Lecture 1.

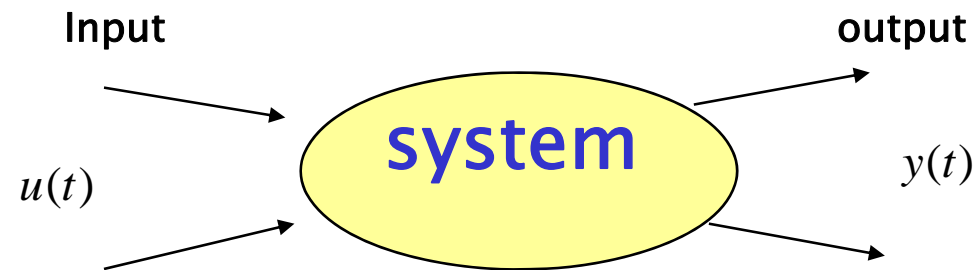# Introduction

Key Concepts

- System : A combination of components acting together

  to perform a specific objective.

- A component : Single functioning unit of a system

  A system is not limited to physical component. It includes

  abstract dynamic phenomena such as economics,

  transportation, populating, biology, etc.

System, Input and Output

Output depends on inputs !

Analysis and Design

- Analysis : the investigation of the performance of a system whose mathematical model is known.

    1. Derive mathematical model.

    2. Parameter variations - a number of solutions.

    3. Interprets and applies the result to the basic task.

- Design : (system design)

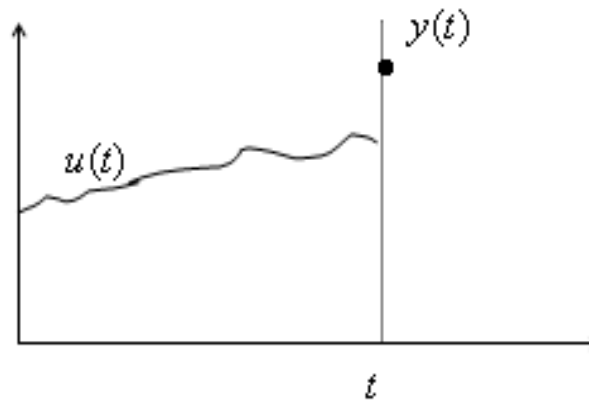   -the process of finding a system that accomplishes a given task.

    Ex)

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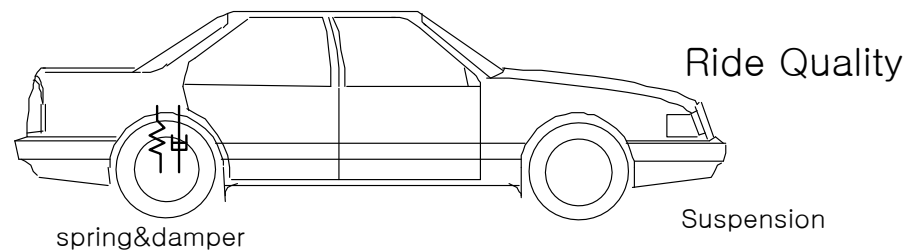
Dynamic Systems, System Dynamics

- Dynamic systems

$$y(t) \quad \text{depends on} \quad \left\{ u(\tau) \,\middle|\, \tau \leq t \right\} \quad \text{(depends on past input)}$$

- Static systems

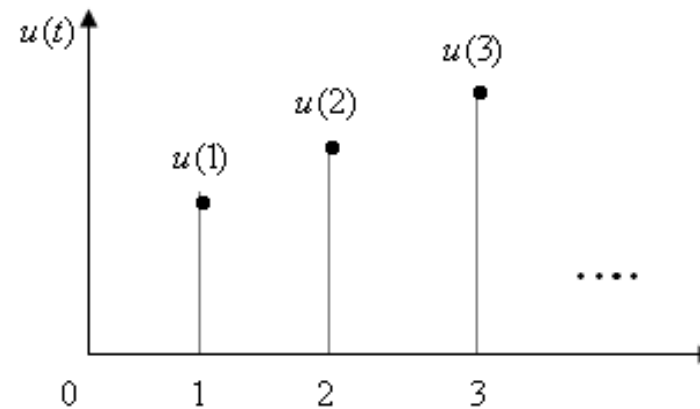$$y(t) \quad \text{depends on} \quad u(t)$$

