Linear System Theory and Design

Text : Linear System Theory and Design,
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Oxford, 3rd Ed.

Evaluation: Homework 30%, Midterm 30%, Final 30%
Attitude 10%,
F for 3 times absence w/o pre-notice

1. Introduction

- ✓ Definition of System
- ✓ Examples of System
- ✓ Linear and Nonlinear System
- ✓ Why study Linear System
- ✓ System Design Procedure
- ✓ Related Courses
- ✓ Scope of the Lecture

Definition of System

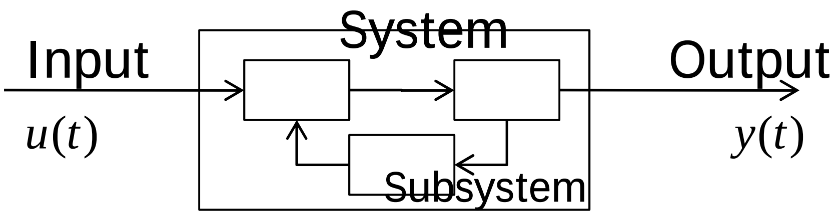
Definition(Webster)**: System** is defined as a collection of objects united by some form of interaction or interdependence.

Static System

$$y(t) = f\,(u(t))$$

Dynamic System (RLC, Spring-Damper system)

$$y^{(n)}(t) = f\,(y^{(n)}(t), y^{(n-1)}(t), ..., y(t), u^{(n)}(t), u^{(n-1)}(t), ..., u(t))$$



Example of System

- ✓ Communication systems
- ✓ Circuits & Systems
- ✓ Control systems
- ✓ Power systems
- ✓ Automotive systems
- ✓ Surveillance systems
- ✓ Human (neural systems)
- ✓ Ocular motor systems
- ✓ Economic systems
- ✓ Biological systems
- ✓ Chaotic systems
- ✓ Etc. ...

Linear and Nonlinear Systems

- ✓ Linear systems
  - Satisfy "Principle of Superposition"

    Additivity: $f(u_1+u_2) = f(u_1) + f(u_2)$

    Homogeneity: $f(\alpha u) = \alpha f(u)$
  - Category: stable, unstable systems

- ✓ Nonlinear Systems
  - Does not Satisfy "Principle of Superposition"
  - Category: stable, unstable, periodic, chaotic systems
  - Most real world systems

    Pendulum: $\ddot{x} + \sigma \dot{x} + g \sin x = a + b \cos \omega t$

    Logistic map (Ecosystem): $x_{n+1} = a x_n (1 - x_n)$

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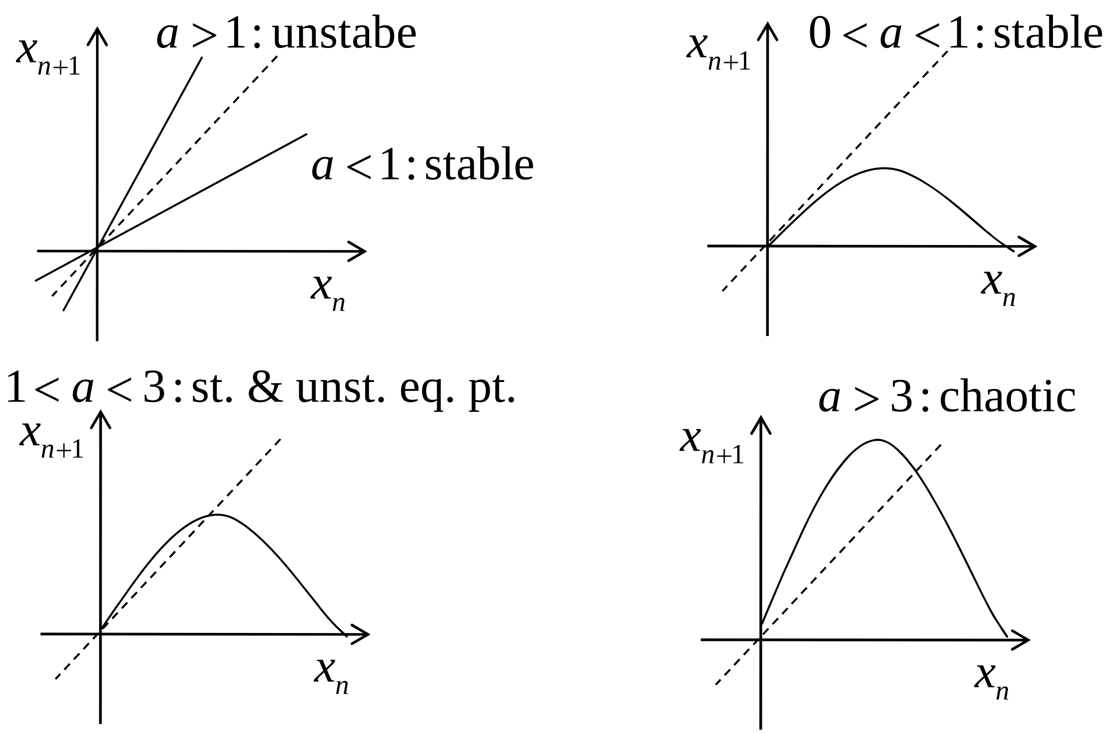
Linear and Nonlinear Systems

