CONTROL ENGINEERING

For Third Year
CONTROL ENGINEERING

Year: Third
Theory: 2 hr/week
Tutorial: 1 hr/week

Introduction to control system 2 Hrs
Definitions, closed loop and open loop control systems

Mathematical model of physical systems 4 Hrs
Linear system, non linear system, transfer functions, mechanical translation system, mechanical rotational system, electrical systems.

Block diagrams 4 Hrs
Procedures for drawing a block diagram, block diagram reduction, closed loop system subjected to a disturbance, multivariable Systems, transfer matrices.

Signal flow graphs 2 Hrs
Signal flow graph representation of linear system, Mason's gains formula for signal flow graph.

Modeling in state space 4 Hrs
How to derive transfer function from the state space equations, state-space representation of dynamic system.

Transient response analysis 10 Hrs
Test signals, impulse response function, first order system, higher order system, definitions of time constant, damping ratio and natural frequency, definitions of transient response specifications, impulse response, dominant poles.

Steady – state error in unity- feedback control system 2 Hrs
Classifications of control systems, static position error coefficients, dynamic error coefficients.

Root Locus 6 Hrs
Root locus plot, general rules for constructing root loci, special cases, conditionally stable system, non-minimum phase systems.

Control system design by the root locus method 4 Hrs
Effects of the addition of poles and zeroes, lead compensator, lag compensator.

Frequency-response analysis 6 Hrs
Bode diagram plot, general procedure for plotting bode diagrams, system type and gain as related to log magnitude curves, experimental determination of transfer functions, phase and gain margins.

Polar plots 2 Hrs

Nyquist stability criterion 4 Hrs
Mapping theorem, stability analysis.

Three term controller 2 Hrs

Analysis of control systems in state space 4 Hrs
Controllability, observability, pole placement, design by pole placement, Ackermann's formula, state observer.

Sampled data system 4 Hrs
Method of analysis, transfer functions, stability.

Recommended Textbooks: K. Ogata "Modern Control Engineering" Prentice-Hall Pub.
Introduction to control system

Automatic control system played a vital role in the advancement of engineering and science.

In addition to its extreme importance in space-vehicle missile guidance and aircraft-piloting system

Automatic control has become an important and integral part of modern manufacturing and industrial processes. For example automatic control is essential in such industrial operations as controlling pressure, temperature, humidity, …

Since advance in the theory and practice of automatic control provide means for attaining optimal performance of dynamic systems, improving the quality and lower the cost of production. Expand the production rate.

Most of engineers and scientist must now have a good understanding of this field.

Bismi-llahi rrahmani rahim
نظرة تاريخية

أول عمل ذو اهمية في مجال السيطرة الطوعية تم بواسطة العالم جيمس واط (James Watts) والذي طبقه على حاكم الطرد المركزي (centrifugal governor) للسيطرة على سرعة المكائن البخارية في القرن الثامن عشر.

العملا المهمة الأخرى في المرحلة الأولى لإنتاج نظريات السيطرة الطوعية تمت بواسطة مينورسكي (Nyquist) و هازن (Hazen) ونيكويست (Minorsky) من بين الآخرين.

في عام (1862) عمل (Nyquist) في مجال السيطرة الطوعية لقياس السفن وبيّن كيف أن الاستقرارية يمكن الحصول عليها عن طريق (Differential equations) التي بدورها تصف النظام. في عام (1932) أوجد (Hazen) طريقة مبسطة لإيجاد الاستقرارية للنظام ذو الدائرة المغلقة (Closed loop control system) واعتماد على أداء النظام ذو الدائرة المفتوحة (Open loop control system) لحالة الثبوت (Steady state) عندما يكون الدخل (Input) موجه جيبي.

في عام (1934) أوجد عبارة Servo mechanisms عبارة Hazen خلال الأربعين طريقة Frequency response جعلت من الممكن للمهندس تصميم الضوئي (Linear feedback control system) والذي يمكن أن الحصول على الأداء المطلوب في نهاية الأربعين وبداية الخمسينات تم اكتمال طريقة Root-Locus في تصميم أنظمة السيطرة الطوعية. هما كلاب ما يسمي Root-Locus & Frequency response طريقتاً وذان يؤثران على نظام مستقر ويحقق الأداء المطلوب. هذا النظام لا يؤدي إلى الاداء المثالي. في أواخر الخمسينات استخدمت التصاميم التي تؤدي إلى الاداء المثالي.
Classical control

BEFORE THE SYSTEM BECAME COMPLEX AND CONTAINED MULTIPLE INPUTS AND OUTPUTS, IT DEALS WITH SYSTEMS THAT HAVE A SINGLE INPUT AND OUTPUT, WHICH IS

† SINGLE INPUT SINGLE OUTPUT (SISO)†

IT HANDLES THE CONTROLLABLE SYSTEMS WHICH ARE USEFUL IN MILITARY AND SPACE APPLICATIONS.

