CSE302 Automatic Control Engineering

Lecture 1: **Introduction**

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The Lecturer

About Me

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- **Asst.Prof.Dr.Ing.** at Computer and Systems Engineering Dept., Faculty of Engineering, Zagazig University.
- **Researcher** at DFKI–Robotic Innovation Center, Bremen, Germany.
- Research Interests: **Robotics**, **Control**, Modelling and Simulation, and Mechatronics

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The Lecturer

Some robots I worked with

SpaceClimber

CREX

The Lecturer

Some robots I worked with

LIMES (Mantis)

EOscc2

The Lecturer

Some robots I worked with

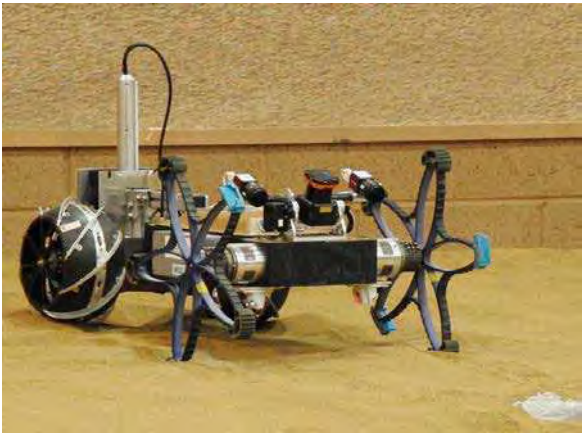
AILA

Mr.SemProm

The Lecturer

Some robots I worked with

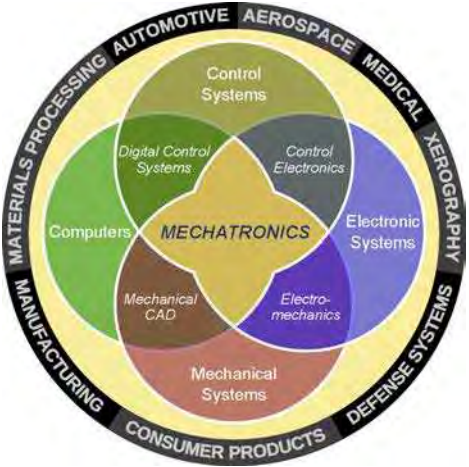
MIRA



Coyote2

The Course

CSE302 Automatic Control Engineering



https://en.wikipedia.org/wiki/Mechatronics

The Course

CSE302 Automatic Control Engineering

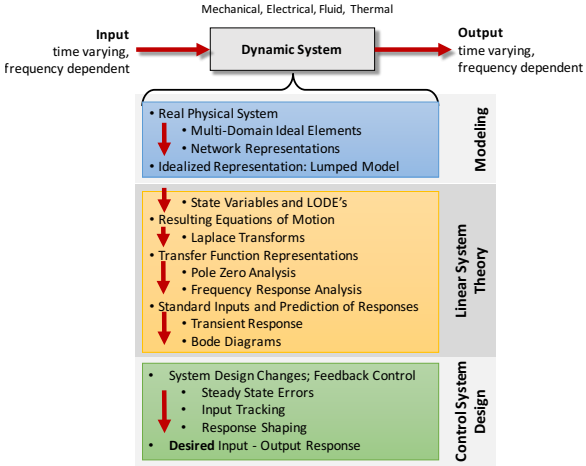
The course introduces fundamental concepts in the **theory, analysis and design of control systems**. It enables you to:

- Knowledge and understanding
  - **Model** and analyze control systems
  - Evaluate the **performance** of control systems
- Professional and practical skills
  - **Design and simulate** industrial and practical systems
  - Improve performances of control systems
- General and transferable skills
  - Understand the requirements and operations of control systems
  - Design and tuning techniques for performance improvement

CSE302 Automatic Control Engineering

Topics to be covered (subject to change!)

