Control Systems - 7^{th} Semester - Week 1

- Dr. Salman Ahmed

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Course Information

Course Title: Control Systems.

Course Code: CSE-310

Credit Hours Theory: 3hr

Credit Hours Lab: 1hr

Time Schedule:

- Lectures: Tuesdays and Wednesdays

Primary Textbook: Norman S. Nise, *Control Systems*, 8^{th} Edition.

Reference Textbook: R. C. Dorf. and R. H. Bishop, *Modern Control Systems*, 12^{th} Edition, Pearson

Instructor Information

Instructor: Dr. Salman Ahmed, Assistant Professor

Qualification:

- PhD majors in Control Systems, University of Alberta, Canada (2013)
- MSc majors in Signal Processing and Control Systems, Universiti Teknologi Petronas, Malaysia (2007)
- BSc in Computer Information Systems Engineering (Gold Medalist), UET Peshawar (2005)

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Control Systems

What is the definition of Control Systems in simple terms?.

- Forcing the output(s) of a system to have specific value(s)
- A system which processes the input to produce an output
- ...
- A system which changes in response to an input (or something e.g. time)

Where are control systems in this world and are they present in the field of computer systems engineering?

Examples from Real-World

The paper that we use to write and make notes

The water that we drink from a tap or purifier (water control systems)

The medicines that a patient consumes (medicine control systems)

Homes:

- Thermostat of air-conditioner to regulate the temperature
- Washing machines to clean dirty clothes
- Water boiler (geyser) to warm water in winter season

Automobiles:

- Speed control, temperature control
- Stability in terms of shock absorber
- Anti-skid brakes such as ABS or traction control

Examples from Real-World

Figure: An example of automobile/car manufacturing factory where a network of computers are controlling the factory

Examples from Real-World

Figure: An example of packaging of P ottles in group of 6, job controlled by a network of computers

Control Systems in DCSE

By now (7^{th} semester), yo e studied courses related to programming, networks, signal processing embedded systems.

Why do we need Control ms or what are t efits of studying Control Systems?

Let me give you a simple nple from programming subject

Addition program

```
#include <iostream.h>

void main()
{
    int x;
    int y;


    std::cin>>x;

    y=x+2;

    std::cout << "The sum is "<<y;
}
```

Figure: An example of addition code

Addition program

In the previous slide, one input was taken as input and the output was sum of input and 2.

May be if we are asked to write a program for the following data

Input, x	Output, y
1	-0.5
2	2
3	4.5
4	7

Table: One input one output program

Code for Data in table

```
#include <iostream.h>

void main()
{
    int x;
    std::cin>>x;
    if(x==1)
        std::cout << "The output y is -0.5";
    else if(x==2)
        std::cout<<"The output y is 2";
    else if (x==3)
        std::cout<<"The output y is 4.5";
    else if (x==4)
        std::cout<<"The output y is 7";
}
```

Figure: Code for the data given in table

Code for Data in table

Do we need any Control Systems to write the code/program?

The answer is No. We donot need any Control Systems to write the computer code.

Let us add some more data to the table.

Adding more data in table

Input, x	Output, y
1	-0.5
2	2
3	4.5
10	22
20	47
33	79.5
35	84.5
39	94.5
44	107

Table: One input variable, one output variable data

Code for More Data in table

Do we still need any Control Systems to write a code/program?

The answer is No. We do not need any Control Systems to write the computer code.

What if you have ten thousand (10,000) lines of data or even more.
Is if and $else$ an easy approach in programming to solve problems?

What will happen if instead of one input variable, we use two or three input variables or more?

Adding more data in table

Input, x_1	Input, x_2	Output, s
1	2	-2.5
2	4	-2
3	2	2.5
4	5	2
10	9	13
20	1	46
33	0	79.5
33	5	74.5
33	9	70.5

Table: Two input variables, one output variable

The need for Control Systems

The previous data was generated using the following formula:

$$y = mx + c$$

I used the following values to generate the first table (one input variable):

$$y = 2.5x - 3$$

I used the following values to generate the two-variables table ($y = m_1x_1 + m_2x_2 + c$)

$$y = 2.5x_1 - 1x_2 - 3$$

The need for Control Systems

A programmer or computer expert with no knowledge of mathematics would try to write everything using if and $else$ statements, or arrays

A programmer with little knowledge of mathematics can easily implement $y = mx + c$ equation instead of writing of long codes

If we know the equations, then we can easily use equations instead of if and $else$ statements.