Static System vs. Dynamic System

Ex) Interest and Balance of a
saving account

1% monthly interest

$u(t)$: monthly payment

$y(t)$: balance

$y(1) = u(1)$

$y(2) = u(1) \times 1.01 + u(2)$

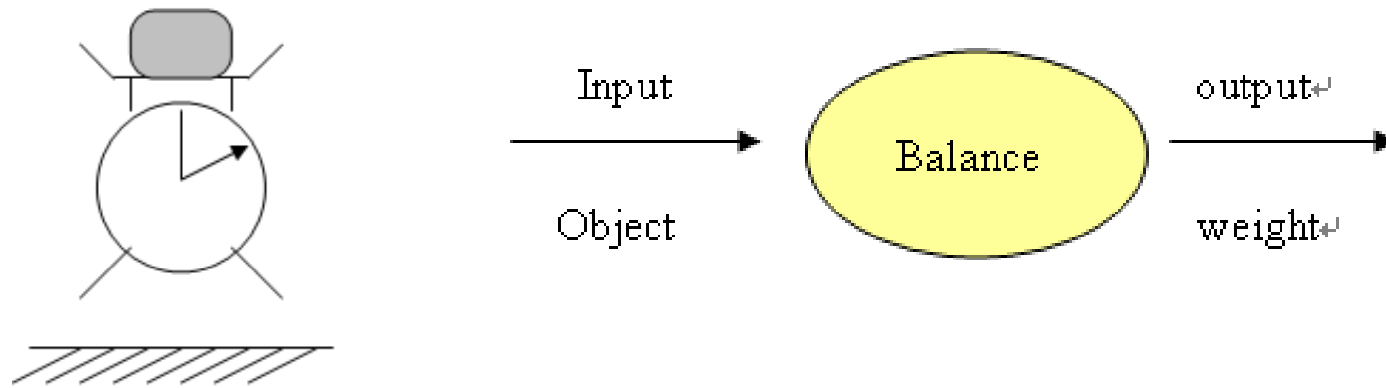$y(3) = y(2) \times 1.01 + u(3) = \{ u(1) \times 1.01 + u(2) \} \times 1.01 + u(3)$

$\vdots$

$y(k) = y(k-1) \times 1.01 + u(k)$

=>   Dynamic System

Static System vs. Dynamic System

Ex) Balance

=>   Static System

Static System vs. Dynamic System

- Static systems : algebraic equations
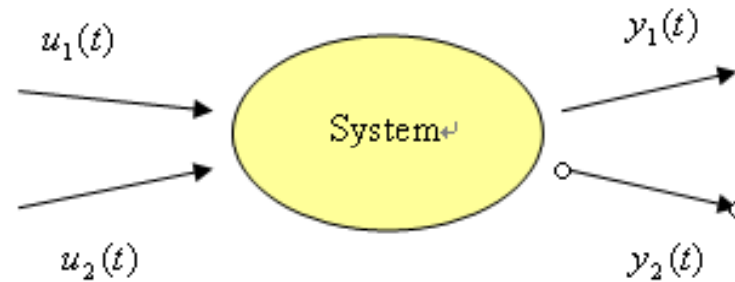
$$y(t) = f(u(t))$$

- Dynamic systems : differential equations or difference equations

$$y(k) = f(y(k-1), u(k-1), k)$$
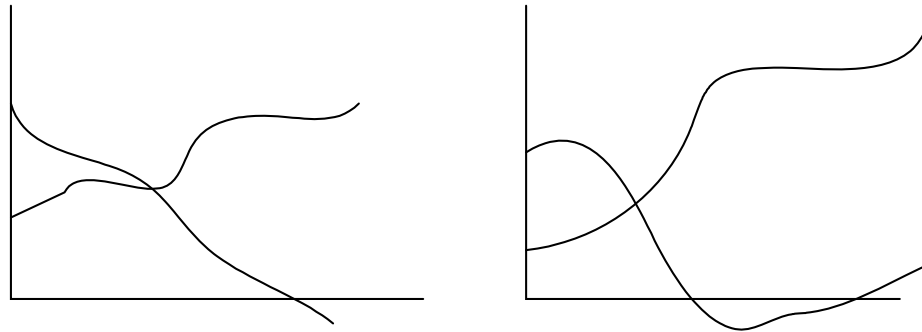
$$\frac{dy}{dt} = f(y, u, t)$$