- System Modeling
  - Transfer Function
  - Block Diagrams
  - State space
  - Signal Flow Graphs
- System Analysis
  - Time Domain Analysis
  - Frequency Domain Analysis (Bode Plots, Nyquist Plots)
  - Root Locus
- System Design
  - Compensation Techniques
  - PID Control



The Course

CSE302 Automatic Control Engineering

Assessment Methods

Method	Time	Weight
Assignments, Quizzes, $\cdots$	weekly	5%
Midterm	week 6	15%
Project (Project Report + Demo)	week 10	10%
Final	week 12	70%

Recommended Textbooks

- Katsuhiko **Ogata**, *Modern Control Engineering* (5^{th} ed.), Upper Saddle River, 2011.
- Richard C. **Dorf** and Robert Bishop, *Modern Control Systems*, Addison-Wesley, 2004.

Relevant Websites

- Lecture slides, notes and others on course webpage: `https://mnourgwad.github.io/CSE302`

Teaching Assistant

- *Eng.* Shimaa Mohamed `eng.shimaa2003@yahoo.com`

Prerequisites

- Mild linear algebra
- Multivariable calculus
- Integration and differentiation
- Laplace transforms

- **MATLAB** will be required for homework assignments and course projects
  - Most answers to homework questions can be verified via MATLAB/Simulink
  - a *short* MATLAB Basics tutorial can be found here:
    `https://mnourgwad.github.io/MEC301/lectures/MATLABbasics.pdf`
  - for Simulink, a tutorial is found here:
    `https://mnourgwad.github.io/MEC301/lectures/simulinkTutorial.pdf`
  - a very useful tutorial on control, MATLAB, and Simulink can be found at:
    `http://ctms.engin.umich.edu/CTMS/index.php?aux=Basics_Matlab`

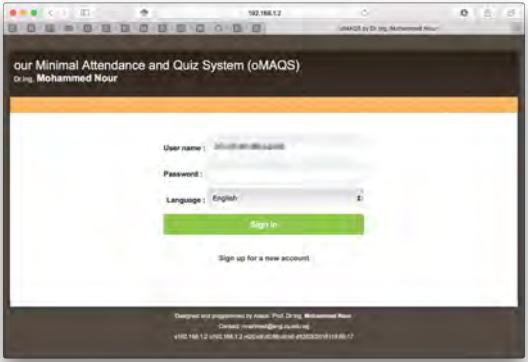
Sign up to the System

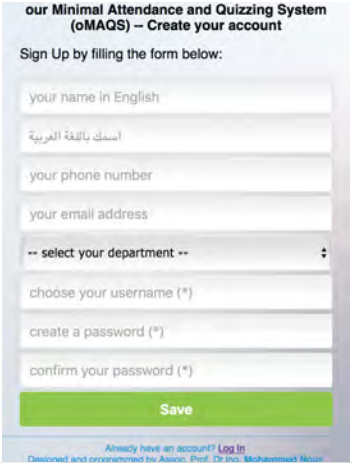
In your **smart** phone:

1. connect to WiFi network **Nour**
2. password: **12345678**

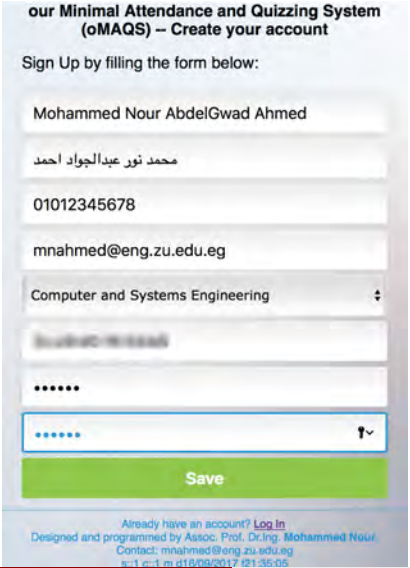
in phone Internet **browser**:

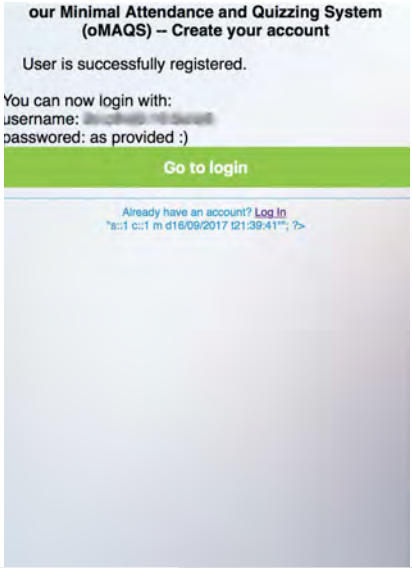
1. navigate to the address: **192.168.1.2**





Sign up to the System





Sign up to the System

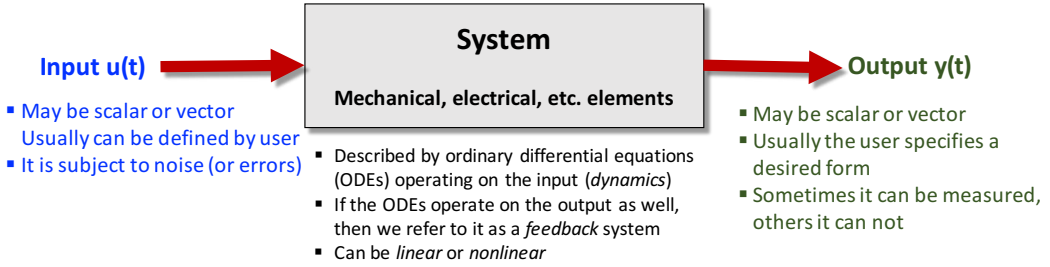
Lecture: 1

Introduction

- Basic Definitions
- Linear control Systems
  - Major Components
  - Basic Operations
  - Advantages and Disadvantages
- Course Roadmap

Control systems

What is a control system?



- **System**: An interconnection of elements and devices for a desired purpose and/or objective.
- **Process**: The device, plant, or system under control. The input and output relationship represents the cause-and-effect relationship of the process.

Control systems

What is a control system?

Control system

mechanical, optical, or electronic device, or set of devices, that manages, commands, directs or regulates the behavior of other devices or systems **to maintain a desired output**.

- Control system: An interconnection of components forming a system configuration that will provide a desired response
- the **purpose of control** is to ensure that output waveform resembles the waveform desired by the user, despite the system dynamics and disturbances by noise

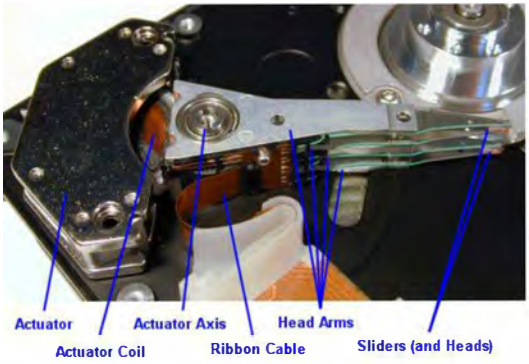
Control systems

What is a control system?

Control systems vary in complexity, size, type, but $\cdots$ they are everywhere

- In this room, in your tablets and phones
- In traffic lights, robots, the Internet, sports, music
- In your kitchen: fridge, toaster, coffee maker
- Hoverboards and Segways
- Most complex control system: the human body

Hard Disk Drive : Speed Control and Head-Disk Tracking

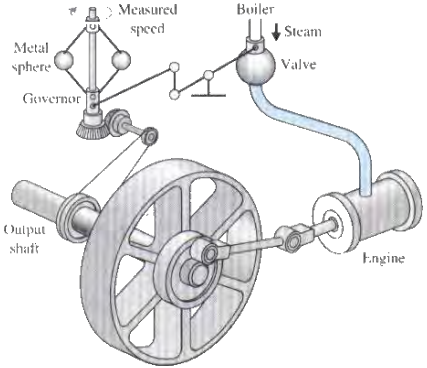


Brief History of Control

Fly-Ball Governor

invented by James Watt,1769[1]

- The first modern controller
- Regulated speed of steam engine
- Reduced effects of variances in load
- Propelled industrial revolution



[1]Stuart Bennett, A Brief History of Automatic Control, IEEE Control Systems, V16, Issue:3, P17–25, IEEE, 1996.

