EBU6503 Control Theory

Introduction

2019-20 Semester 1

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Course Format

- **Lectures/Tutorials**
  - **5 x 2 hours/week over 4 weeks**
  - **(weeks 7, 11, 12, 15)**
  - **Group 1 TB3-437**
  - **Group 2 TB3-435**
  - **Teaching weeks 1 and 2- Andy Watson**
  - **Teaching weeks 3 and 4- Prof Shuang-Hua Yang**
  - **Group 1 Tutorial: Wednesday 18:30-19:15, TB3-437**
  - **Group 2 Tutorial: Thursday 11:30-12:15, TB3-435**

Assessment

- **Exam. (Weighting 75%)**

  2 hours, 4 questions, 25 marks each.
- **Coursework (Weighting 25%).**

  Coursework comprises labwork (Matlab) and short answer tests
- **Labs:**

  Classes 2017215117-22 (180 people)

  Weeks 13 and 17, Fridays sessions 3, 4 and 5 (9:50-12:15), new research building computer rooms 116 and 120.

Context

- **In Signals and Systems, you learned a little about system stability and how it can be predicted from a mathematical model of a system (its "Transfer Function").**
- **One application of Control Theory is in the design of systems that are stable and that behave in predictable and desired ways.**

Context

- The Internet of Things is a term applied to a complex interconnected system of physical objects integrated into an information network.
- This interconnected network contains both open-loop and closed-loop sub-systems, and sensors are required to allow the attributes of the objects to be measured.
- These subsystems can then be controlled.

Aims

- The broad aims are to provide a knowledge and understanding of the principles, theory and applications of control theory. It is limited to the analysis and design of linear systems.

- This module is designed to introduce control theory and its applications to the measurement, processing and regulation of electronic signals.

Outcomes

The main outcomes are:

- **Ability to explain the principles of operation of system elements and sub-systems**
- **Ability to mathematically model system elements and sub-systems**
- **Ability to apply appropriate techniques to the analysis of system behaviour**
- **Design appropriate control strategies and evaluate their effectiveness**

Coursework Format

Coursework comprises:

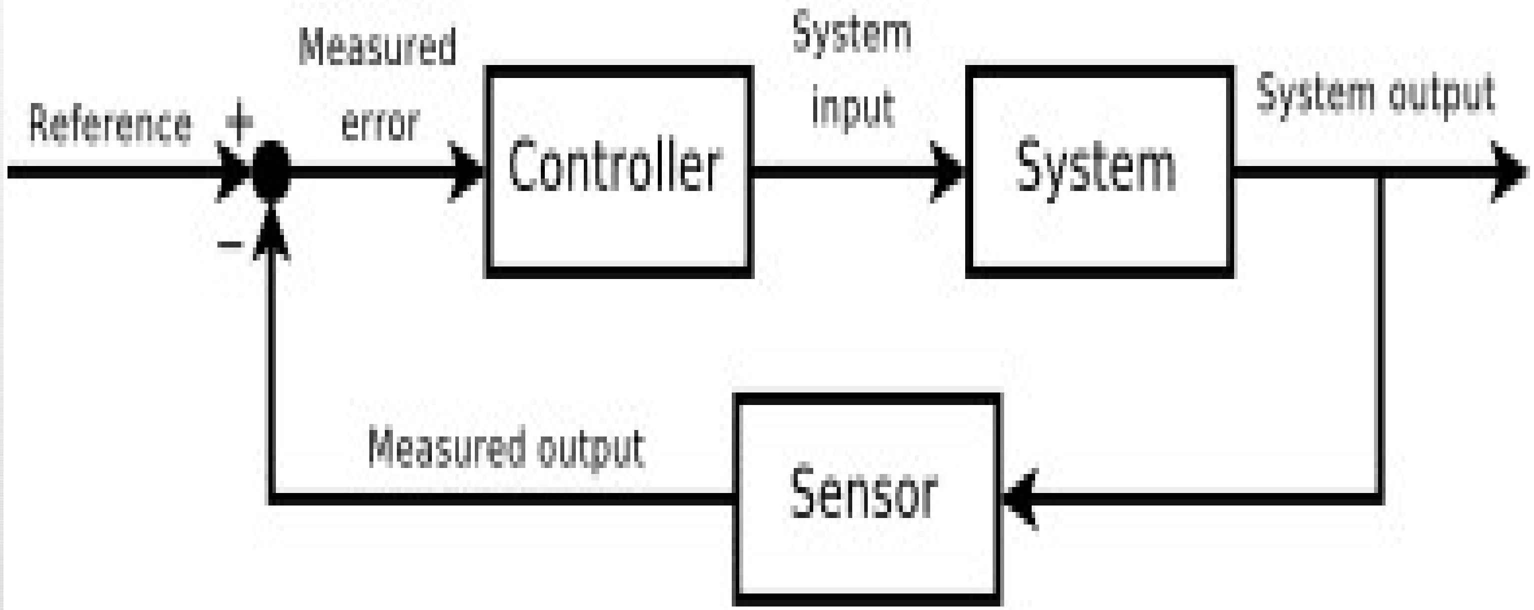
- **Laboratory exercises involving the modelling and analysis of systems and discussing the effects of different control strategies**
- **Short answer tests based on lecture material and labwork**

