101}\,w$$

$$y_{cl} = \frac{100}{101}\,r - \frac{5}{101}\,w$$

$$\%\ \text{error} = \frac{100}{101} + \frac{500\,w}{101\,r}$$

Motivating Example: Cruise Control of An Automobile

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

$$e_{cl} = \frac{1}{101} r + \frac{5}{101} w$$

$$\% \text{ error} = \frac{100}{101} + \frac{500\, w}{101\, r}$$

- w = 0, $y_{cl} = \frac{100}{101} r$

  $e_{cl} = \frac{1}{101} r$ % error $\approx 1\%$

- w = 1, $y_{cl} = \frac{100}{101} 65 - \frac{5}{101} 1$

  $e_{cl} = \frac{1}{101} 65 + \frac{5}{101} 1$

  $\% \text{ error} = \frac{100}{101} + \frac{500 \times 1}{101 \times 65} = 0.99 + 0.0762 = 1.0662$

- w = 2, $y_{cl} = \frac{100}{101} 65 - \frac{5}{101} 2$

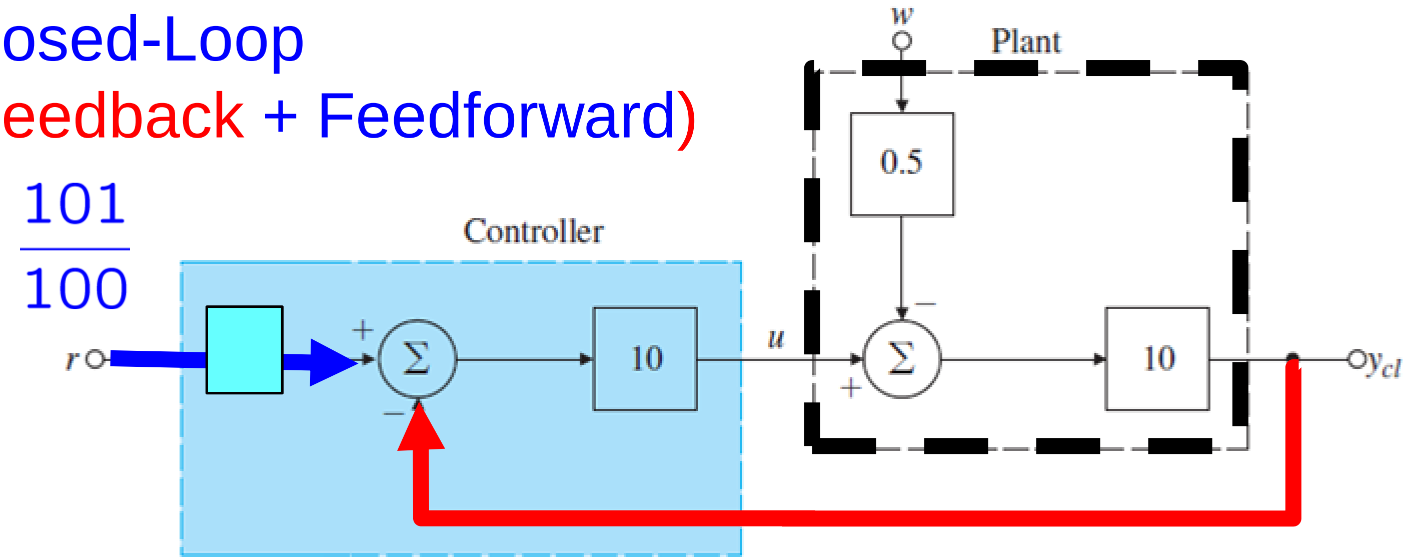
  $e_{cl} = \frac{1}{101} 65 + \frac{5}{101} 2$

  $\% \text{ error} = \frac{100}{101} + \frac{500 \times 2}{101 \times 65} = 0.99 + 0.1523 = 1.0423$

r = 65 w	error Open	% error Open	
0	0	0	
1	5	7.69%	
2	10	15.38%	

Motivating Example: Cruise Control of An Automobile

- Closed-Loop (Feedback + Feedforward)



