A Simple Introduction to Embedded Control Systems (PID Control)

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Acknowledgements

- The material in this lecture is adapted from:
  - F. Vahid and T. Givargis, **Embedded System Design—A Unified Hardware/Software Introduction**, John Wiley & Sons, 2002 (Chapter 9)
  - T. Wescott, "PID Without a PhD"
    - http://www.embedded.com/2000/0010/0010feat3.htm

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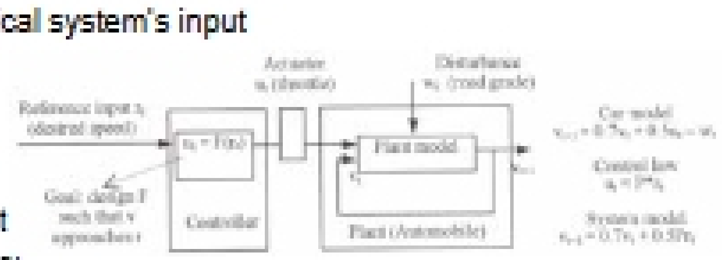
Control System

- Control physical system's output
  - By setting physical system's input
- Tracking
- E.g.
  - Cruise control
  - Thermostat cont
  - Disk drive contro
  - Aircraft altitude control
  - Chemical processes
- Difficulty due to
  - Disturbance: wind, road, tire, brake; opening/closing door…
  - Human interface: feel good, feel right…



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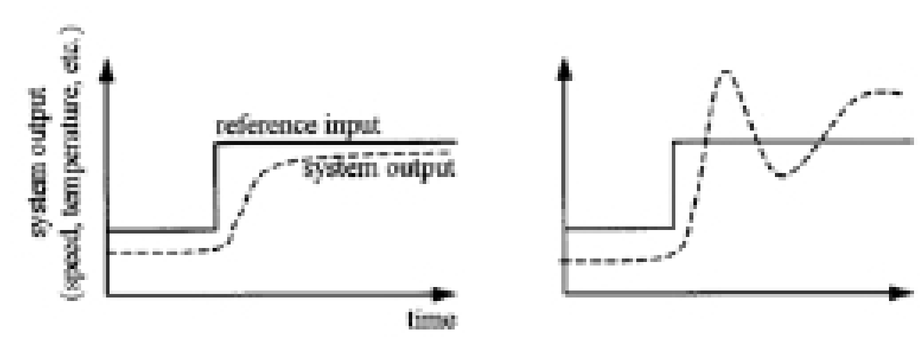
Tracking



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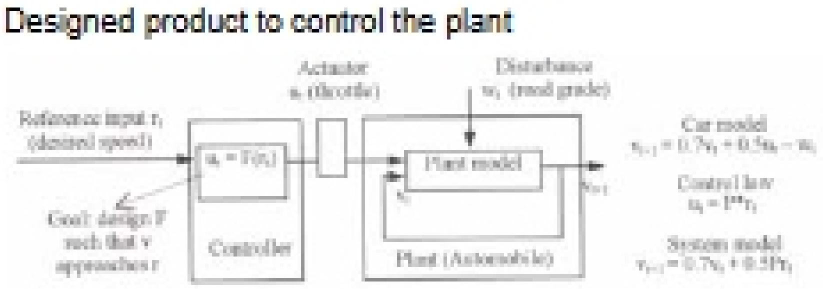
Open-Loop Control Systems

- Plant
  - Physical system to be controlled
    - Car, plane, disk, heater,…
- Actuator
  - Device to control the plant
    - Throttle, wing flap, disk motor,…
- Controller
  - Designed product to control the plant



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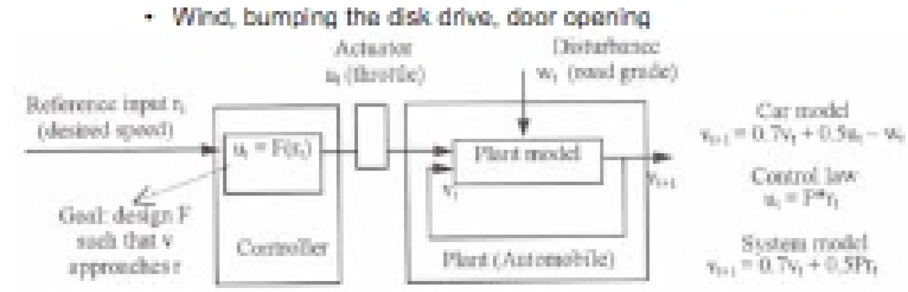
Open-Loop Control Systems

- Output
  - The aspect of the physical system we are interested in
    - Speed, disk location, temperature
- Reference
  - The value we want to see at output
    - Desired speed, desired location, desired temperature
- Disturbance
  - Uncontrollable input to the plant imposed by environment
    - Wind, bumping the disk drive, door opening



