ENGSCI 332

- Note: 6 lectures – only an introduction to control systems
- Aim is to provide an understanding of control systems concepts and terminology, and to introduce some of the mathematical and design tools.
- Objectives:
  - Understand basic control system concepts
  - Express a system as block diagram or transfer function
  - Understand Laplace transform and frequency domain representations
  - Manipulate transfer function – e.g. poles and zeros
  - Obtain the Bode frequency plot (gain and phase) of simple system
  - Understand controller requirements – errors, stability, step response
  - Understand relationship between step response and frequency function
  - Simple design rules for PID controllers and approaches to feedback design from Bode plot and transfer function.

Outline

1. Introduction to control systems – why and what
2. Techniques for modelling signals and systems
   - Block diagrams / signal flow
   - Differential equations and Laplace transforms
3. Basic control systems – concepts and terminology
   - Open-loop and closed-loop transfer functions / poles and zeros
   - PID controller and design
4. Analysis of control systems
   - Frequency analysis – Bode plot
5. Design of feedback control
   - Design goals – stability / accuracy / response / sensitivity
   - Step response and transfer function
6. Practical design methods
   - Frequency compensation / pole assignment

Resources

Textbooks

"Control System Design", Goodwin, Graebe, Salgado. Prentice Hall, 2001.

"Linear System Theory and Design", Chen. Prentice Hall 1998.

“Analog & Digital Control System Design”, Chen, Saunders 1993

“Feedback and Control Systems” Di Stefano, Stubberud, Williams. Schaum’s Outline Series, 1967-

Web

Control Tutorials for Matlab – http://www.engin.umich.edu/group/ctm/

Control System Design (web site) - http://csd.newcastle.edu.au/control/

ENGSCI 332
Control Systems

Lecture 1

William Thorpe

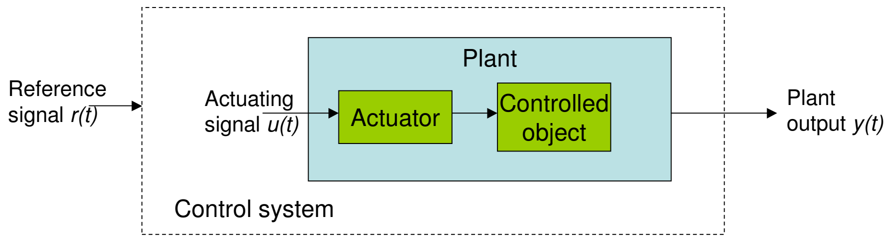
Why control systems?

- How do you make a machine do what you want – precisely?
- How does a machine maintain a steady (speed/force) when the load keeps changing?
- Not just machines – what about physiology?
  - How does our body maintain blood pressure, temperature, etc?
  - How can we exert precise muscular effort to perform some task?

Control system examples

- Speed control or "governor"
  - ie maintain constant speed despite changing loads
    - Cruise control in a car
    - (Rotational) speed control on industrial plant
- Position control
  - ie set precise position despite changing demands and loads
    - Power steering in car
    - Aiming at a target (eg satellite dish)
- Trajectory tracking
  - ie follow a moving target
    - Satellite/aircraft tracking station
    - "robot hand" – matching movement of operator's hand
- Temperature/process "state" control
  - eg maintain temperature or pressure at desired set point

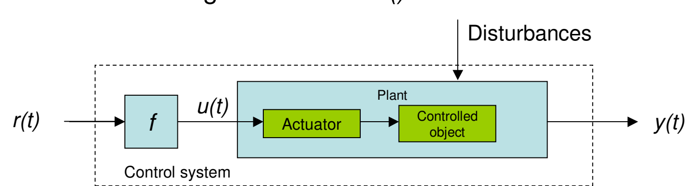
Control system terminology



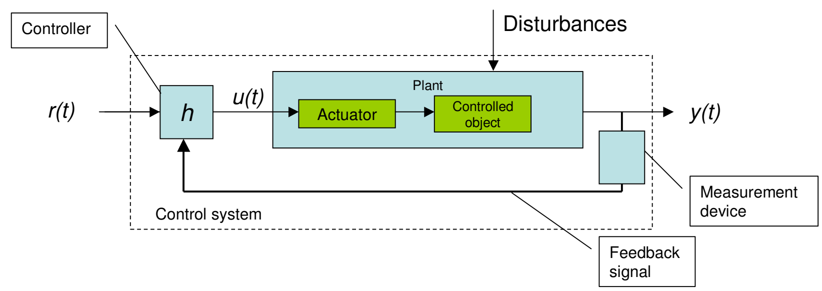
- Problem of control system design is how to adjust Actuating signal in order to make plant output match the desired reference signal.