Instead of $y = mx+c$, we may have complex equations like trigonometric equations and differential equations

The need for Control Systems

Sometimes in programming and computer sciences, if we have little knowledge of mathematics (equations), then life becomes easier for us.

In Control Systems course, we study the mathematics for systems. Let me introduce anther term which is called as cyber-physical systems

Cyber-Physical Systems

Cyber world includes all aspects of computing, including data acquisition, data storage on hard disk (or other mediums), data retrieval, data transmission over a network and data analysis.

We live in this physical world which consist of nature, things, human beings, trees, animals, birds and so many other systems.

Connecting the cyber world to physical world give rises to another branch of computer engineering which is termed as Cyber-Physical Systems (CPS)

Examples of CPS: Smart grids, medical monitoring of patients, industrial control systems, robotics, driverless cars.

Cyber-Physical Systems

If we know the simple mathematics behind every system, we can easily connect them to cyber-world.

Infact, we can have decision making process embedded in each CPS.

Control Systems Course Brief

This course is be divided into 3 sub areas:

- Understand the language used to model system e.g. $y = mx + c$
- Analyze the model of a system
- If required, design controller for a system, and connect the controller with the system for better performance

Week 2 Contents

In next week, we will study the languages used to model a system.

There are 2 main languages used to model a system.

- Transfer function (used mostly for SISO systems)
- State-space (used for SISO as well as non SISO system)

Control Systems - 7^{th} Semester - Week 2

Mathematical Modeling of Systems

Dr. Salman Ahmed

Model

A model is representation or abstraction of reality/system.

Who invent model? We, human beings, invent model based on our knowledge.

This means the more knowledge a person has, the better he/she can write a model.

What is mathematical model? A set of equations (linear or differential) that describes the relationship between input and output of a system.

Types of Model and System

In mathematics, we broadly classify systems into 2 types, namely stochastic (random, probabilistic, uncertain) and deterministic (fixed relation between input and output)

To write model for a deterministic system, there are three techniques

- Black Box
- Grey Box
- White Box

Black Box Model

It is used when only input and output data are available

The internal dynamics are either too complex or totally unknown (sometimes for cyber security purposes, we do not want to label/show the hardware)

Figure: Black Box Model of a System

It is very hard to analyze or conclude something based on I/O data without having knowledge about the system

Grey Box Model

It is used when input and output data is known (known means labeled), plus some information (information means knowledge) about internal dynamics of the system are known

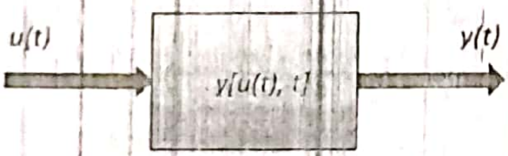

Figure: Grey Box Model of a System

In complex systems, we use grey box modeling to identify or estimate the system model

White Box Model

It is used when the input, output and internal dynamics of the system are known

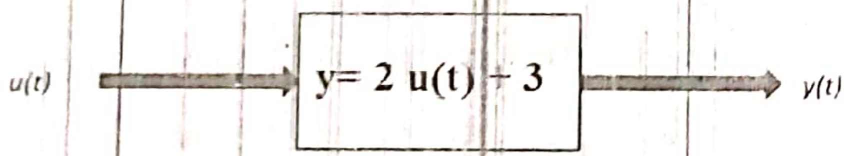

Figure: White Box Model of a System

White box models are very easy to predict any future values

Obtaining white box models requires us to know exact mathematical formulas and equations

Summary of Model Types

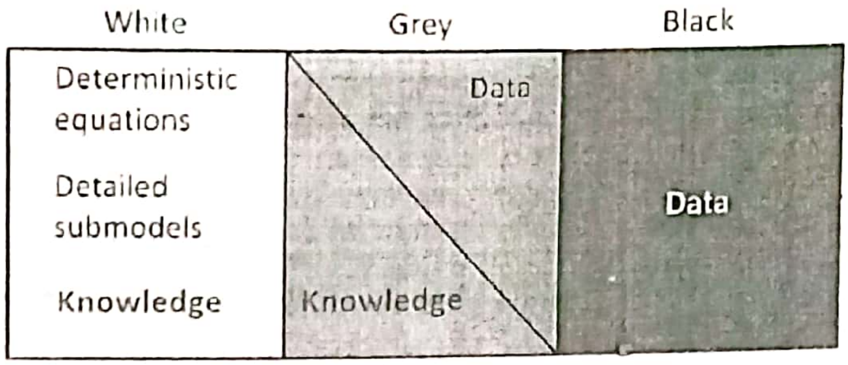

Figure: Techniques for obtaining models of a system

Equation Writing

In mathematics, we can write static equations as follows:

