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

Find …

3) Non-parametric Identification

Given, find

* Relation between Machine Learning / AI

Given data, find some features inside the data

* Machine Learning:

Supervised Learning : example/ training

Unsupervised learning: classification,

* 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 :PID, LQG,..
   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

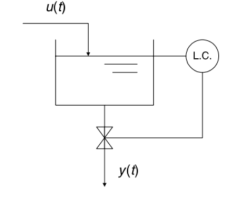
Assumption: input output .

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

* Kim : Problem 1.2

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

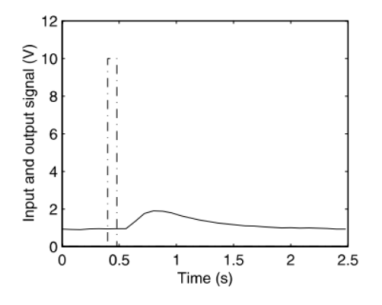
In general, let input as

Then the output is from (2.5)

where the measurement noise

* The estimator of

The error

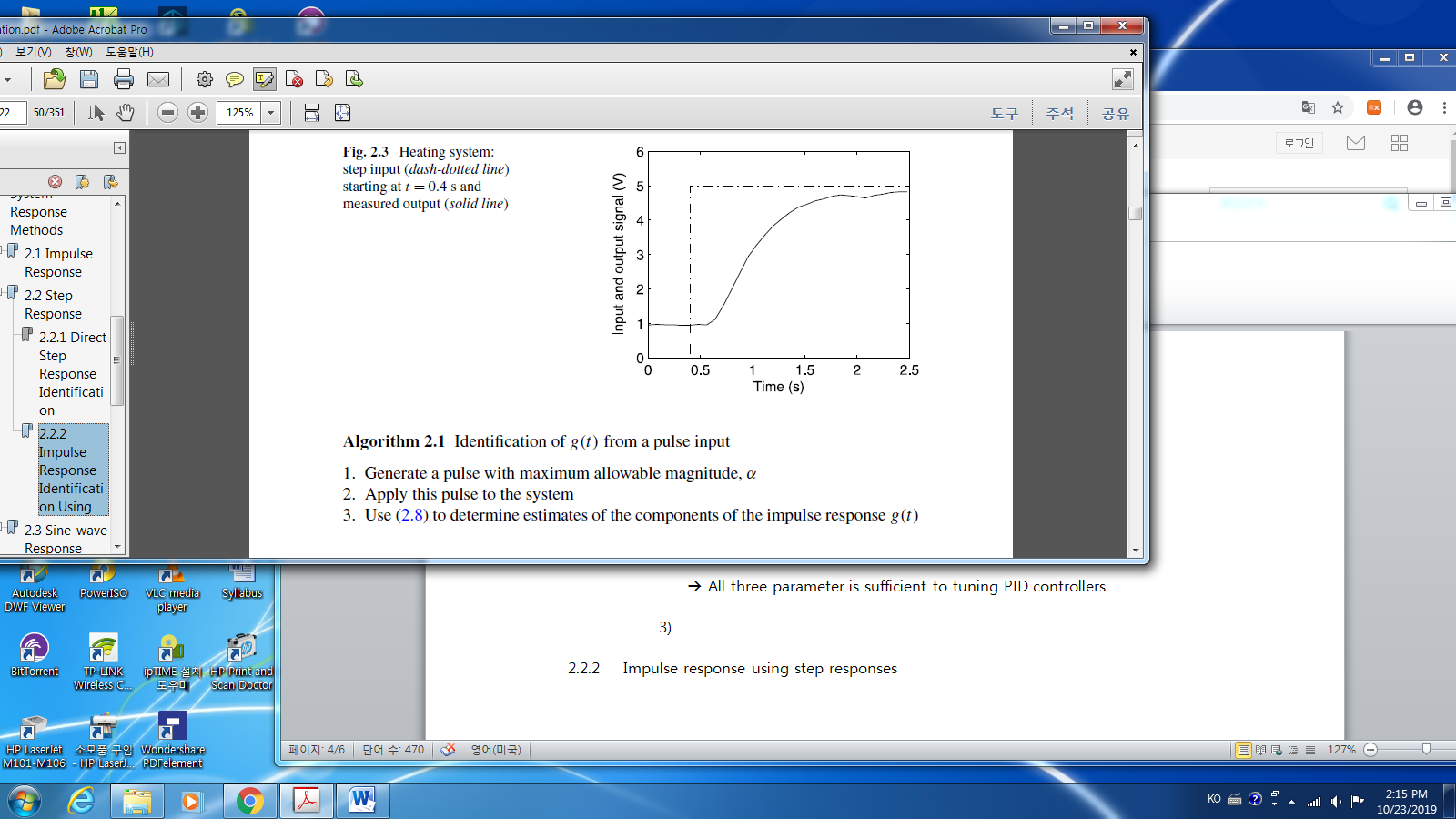
* should be large to minimize error
* : modeled as a memoryless, i.e., no dynamics.
* Ex.2.2 Heating system

Input:

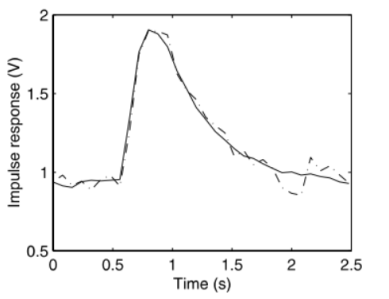
Output: the voltage of a thermometer

* Is this a linear system? You need to prove the linearity
* If it is a linear, then you may try to get a transfer function.
  1. Step response
     1. Direct Step Response
* Ex.2.3 Heating system

Input :

* Dead time(delay time) : 0.2sec
* Time constant : time to reach to 63%(~1/e) of the steady state value
* Static gain : ~ ~ (4.8-1)/(5-0)= 0.76
* Kim: Let’s assume as a first order time delay system as

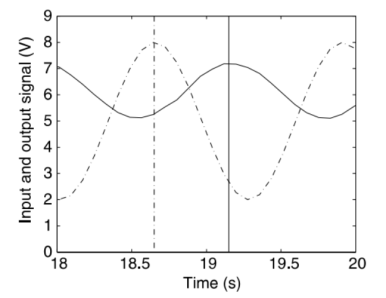
🡪 All three parameter is sufficient to tuning PID controllers

* + 1. Impulse Response Identification Using Step response

From (2.9) to (2.5)

* 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