Open-loop control

- Simplest control strategy is to set actuator according to input reference
  - ie $u(t) = f(r(t))$
    where $f()$ is function of input only
  - eg set throttle on the lawnmower; or turn on the heater
- But what will output be?
  - eg load may change – disturbances to system
  - house may get warm(er) – don't know when to change actuator
  - Would be good if form of $f()$ had some constraints



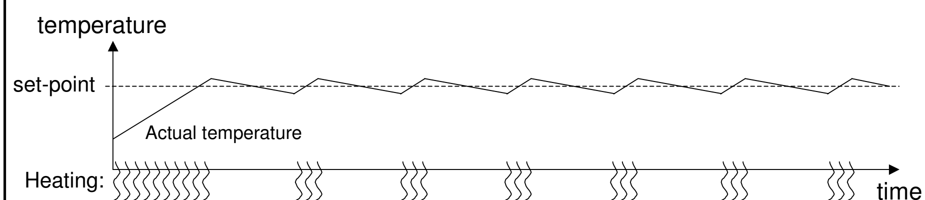
Closed-loop control



- By *measuring* the plant output, can automatically adjust actuator signal so that desired reference is matched
- Actuator signal then depends on both input reference and *feedback* of actual output
  $u(t) = h(\, r(t), y(t) \,)$
  - $u(t)$ determines how well $y(t)$ matches or tracks $r(t)$.

Control System example

- "on-off" control – eg temperature, pressure, tank level
  - May be desirable for actuator or controlling device to be either ON or OFF
  - Have desired temperature – reference input
  - Measure actual temperature – "plant" output
  - Switch ON or OFF depending on whether output is above or below input
  - In general, output won't be constant
  - May need some hysteresis in switching levels



Control system examples

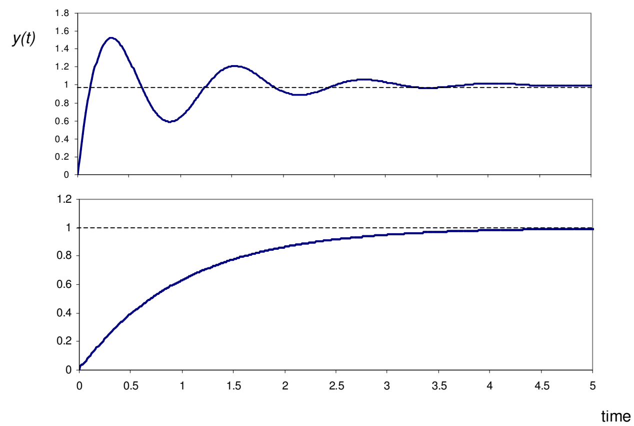
- "Proportional" engine speed governor
  - Eg. Watt's flyball governor
  - Reference input (eg control knob) determines the set point
  - Plant output is the actual speed
  - Speed is determined by
    - Input power (eg voltage, fuel, steam, water pressure)
    - Load (eg electricity demand, weight lifted, material quantity)
  - Actuator (throttle/valve) is gradually closed off as speed increases, and opened if speed reduces
  - May be error in controlled speed
    - ie if throttle is proportional to speed, speed must change in order for throttle to change.

Control system requirements

- Want to minimise error $e(t) = y(t) – r(t)$
  - But what happens when $r(t)$ is time-varying?
  - Error minimisation may occur over some time
- Want to quickly reach desired output
  - How fast is fast enough?
- Want to avoid "overshooting" the target
  - May be trade-off between speed of response and overshooting
- Want stability
  - Eg how much "cycling" of output can be tolerated?

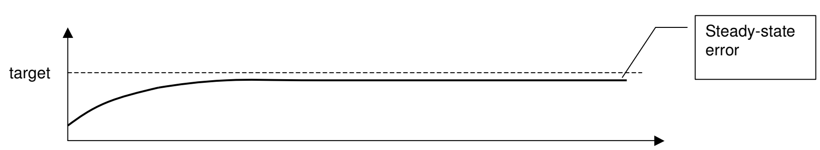
Concepts – step response

- How quickly does output reach input?
- Does it overshoot?

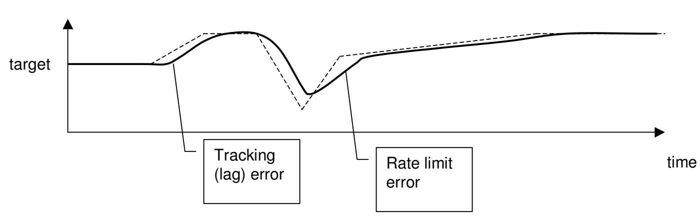


Concepts – tracking error

- Does it match desired level exactly?



- Does it match changing level?



Summary

- Want to control some machine or other system
- Need to know what system is doing in order to make appropriate adjustments to input – *feedback*
- The *problem* of control systems is to design feedback controller such that overall system:
  - Provides desired outcome – accuracy
  - Responds to changes – response time
  - Is stable in all situations – stability

- Goodwin, Graebe, Salgado: Chapter 1