$$y = 2u + 3$$

If the equations are a function of time (means time-varying), then we equations as follows:

$$y(t) = 2u(t) + 3$$

Remember: If one variable is changing with time (like $u(t)$), then the whole equation changes with time. Mathematically, the following equation is incorrect

$$y = 2u(t) + 3$$

Equation Example

For example: if $u(t)$ is given as follows:

Time	Value
1	1
2	3
3	5
4	8

Table: Example of $u(t)$

MATLAB code for plotting the above signal $u(t)$

```
clear;
clc;
u=[1 3 5 8];
stem(u)
```


Equation Plot

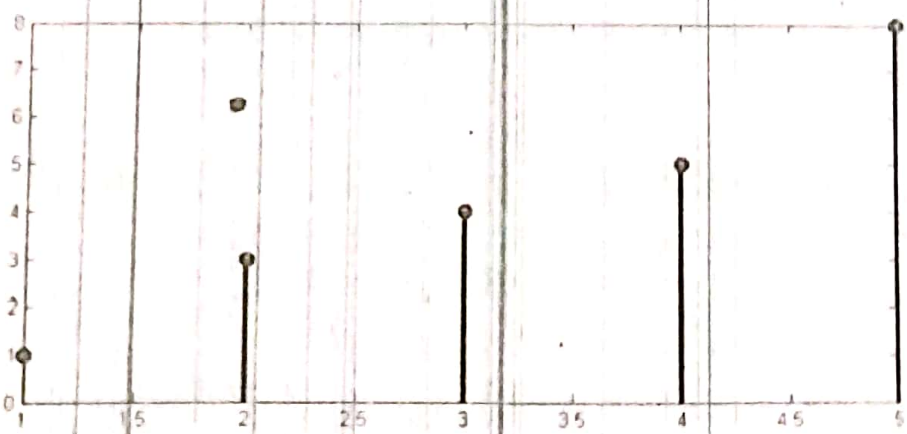

Figure: Plot of $u(t)$

Equation Plot

Let us put `axis` function in MATLAB code as follows:

```
clear;

clc;

u=[1 3 5 8];

stem(u)

axis([0 6 0 9])
```


Equation Plot

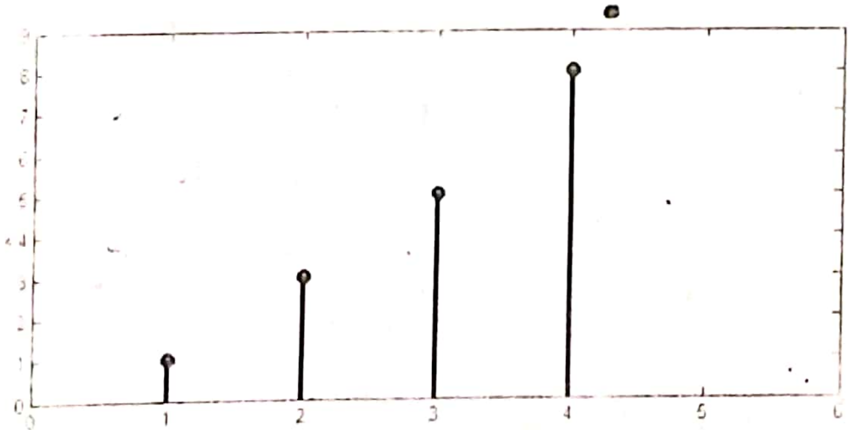

Figure: Plot of $u(t)$ with extended axis

Still missing something: the labels for x-axis and y-axis

Equation Plot

Let us put xlabel and ylabel function in MATLAB code as follows:

```
clear;

clc;

u=[1 3 5 8];

stem(u)

axis([0 6 0 9])

xlabel('Time (sec)') ; ylabel('Amplitude')
```