General Study Tips

- Read the lecture material and make notes
- Attend lectures. There is a correlation between attendance and performance
- Ask questions about things you do not understand
- Attend labs as scheduled. TA assistance is provided at scheduled labs. If you do not attend these and then try the labs in your own time you will not get the help that you may need in using the software

What is a Control System?

Diagram from Wikipedia “Control Theory”



Content

Topics covered are:

- **Principles of operation of sensors**
- **Mathematical Modelling**
- **Control System Characteristics**
- **Performance Indices**
- **Stability**
- **Analysis Methods (Root Locus, Frequency Response, Time Domain)**
- **Compensator and Controller Design**
- **Digital Control Systems**
- **Robust Systems**
- **Safety Critical Systems.**
- **Supplementary topics: MIMO Systems, State-Space Representation, Observability, Controllability**

Sensors

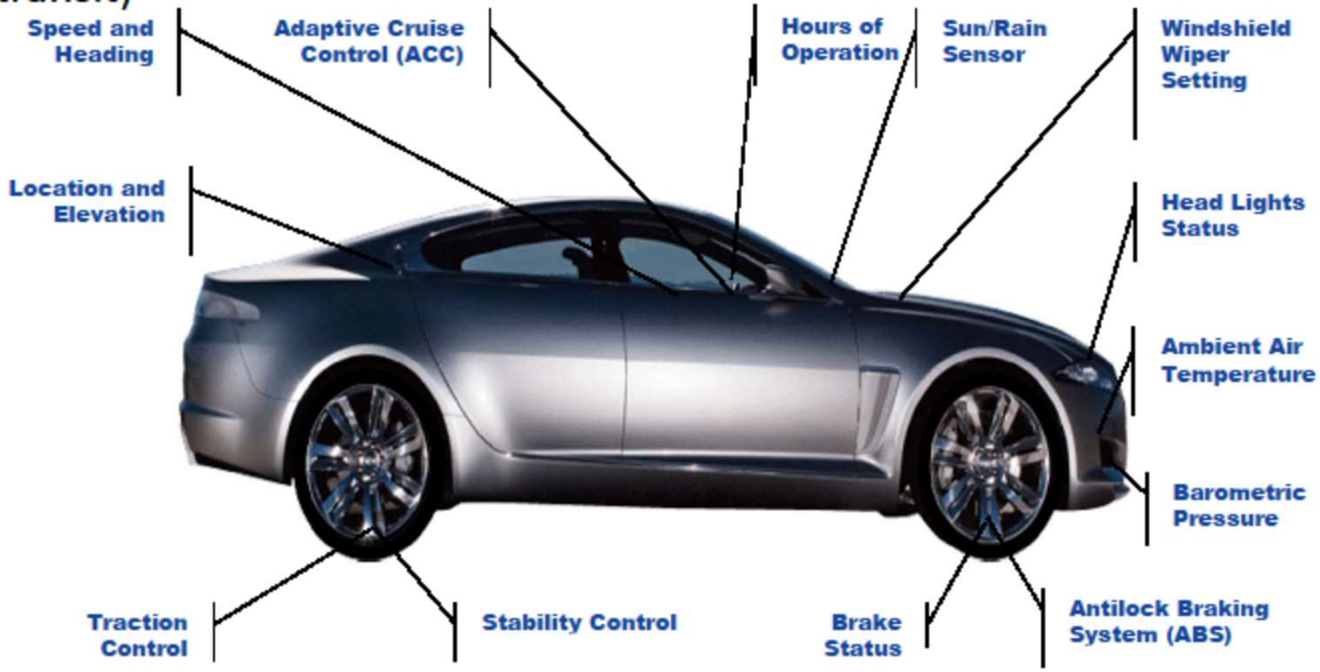
- Generally, sensors are devices that convert physical quantities (e.g. temperature, pressure, speed, displacement, etc) into electrical signals
- There are many different types and principles of operation
- Principles of operation could be classed as:

a. Resistive
b. Capacitive
c. Inductive
d. Other

Ideas for Realizing Environmental Benefits

Imagine:

