Introduction: System Identification.

* Def: System identification is the study of Modeling dynamic System from experimental data.

1. Modelling

* Mathematical Description of System Linear / nonlinear, Time invariant /varying.
* Parametric / non parametric

1. Parametric identification/estimation

3) Non-parametric Identification

Given, find

* Relation between Machine Learning / AI

Given data, find some features inside the data

* Machine Learning: Supervised Learning / unsupervised learning: classification,

Usually static system.

* System Identification: In/Out relations, Usually dynamic system

Ch.1 Introduction

1. Introduction
   1. System Theory
      1. Terminology

Input

Disturbance:

State:

Disturbance:, output disturbance ( sometimes noise)

Output:

* + 1. Basic Problems
* Modeling / Analysis / Estimation / Control

1. Modeling

Relation between variables on the basis of prior knowledge, assumption about the uncertainties

Unknown / incomplete known coefficients :

1. Analysis

In system identification, **identifiability analysis:** “can the unknown parameter be uniquely, albeit locally, identified?”

1. Estimation

-State estimation / parameter estimation

-State estimation: based on the assumption that model is perfect, parameters are exactly known

-Parameter identification: estimate the model parameter from

1. Control
   1. Mathematical Models
      1. Model Properties

-Discrete-time

-Continuous-time

* Linearity

Assumption: Input: corresponding output:

The system is linear if

Input: then Output:

* Time- Invariance

Assumption: input output .

Then if input ,then

* Causality: The output does not depend on the future value of the input
* Estimation/ Prediction
* Dynamics

If the system depends on its history, and not just on the present input, it is called a dynamic system. See (1.1), (1.2)

* + 1. Structural model Representations
* Ex.1.4 / 1.5 A liquid storage tank:

The volume of the liquid in the storage tank: =

Inflows / outflows:

A proportional level controller:

* Let
* Differential Equation

1. The homogeneous solution: with
2. The total solution with initial condition
3. The system is linear
4. The system is time – invariant, because

1. The system is causal
2. The impulse response
3. Convolution model: the output is modelled as (1.5)
4. Differential equation model / state-space model

* The choice of model

-white box / black box (linear) / grey box

Part I data-Based Identification

* SISO LTI, classical data-based / non-parametric identification

1. System Response Methods
   1. Impulse Response
      1. Impulse Response Model Representation

* Unit Impulse function

* Convolution Model (Impulse response model)
* If is known, then is easily computed given
  + 1. Transfer Function Model Representation
* Laplace transform
* The transfer function
* Ex.2.1: Recall the liquid storage tank
* The transfer function
  + 1. Direct Impulse Response Identification
* Identification of given in Discrete Convolution Model