Classification of control systems

1. According to structure

Open-loop control

- output has no effect on control action.
- it is neither measured nor fedback for comparison with input.
- For each reference input, there corresponds a fixed operating conditions;
- accuracy of the system depends on calibration.
- in presence of disturbances, the system will not perform the desired task.

Closed-loop control

often referred to as **feedback** control systems.

- idea of feedback:
  (i) Compare actual output with expected value;
  (ii) Take actions based on the difference (error).
- This seemingly simple idea is tremendously powerful.
- Feedback is a key idea in control discipline.

Composition control

Composition control system = Open-loop + Closed-loop

Classification of control systems

2. According to reference input

Constant-value control

- reference **input** (expected value) is a **constant** value
- controller works to keep output around the constant value, e.g., constant–temperature control, and liquid level control.

Servo/tracking control control

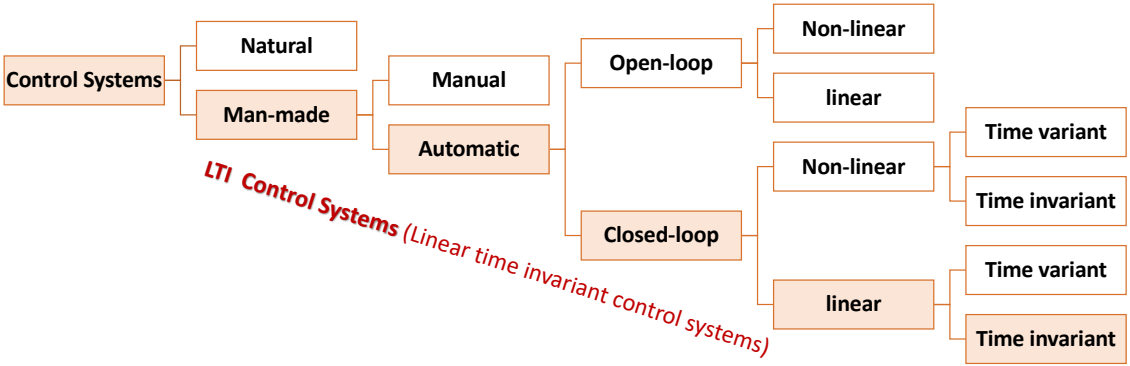
- reference **input** may be unknown or **varying**
- controller works to make output track the varying reference, e.g., automatic navigation systems on planes, satellite–tracking antennas

Programmed control

- The **input** changes according to a **program**
- controller works according to predefined command, e.g., numerical control machine

Classification of Control Systems

3. According to Structure



Two Control Strategies

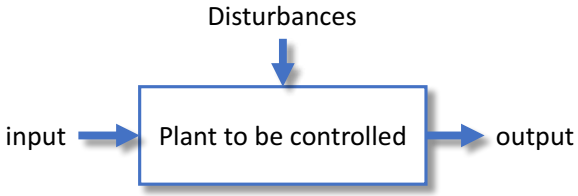
1. **Black–Box** Strategy
   - Learn by **training**
   - No idea what processes are happening inside your system
   - Disadvantage: cannot analyze
   - Advantage: no need for a physical understanding
2. **Model-Based** Strategy
   - Build a **mathematical model** through equations
   - Equations relate system inputs to outputs
   - Advantages? Disadvantages?

Model-Based Control

Two **approaches** for control:

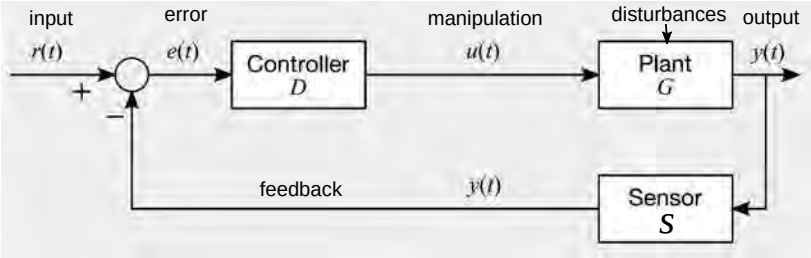
- Open loop control.
- Closed–loop (feedback) control.