Equation Plot

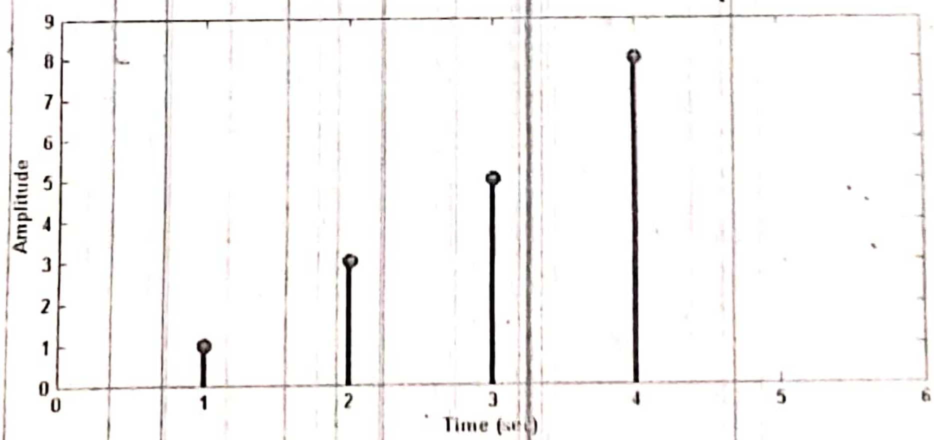

Figure: Plot of $u(t)$ with correct labels of axes

Now, we have the following equation:

$$y = 2u(t) + 3$$

Equation Plot

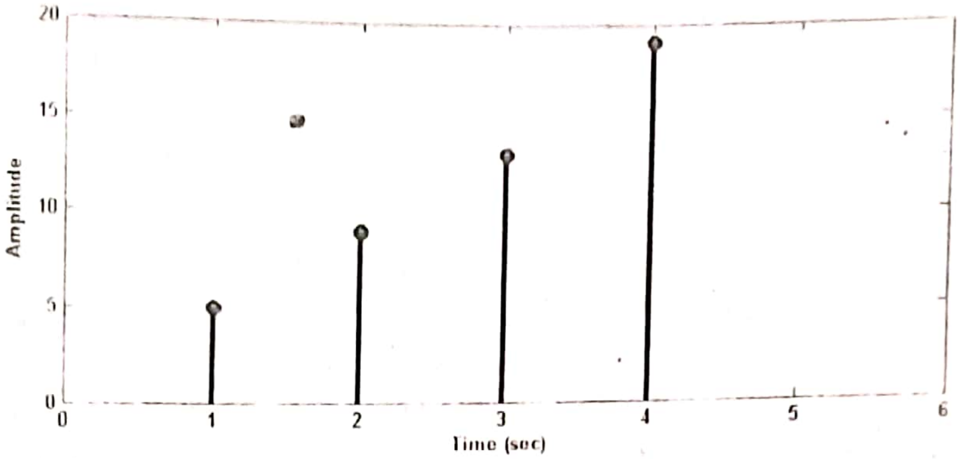

Figure: Plot of $y(t) = 2u(t) + 3$

Equation Plots

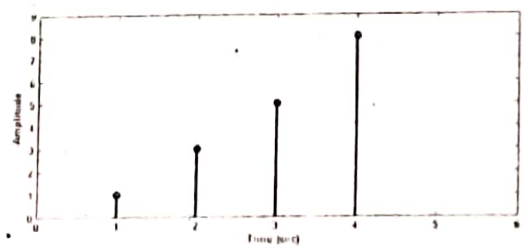

Figure: Plot of $u(t)$

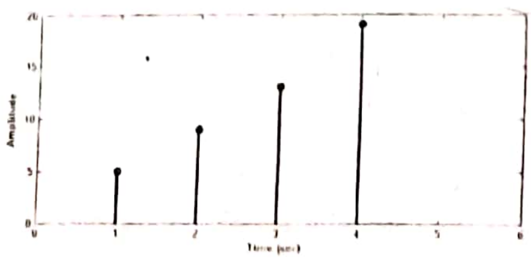

Figure: Plot of $y(t) = 2u(t) + 3$

Transfer function

Transfer function: Mathematical model (or relationship) between input and output of a system

What is relationship called in urdu?

تعلق

Figure: Transfer function

Transfer function Symbol

Ohm Law: $V = IR$

Is $A = BC$ Ohm Law?

The answer is yes, but if A denotes voltage, B denotes current and C denotes resistance.

V is popular symbol to denote voltage and similarly I for current and R for resistance.

A transfer function can be denoted by any alphabet from A to Z, but popular symbols are $G(s)$, $P(s)$, $H(s)$ and $T(s)$.

Abusive notation is G, P, H and T [ignoring the brackets and s term i.e. ignore (s)]