Linear   vs.   Nonlinear

Linear systems   :   linear superposition principle

Linear system

$$u(t) = \alpha_1 u_1(t) + \alpha_2 u_2(t) \qquad \longrightarrow \qquad y(t) = \alpha_1 y_1(t) + \alpha_2 y_2(t)$$

Mathematical Modeling

- Mathematical model (of Dynamic systems)

    –Differential equations obtained by applying natural laws to the systems.

    –Differential equations that describe the dynamic behavior of the system.

· Modeling methods ;

    1. Analytic: physical laws $\Rightarrow$ mathematical models

    2. Experimental: Experimental results.

        $\Rightarrow$ Input–output relationships. (mathematical models)

- Compromise in modeling process;

    "Simplicity versus Accuracy"

Mathematical Modeling Procedure

1. Draw a schematic diagram of the system and define variables.

2. (Physical laws) Write <u>dynamic equations</u> to obtain a mathematical model

3. (validation) <u>Compare</u> the solution of the equations of the model <u>with experimental result.</u>

4. Modification of the model to obtain a satisfactory agreement <u>between prediction and experimental results.</u>

    · <u>Linear Dynamic Systems</u> $\Rightarrow$ <u>linear D.E</u>

    · <u>Nonlinear Dynamic Systems $\Rightarrow$ Nonlinear D.E</u>

Analysis and Design

- Analysis : the investigation of the performance of a system whose mathematical model is known.

    1. Derive mathematical model.

    2. Parameter variations – a number of solutions.

    3. Interprets and applies the result to the basic task.

- Design : (system design)

    –the process of finding a system that accomplishes a given task.

    Ex)

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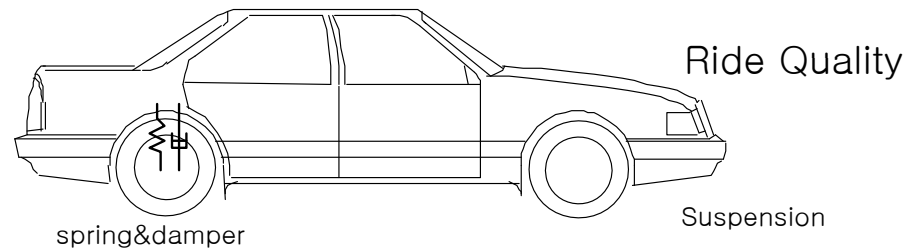
Synthesis

(we mean) The use of *an explicit procedure* to find a system

that will perform in a specific way

    1) system characteristics

    2) use various mathematical techniques

 – completely *mathematical* from the start to the end of the
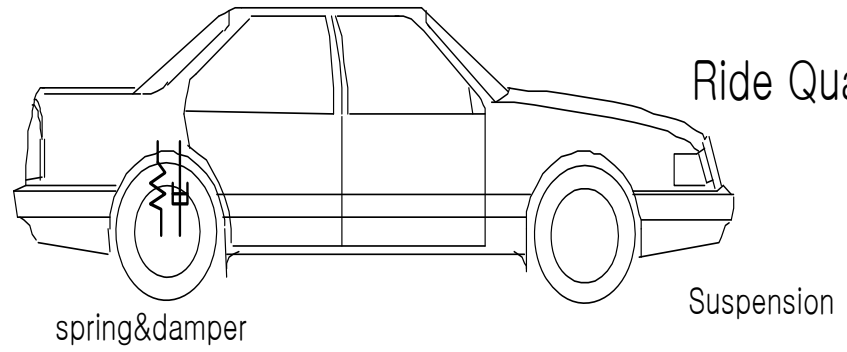design procedure

Design of dynamic systems

- Theoretically, synthesis of linear system is possible
  - Can systematically determine the components necessary to realize the system's objective

- Practically, no synthesis methods are applicable
  - Constraints
  - Nonlinearities
  - Uncertainties

Design procedures

1. Trial-and-error procedures

2. Model-based (analysis and design) procedure

Analysis and Design

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Model-based design procedure