Open-loop control



- Controller determines the plant input without looking at output
- adjust input to keep the output as close as possible to some desired value.
- Advantage: only used if one has accurate modeling of the system
- However, because of the unknowns in the system model and the effects of external disturbances open-loop control is not accurate.
- Examples: washing machines, light switches, gas ovens

Closed-loop (Feedback) control

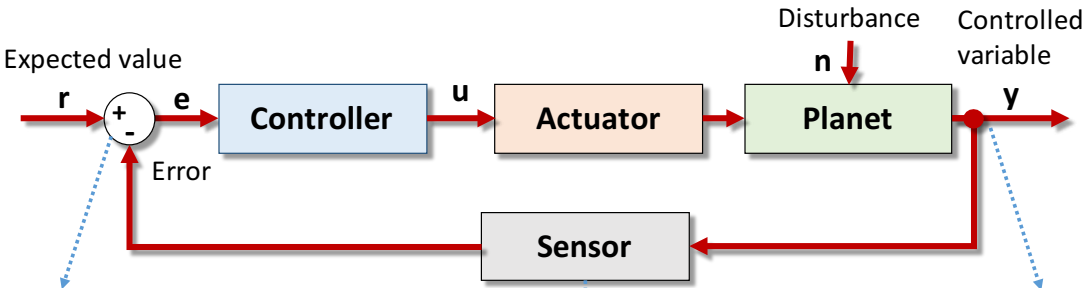


- measurements of plant output is used to modify its input.
- controller receives the error signal, then generates a suitable value of the plant input, hence closing the loop.
- Advantages: **robust** to external and internal disturbances
- Examples: air conditioners, refrigerators

Advantages of closed-loop control

- Remove (isolate or **reject**) the unwanted **disturbance** signal(s)
- **Reduces sensitivity** of output to variations in plant parameters.
  - plant model is not required to be exactly known.
- Can **stabilize** the system (if unstable)
  - Open-loop control can not be used in this case!
- **Command Tracking**: cause the output to track the reference input closely

Block diagram of a control system



Comparison component (comparison point) : its output equals the algebraic sum of all input signals.

block represents the function and name of its corresponding mode, we don't need to draw detailed structure, and the line guides for the transfer route.

Lead-out point: Here, the signal is transferred along two separate routes.

Basic concepts of a control system

Plant

a physical object to be controlled such as a mechanical device, a heating furnace, a chemical reactor or a spacecraft, a car, a missile.

Controlled variable

the variable controlled by a automatic control system , considering as a system output

Expected value

the desired value of controlled variable based on requirement, often it is used as the reference input

Basic concepts of a control system

Controller

an unit that can compute the required control signal.

Actuator

a mechanical device that takes energy, usually created by air, electricity, or liquid, and converts that into some kind of motion

Sensor

a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

Disturbance

the unexpected factors disturbing the normal functional relationship between the controlling and controlled parameter variations.

Course Content

1. System Modeling
   - How to construct the math behind the physics?
   - From basic laws of physics to differential equations
2. Control System Analysis
   - Given the math depicting the physics, can I analyze the system?
   - Can I change my input to have better system performance?
3. Control System Design
   - Can I design a subsystem, a controller, so that my output follows a certain trend?
   - How good is this design? What if the math was inaccurate?

Course Roadmap

- Laplace Transforms
- Transfer Functions
- Solution of ODEs
- Modeling of Systems
- Block Diagrams
- Linearization

- 1^{st} & 2^{nd} Order Systems
- Time Response
- Transient & Steady State
- Frequency Response
- Bode Plots
- RH Criterion
- Stability Analysis

- Root-Locus
- Modern Control
- State-Space
- MIMO System Properties

Thanks for your attention.

Questions?

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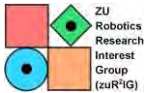

Robotics Research Interest Group (zuR^{2}IG)
Zagazig University | Faculty of Engineering | Computer and Systems Engineering Department | Zagazig, Egypt