† MODERN CONTROL†

IT WENT TO A HIGH levels OF EFFORT IN THE DESIGN OF COMPLEX SYSTEMS WITH MANY EQUATIONS AND SIMULATIONS.

† MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)†

IT HAS BEEN USED IN INDUSTRIAL AND OPERATIONAL PROCESSES.

† OPTIMAL CONTROL†

IT HAS BEEN USED IN CONSIDERATION OF THE SYSTEMS THAT CONTAIN NOISE AND DO NOT CONTAIN NOISE.

† DETERMINISTIC AND STOCHASTIC CONTROL†

IT HAS BEEN USED IN ADAPTIVE CONTROL, WHICH TAKES ADVANTAGE OF LEARNING AND DYNAMIC CONTROL, STOCHASTIC CONTROL AND GENETIC CONTROL, IN ADDITION TO THE CONTROL METHODS.

† ROBUST CONTROL†

IT DEPENDS ON THE SYSTEMS THAT ARE MODERN AND ENHANCED.
DEFINITIONS

Plants:
A plant is a piece of equipment, perhaps just a set of machine parts functioning together. In this lectures, we call any physical object to be controlled a plant (such as a heating furnace, a chemical reactor, or space craft).

Process:
Progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead towarded a particular results or end. In this lectures we call any operation to be controlled a process.

System:
A system is a combination of components that act together and perform a certain objective.

Disturbance:
A disturbance is a signal which tends to adversely affect the value of the output of a system.
* Internal disturbance: it is generated within the system.
* External disturbance: it is generated outside the system and is an input.

Feedback control systems:
It is one which tends to maintain a prescribed relationship (in the presence of disturbance) between the output and the reference input by comparing these and using the difference as a mean of control.

Servomechanisms:
It is a feedback control system in which the output is some mechanical position, velocity, or acceleration.

Automatic regulating systems:
It is a feedback control system in which the reference input or the desired output is either constant or slowly varying with time and in which the primary task is to maintain the actual output at the desired value in the presence of disturbance. For example a home heating system in which a thermostat is the controller.

Process control systems:
An automatic regulating system in which the output is a variable such as temperature, pressure, flow, liquid level is called a process control system.
Closed Loop Control & Open Loop Control

Closed loop control system: A closed loop control system is one in which the output signal has a direct effect upon the control action. That is the closed loop control systems are feedback control systems. *The actuating error signal* (which is the difference between the input signal and the feedback signal) is fed to the controller so as to reduce the error and bring the output of the system to the desired value.

Example: Temperature control
* Human being act as controller
* thermometer measure the actual temperature of the hot water (output)

A human watches the thermometer, he find:
  a- temperature higher than the desired one then he reduce the amount of steam supply in order to lower the temperature
  b- temperature lower than the desired one he increase the amount of steam

If an automatic controller is used to replace the human operator, the control system become automatic.
* The position of the dial on the automatic controller sets the desired temperature.
* The output; the actual temperature of the hot water is compared with the desired temperature in order to generate an actuating error signal.
* The measured temperature is converted to the same unit of input by means of transducer (A transducer is a device which converts a signal from one form into another).
* Error signal produced in automatic controller is amplified and sent to the control valve in order to change the amount of steam. If there is no error, no change the value.
* In system considered, the ambient temperature & cold water temperature may be considered as external disturbance.

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+-------------------+     +-------------------+     +-------------------+
|      input        | ⋅     |      Error signal  | ⋅     |      output        |
|                   | ⋅     | amplifier          | ⋅     |                   |
|                   | ⋅     | actuator           | ⋅     |                   |
|                   | ⋅     | plant              | ⋅     |                   |
|                   | ⋅     | Measuring device (transducer) |
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Example:

* The radar antenna detects the position and the velocity of the target airplane.
* The computer takes the information and determines the correct firing angle for the gun.
* Firing angle includes the necessary lead angle so that the shell reaches the projected position at the same time as airplane.
* The output signal of the computer (actuating signal) is fed into a power amplifier whose output voltage is applied to derive motor.
* The motor rotate the gun to the desired firing angle.

**Open Loop Control Systems**

The open loop control systems in which the output has no effect upon the control action. That is, the output is neither measured nor fed back for comparison with input.

**Examples:**
1. **Washing machine** which operate on time basis. The machine does not measure the output signal, namely the cleanliness of the clothes.
2. **Traffic control** by means of signal operated on a time basis.

For each reference input, there corresponding a fixed operation condition. Thus the accuracy of system depends on calibration.

**Major advantages of open loop control system**

1. Simple construction and ease of maintenance.
2. Less expensive than the corresponding closed loop system.
3. There is no stability problem.
4. Convenient when output when output is hard to measure or economically not feasible.

**The disadvantages of open loop control systems are as follows**

1. Disturbances and changes in calibration cause errors and the output may be different from what is desired.
2. To maintain the required quality in the output, recalibration is necessary from time to time.