Introduction to System Identification

Basic concepts in System Identification

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Main content of the course

- Purpose of System identification
- Identification methods
- Specific steps for identification

How to study:

- What does the course do?
- What problem is mainly solved?
- What are the methods?
- What are the advantages and disadvantages of each method?
- What is the scope of application of each method?

Status and purpose of system identification

Control thesry classical control theory、modern control theory、intelligent control theory

Classical control applying the time domain method, the root locus method and the frequency domain method to design controller for a plant

Modern control linear system theory、optimal control theory and optimal estimation theory, etc.

intelligent control neural network, expert system and artificial intelligence

The basis of modern control, mainly to solve the model description and basic knowledge of the system. That is, a linear system can generally be described as:

$$\dot{x} = Ax + Bu \tag{1}$$

$$y = Cx + Du \tag{2}$$

Optimal Control Solve how to obtain the optimal input u(t) under the constraint of a certain performance criteria;

Optimal estimation Mainly solve the estimation and prediction of the state variable X

System identification purpose

- Prerequisites for solving the above problem：
  - A, B, C, and D in the model are known.
  - That is, the structure and parameters of the system are known.
  - That is to know the transfer function of the system, or the impulse transfer function, or the difference equation, or the frequency characteristics of the system。
- So how do you get the structure and parameters of the system?
- System identification purpose: How to get the model of the system and its parameters?

System model definition and characteristics

Model definition Part of the essence of the system is reduced to a useful form of description.

Model characteristics

- Multiple model descriptions can be used for the same system;
- The same model can reflect different actual systems;
- Model accuracy and complexity。

model representation

- intuition model
- physical model
- chart model
- mathematical model.

Among them, the chart model is a non-parametric model, and the mathematical model is a parametric model.

mathematical model classification

time domain
- differential equation
- difference equation
- equation of state

Complex domain
- transfer function
- impulse transfer function

frequency domain
- frequency characteristics
- description function

system identification acquires the non-parametric model and parametric model of a system.

non-parametric model
- frequency characteristic curve
- impulse response curve

parametric model
- differential/difference equation
- transfer function
- impulse transfer function

model conversion
- The parametric models can be transformed from each other;
- The non-parametric model can be transformed into a parametric model.

model creation method

- theoretical analysis method
- experimental test method: use the system input and output data to establish a mathematical model of the system.

modeling principles

- The purpose of the model is definite;
- clear physical concept;
- identification is unbiased and consistent;
- conforms to the law of parsimony(Occam's razor). The number of parameters to be identified is small.

System identification definition

- Definition: Based on the system input and output data, determine a model equivalent to the system being tested from a given set of model classes.
- Three elements of system identification: data, model classes and criteria.
  - Data: recorded input/output data, often containing noise;
  - Model class: selected models
  - Criterion: This is the cost function, usually the error criterion.

System Identification General Process

System identification is divided into model structure identification and model parameter identification. The general process is:

- clarifies the purpose of the identified system model;
- pre-select the type of mathematical model of the system to be identified;
- design the experiment for identification, recording I/O data;
- data preprocessing, wild point culling;
- model structure identification, identification system order n;
- select the parameter estimation method to identify other parameters of the system;
- model validation.

The focus of this course: parameter estimation method

System Identification Category

- linear system identification and nonlinear system identification;
- centralized parameter identification and distributed parameter identification;
- system structure identification and system parameter identification;
- classic identification and modern identification;
- open loop system identification and closed loop system identification;
- Offline identification and online identification.

offline identification

- Process: After the system model and order n are selected, record all the I/O data of the system, and then use the parameter estimation method to identify the model parameters of the system.
- Features: The amount of data to be stored is large, the amount of calculation is large, and the recognition accuracy is high. Post-mortem data processing methods cannot be used in real-time control systems.

- process: After the system model and order n are selected, first obtain a small amount of data, estimate the system model parameters, and then obtain new I/O data, and use the recursive correction algorithm to obtain new parameter estimates, and repeat the above process. Until the system stops running.
- Features: Small amount of data, small amount of calculation, and slightly lower recognition accuracy. It is an online data processing method for real-time control systems.

System Identification Error Criteria

Error criteria are usually expressed as functionalities of errors

$$J(\theta) = \Sigma_{k=1}^{N} f(\epsilon(k)) \tag{3}$$

$\epsilon(k)$ is the error between the model and the actual system. It can be output error or input error, or it can be generalized error. The general function f is taken as the square of the error:

$$f(\epsilon(k)) = \epsilon^2(k) \tag{4}$$

- Input error $\epsilon(k) = u(k) - u_m(k) = u(k) - S^{-1}[y_m(k)]$
- output error $\epsilon(k) = y(k) - y_m(k)$

This course uses output errors.

thinking

- What is the relationship between system identification and other courses?
- How to learn system identification?