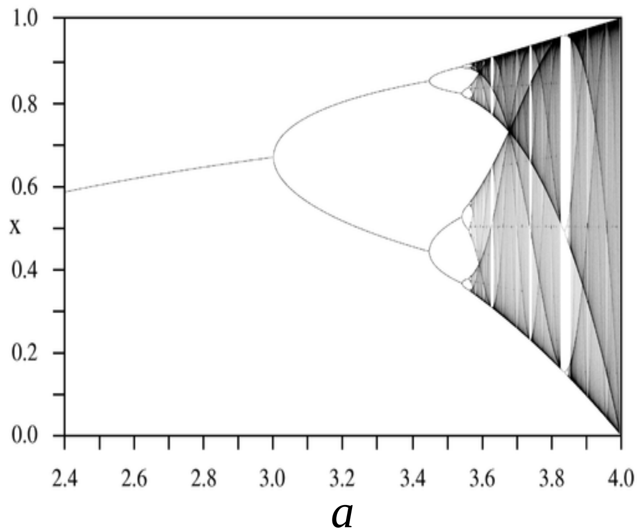
Ecosystem: $x_{n+1} = ax_n(1-x_n)$

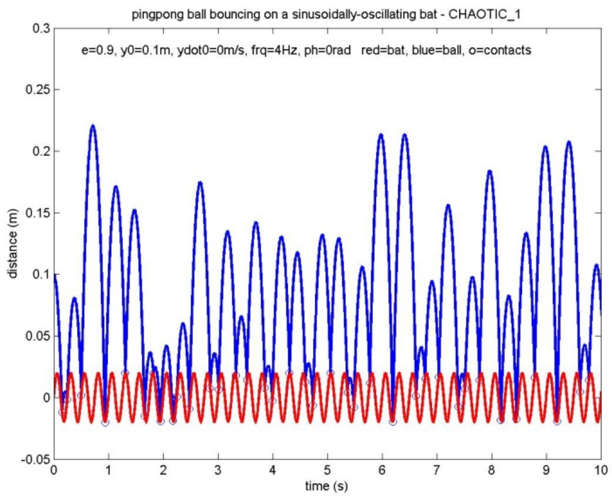
Linear system: $x_{n+1} = ax_n$



Linear and Nonlinear Systems

Ecosystem: $x_{n+1} = ax_n(1 - x_n)$





Why study Linear Systems

- ✓ Many physical systems can be modelled by linear systems over their normal operating ranges
- ✓ The theory of linear systems is complete and well organized
- ✓ The theory is the basis for the study of nonlinear systems

(Control) System Design Procedure

- ✓ Modelling
- ✓ Setting up mathematical description
- ✓ Analysis
- ✓ Design

(Control) System Design Procedure

- ✓ Modelling
  - Determine the model order, structure, parameters ...
  - Nonlinear or linear systems
- ✓ Setting up mathematical description
- ✓ Analysis
- ✓ Design

(Control) System Design Procedure

- ✓ Modelling
- ✓ Setting up mathematical description
  - Difference or differential equations
  - Impulse functions (convolution integral equations)
  - Transfer functions
  - State space descriptions
- ✓ Analysis
- ✓ Design

(Control) System Design Procedure

- ✓ Modelling
- ✓ Setting up mathematical description

- ✓ Analysis
  - Quantitative analysis
    - Time response(rising time, settling time, overshoot, ss error …)
    - Frequency response(bandwidth, phase …)
  - Qualitative analysis
    - Stability, controllability, observability, stablizability

- ✓ Design

(Control) System Design Procedure

- ✓ Modelling
- ✓ Setting up mathematical description
- ✓ Analysis
- ✓ Design
  - Improve the system response
    - Time response: rising/settling time, overshoot, ss error ...
    - Frequency response: bandwidth, phase ...
  - Improve the qualitative property
    - Stabilization, robust, gain margin, phase margin
  - Deign techniques
    - State feedback, state estimator (observer, Kalman filter ...)
    - Compensator
    - Optimal/adaptive/nonlinear control

Scope of the Lecture

- ✓ Mathematical descriptions of systems (2 lectures)
- ✓ Linear operator theory for linear system analysis (4 lectures)
- ✓ State space solutions and realizations (2 lectures)
- ✓ Stability (3 lectures)
- ✓ Controllability and observability (4 lectures)
- ✓ Minimal realizations and coprime fractions (4 lectures)
- ✓ State feedback and state estimators (4 lectures)
- ✓ Pole placement and model matching (2 lectures)