1. Discrete convolution model

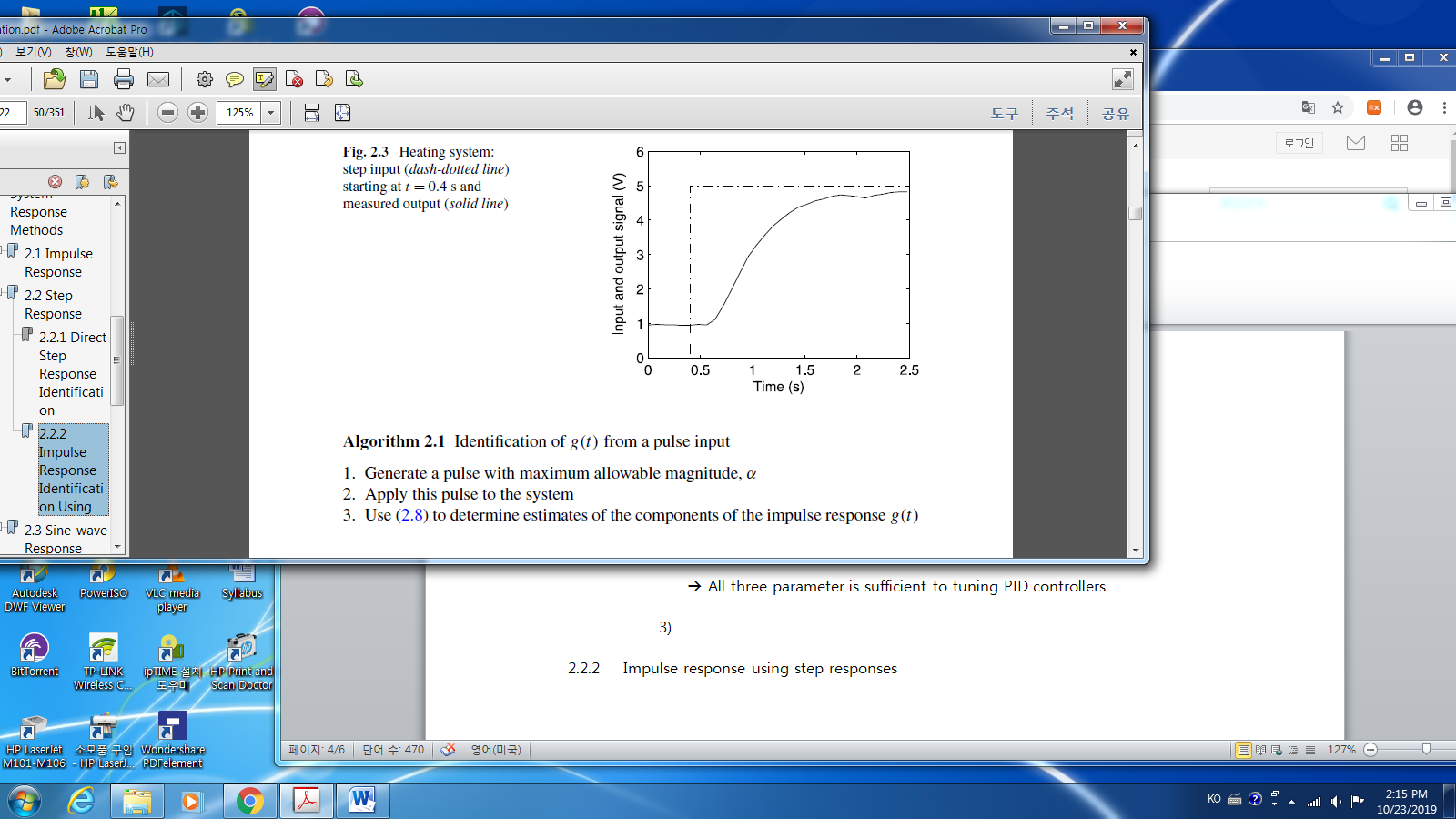
Therefore

1. Case of Pulse Input

In general, let input as

Then the output is

* 1. Step response
     1. Direct Step Response
* Dead time : 0.2sec
* Time constant
* Static gain : ~ ~ (4.8-1)/(5-0)= 0.76
* 🡪 All three parameter is sufficient to tuning PID controllers



* + 1. Impulse Response Identification Using Step response
* How to get :
  1. Sine-Wave Response
     1. Frequency Transfer Function
* Continuous Frequency Response
* A sampled system: Discrete Frequency Response Function
  + 1. Sine wave response Identification
* Input

Output from (2.5) with

* Ex. 2.5

-.

-. Gain: ~ Phase delay =

* Continuous / Discrete Fourier Transform

Laplace transform, z-transform

1. Frequency Response Method
   1. Empirical Transfer-function Identification
      1. Sine wave testing

* In order to get “Bode-plot”, we need infinite
  + 1. Discrete Fourier Transform of Signals
* The Discrete Fourier Transform(DFT)

-. sampled at

where

* Ex.3.1 Sine-wave signal

-. Given

where and

-. Find when

Hence

For simplification, using the following relationship:

so that

* + 1. Empirical Transfer Function Estimate
* Empirical Transfer Function Estimate(ETFE) for Samples systems

For a given N,

* 1. fda

1. Correlation Method
   1. Correlation Functions
      1. Autocorrelation Function
2. Autocorrelation Function

Continuous time case

Discrete-time case

* + 1. White Noise Sequence
    2. Cross-correlation Function
  1. Wiener-Hopf Relationship
     1. Wiener-Hopf Equation

1. The output
2. The cross-correlation between and : Wiener-Hopf Equation

Hence

* + 1. Impulse Response Identification Using Wiener-Hopf Equation

1. Examp. 4.3 : **Impulse response identification**

For asymptotically stable systems, it suffices to determine only the first elements of , so that

* Inputs, and output: , and

After removal of the initial conditions effect,

, and

* The correlation functions can be

And

1. Dsa
   * 1. Random Binary Sequences
     2. Filter Properties of Wiener-Hopf Relationship
   1. asd

Sda

Das