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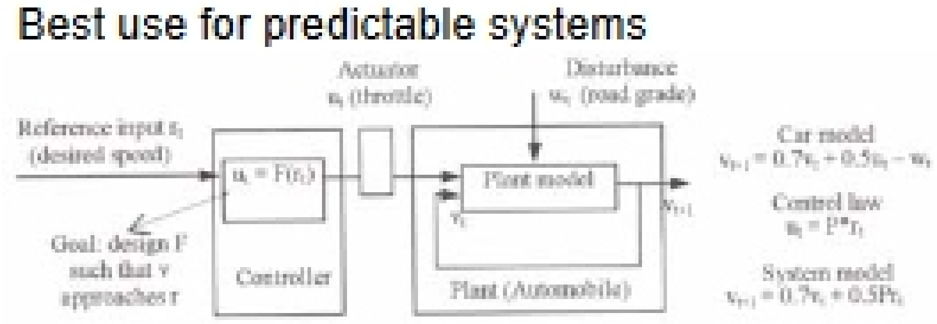
Other Characteristics of open loop

- Feed-forward control
- Delay in actual change of the output
- Controller doesn't know how well thing goes
- Simple
- Best use for predictable systems



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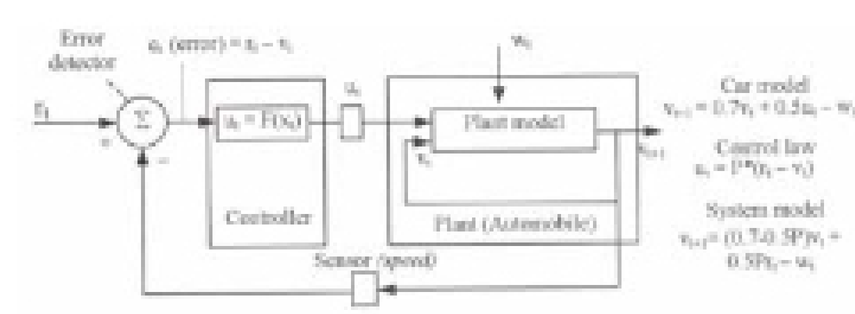
Closed Loop Control Systems

- Sensor
  - Measure the plant output
- Error detector
  - Detect Error
- Feedback control systems
- Minimize tracking error



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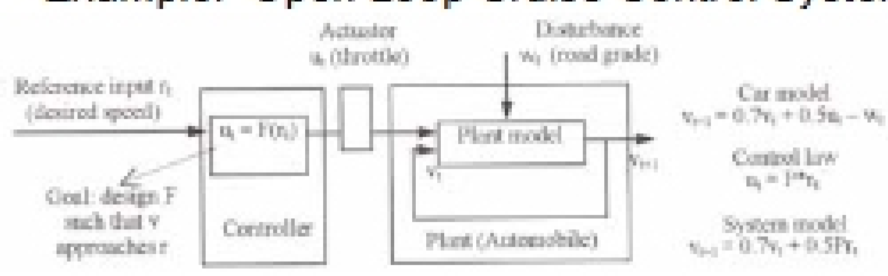
Designing Open Loop Control System

- Develop a model of the plant
- Develop a controller
- Analyze the controller
- Consider Disturbance
- Determine Performance
- Example: Open Loop Cruise Control System



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Model of the Plant

- May not be necessary
  - Can be done through experimenting and tuning
- But,
  - Can make it easier to design
  - May be useful for deriving the controller
- Example: throttle that goes from 0 to 45 degree
  - On flat surface at 50 mph, open the throttle to 40 degrees
  - Wait 1 "time unit"
  - Measure the speed, let's say 55 mph
  - Then the following equation satisfies the above scenario
    - $v_{t+1}=0.7*v_t+0.5*u_t$
    - $55 = 0.7*50+0.5*40$
  - IF the equation holds for all other scenarios
    - Then we have a model of the plant

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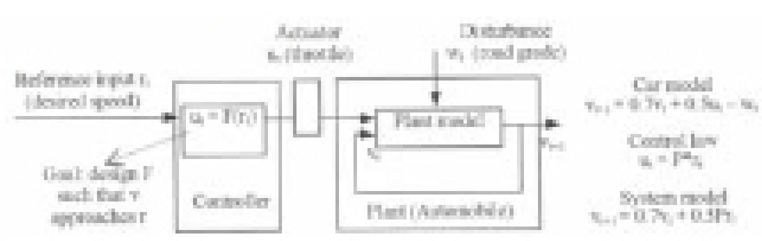
Designing the Controller

- Assuming we want to use a simple linear function
  - $u_t=F(r_t)= P * r_t$
  - r_t is the desired speed
- Linear proportional controller
- $v_{t+1}=0.7*v_t+0.5*u_t = 0.7*v_t+0.5P*r_t$
- Let $v_{t+1}=v_t$ at steady state $= v_{ss}$
- $v_{ss}=0.7*v_{ss}+0.5P*r_t$
- At steady state, we want $v_{ss}=r_t$
- P=0.6
  - I.e. $u_t=0.6*r_t$



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Analyzing the Controller

- Let v_0=20mph, r_0=50mph
- $v_{t+1}=0.7*v_t+0.5(0.6)*r_t$
  $=0.7*v_t+0.3*50= 0.7*v_t+15$
- Throttle position is 0.6*50=30 degrees

Time (t)	v_t
0	20.00
1	29.00
2	35.30
3	39.71
4	42.80
5	44.96
6	46.47
7	47.53
8	48.27
9	48.79
10	49.15
11	49.41
12	49.58

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