- **Managing** your system for environmental and weather events if you knew specific information about the road & vehicles (cars, trucks, transit)



Reference: RITA, US DoT, 2011

ZigBee Light Link in Internet of Things

Reference: Coop, 2012

Mathematical Modelling

- **Mathematical modelling is used to analyse system behaviour without requiring the physical system.**
- **It is based on Transfer Functions**
- **The transfer functions of the elements of a system can be combined together to produce overall transfer functions, both open-loop and closed-loop**
- **The transfer functions can be determined theoretically or by experiment**

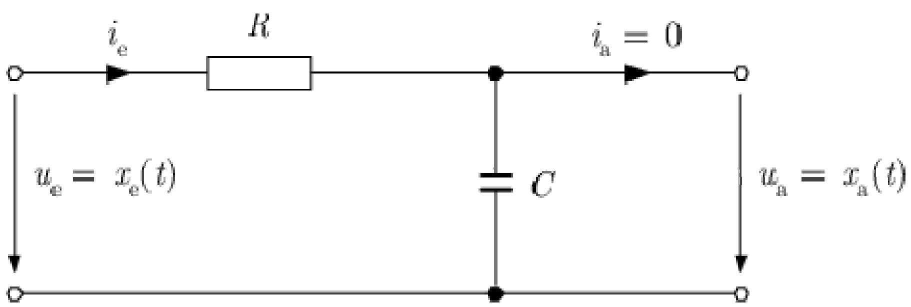
Mathematical Modelling

- **Continuous systems can be modelled by Differential Equations, and the transfer functions found by using Laplace Transforms**

- **Discrete systems can be modelled by using Difference Equations, and then by using either recursive or non-recursive equations, or by using Z Transforms to obtain a sampled-data transfer function**

Mathematical Modelling

- **Mathematical Models can also be used to produce "Analogies". That is, electrical circuits whose behaviour is the same as the physical system**
- **For example, many system elements behave as a "First Order Lag", similar to a charging capacitor**



Control System Characteristics

- **Steady-State Response:**
  a. **Final value**
  b. **Steady-state error**
- **Transient Response:**
  a. **Rise-time**
  b. **Overshoot**
  c. **Settling time**
- **Robustness:**
  a. **Sensitivity to model uncertainties**
  b. **Disturbance rejection**

Performance Indices (PI)

- There are several functions that are used to assess a system’s performance. The controller parameters are adjusted to minimise the PI.

  Examples of PI are:
- Integral of error
- Integral of absolute value of error
- Integral of error squared.

Stability

- **An unstable system is one whose output never settles down.**
- **Absolute Stability is a statement of whether or not a system is stable.**
- **Relative Stability is a measure of how stable a stable system is. It is not an exact amount, but is an empirical judgement of what is an acceptable system response.**
- **In a system's frequency response, it is often given in terms of a gain margin of 10-12dB and a phase margin of 45-50 degrees.**

Analysis Methods

There are several methods used to analyse a system's behaviour.

- **Time Domain. This involves solving the system's differential equation**
- **Frequency Response. This involves predicting the system's closed-loop behaviour by analysing its open-loop frequency response:**

  Nyquist Plot, Bode Plot, Nichols Plot
- **Root Locus Analysis: locus of poles of closed-loop transfer function**

Modification of System Behaviour

- If a system does not behave in a way that the user wants, its behaviour can be modified by designing suitable Compensators and Controllers.
- For example the system may have too much overshoot, or its response may be too slow.
- Compensators are often passive circuits (combinations of R and C) that are inserted in cascade with the system. Controllers are usually elements with several controls to tune the system response (e.g. PID controllers)

Other Topics

- **Digital Control Systems. Systems that are computer controlled, with several layers of access (e.g. DDC, Supervisory, DCS, etc)**
- **Safety Critical Systems. Systems that can cause catastrophic results if something goes wrong.**

Supplementary topics:

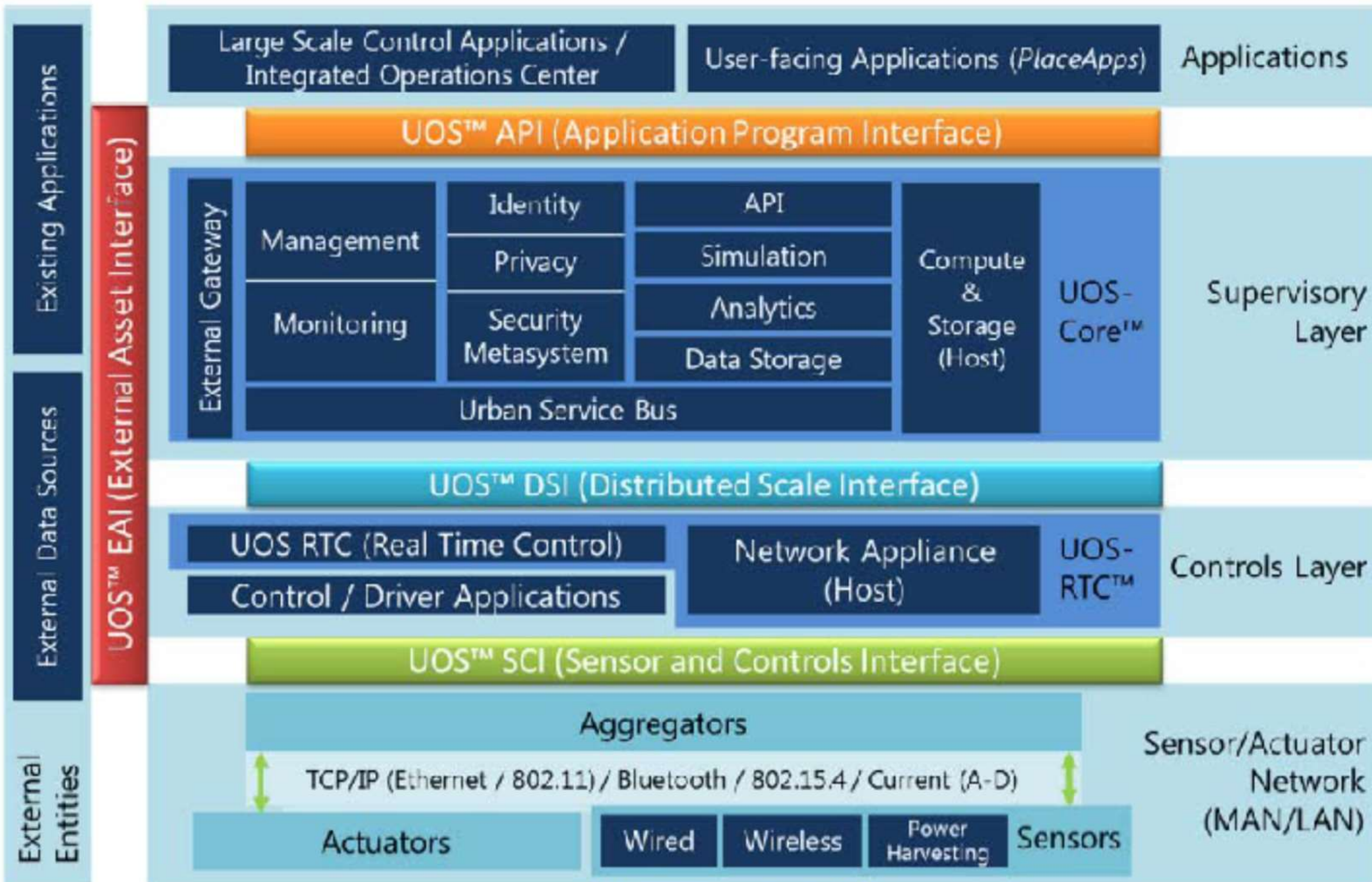
- **MIMO Systems. Systems with multiple inputs and outputs. They may also be interactive.**
- **State-Space Representation. A method of representing the system mathematical model in matrix form.**
- **Observability, Controllability. Observability is whether or not all changes in system behaviour can be observed at the output. Controllability is whether or not all aspects of the system can be controlled.**

Architecture of Urban Operating System (UOS™)

- Layers of Urban Operating System (UOS™)
  - Applications Layer
  - Supervisory Layer
  - Control Layer
  - Sensor and Actuator Network Layer
- UOS™ ensures scalability and reliability by careful control of distribution of functionality.
- The Objective of UOS™ is to centralize management but distribute execution.

Reference:Living PlanIT, 2012

Urban Operating System (UOS™) Architecture



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