$$u = 10\left(\frac{101}{100} r - y_{cl}\right)$$

$$y_{cl} = 10\,(u - 0.5\,w)$$

$$= 101\,r - 100\,y_{cl} - 5\,w$$

$$101\,y_{cl} = 101\,r - 5\,w$$

$$y_{cl} = r - \frac{5}{101} w$$

$$e_{cl} = r - y_{cl}$$

$$= \frac{5}{101} w$$

$$\%\ \text{error} = \frac{500\,w}{101\,r}$$

Motivating Example: Cruise Control of An Automobile

$$y_{cl} = r - \frac{5}{101} w$$

$$e_{cl} = \frac{5}{101} w$$

$$\% \text{ error} = \frac{500\, w}{101\, r}$$

- w = 0, $y_{cl} = r$

$$e_{cl} = 0 \qquad \% \text{ error} = 0\%$$

- w = 1, $y_{cl} = 65 - \frac{5}{101} 1$

$$e_{cl} = \frac{5}{101} 1$$

$$\% \text{ error} = \frac{500 \times 1}{101 \times 65} = 0.0762$$

- w = 2, $y_{cl} = 65 - \frac{5}{101} 2$

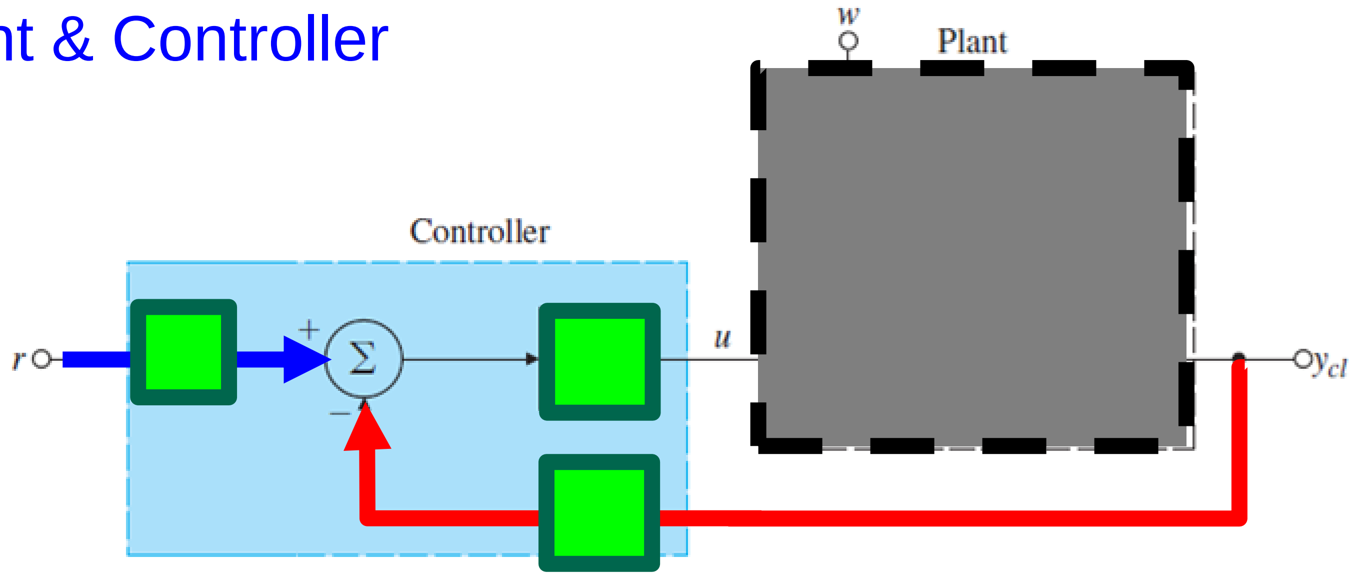
$$e_{cl} = \frac{5}{101} 2$$

$$\% \text{ error} = \frac{500 \times 2}{101 \times 65} = 0.1523$$

r = 65 **w**	**error** **Open**	**% error** **Open**	
0	0	0	
1	5	7.69%	
2	10	15.38%	

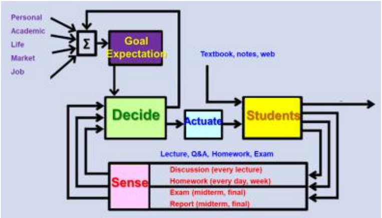
Motivating Example: Cruise Control of An Automobile

- Plant & Controller

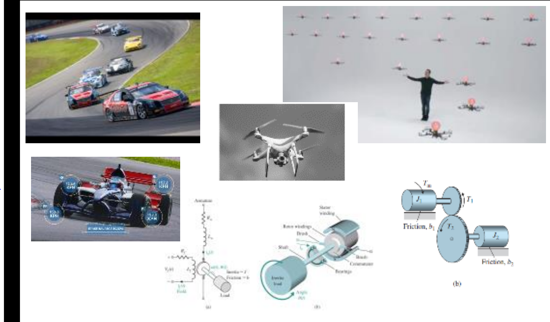


r = 65 w	error Open	% error Open	% error Closed (Feedback)	% error Feedback+Feedforward
0	0	0	0.99%	0%
1	5	7.69%	1.0662%	0.0762%
2	10	15.38%	1.0423%	0.1523%

Plant, Input, Output, Action, Goal



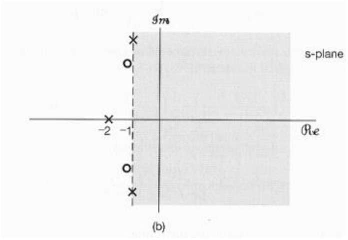
Plant (P)

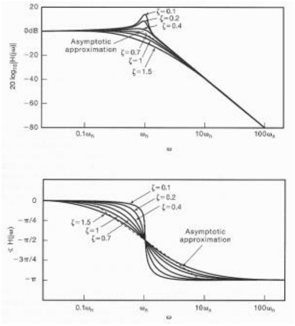


Ref (r) **Input (u)** **Output (y)**

$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} - 3\,y(t) = 5\,u(t)$$

$$P(s) = \frac{Y(s)}{U(s)} = \frac{5}{s^2 + 2s - 3}$$





1. Model
2. Response
3. Analysis
4. Feedback
5. Control

Controller

$$\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 3\,y(t) = 3\,r(t)$$

$$G(s) = \frac{Y(s)}{R(s)} = \frac{3}{s^2 + 4s + 3}$$