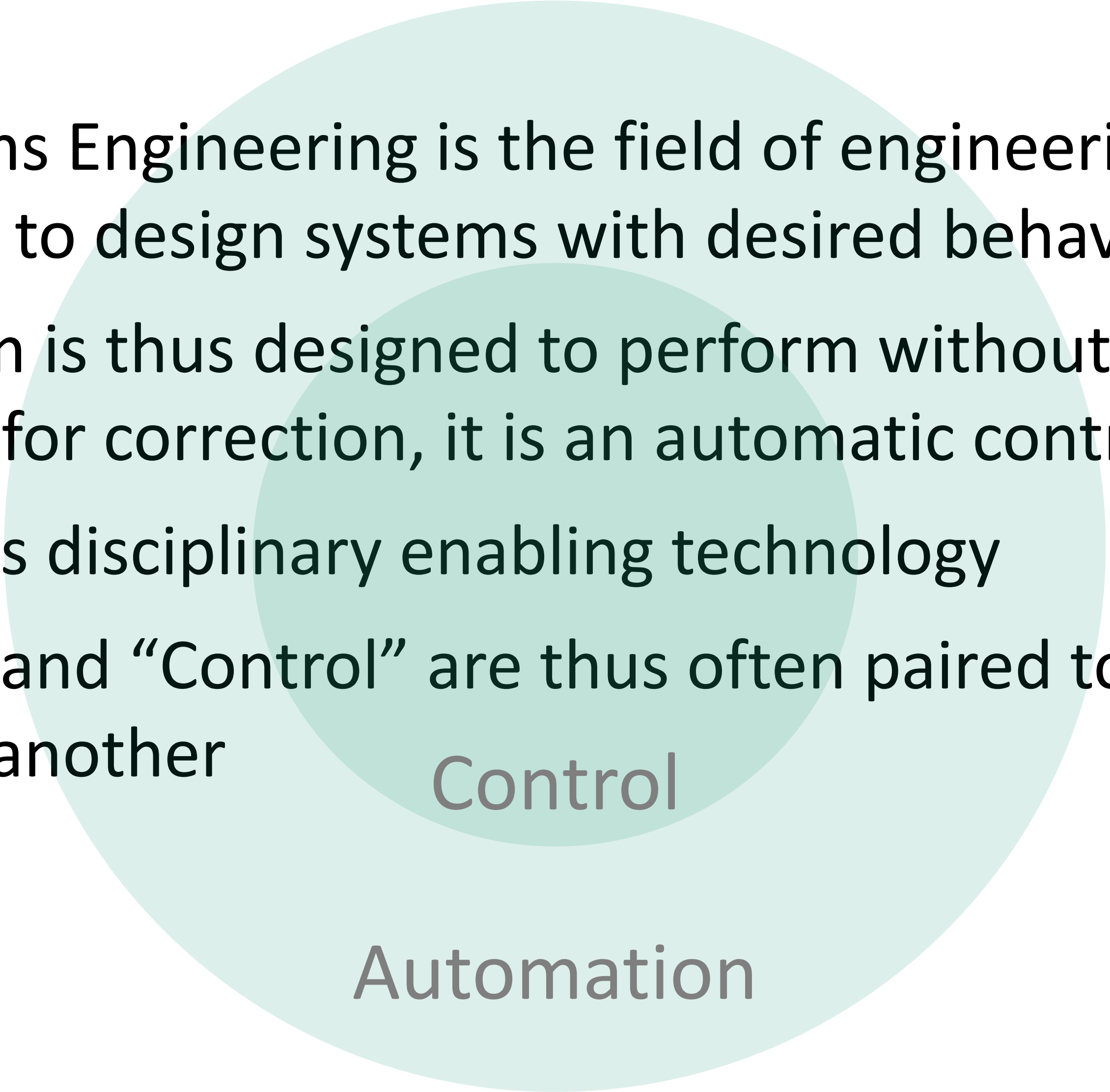
EE5110/EE6110
Selected Topics in Automation and Control

Module Outline

- Target students: MSc, MEng and PhD
- Pre-Requisites: EE4302 or Feedback Control Module at Undergraduate level
- Co-Requisites: EE5101 or EE5103 or EE4302
- Preclusion: EE6110/EE5110, EE5062

Automation and Control

- Control Systems Engineering is the field of engineering that applies control theory to design systems with desired behaviors
- When a system is thus designed to perform without the need of human inputs for correction, it is an automatic control system
- Multi and cross disciplinary enabling technology
- “Automation” and “Control” are thus often paired together as one is at the core of another



What is a System?

- A system is just an object whose properties we want to analyze or synthesize. Many things (properly defined) under the sun may be classified as systems.
- Examples: Mechanical devices, electronic circuits, chemical processes, UAVs, medical instruments, electric vehicles, etc.




Teaching “Knack” in Applications: a Challenge

- Diverse as the SYSTEMS they apply to, the applications of automation and control cut across multiple disciplines and span across different industries.
- While the teaching of control theory can be generic, bringing the applications of this enabling field to the classroom is highly challenging since they are dynamically evolving all the time in old and new domains.
- A common grouse from the industries on their newly recruited control engineers is the lack of a comprehensive skillset and perspective of the cross disciplinary requirement of practical applications.
- These serve as the motivation for EE5110/EE6110.

Course Mechanics – Macro

- Skeletal module, not bounded by a set of syllabus which constrain the delivery of special topics. The exact set of special topics to be covered can vary from one offering of the module to the next.
- Taps on the repertoire of knowledge and expertise available in the control group often available only to a specific group of researchers in the projects. The nature of such a module allows fresh and recent topics, problems and solutions to be shared with the students.
- It is useful for students who would like to have a good overview of this area prior to embarking on higher level research in a specific field therein; and for students who are already engaged in the field to experience its multi-faceted nature.

Course Mechanics – Micro

- Organized into five segments (A-E), each focusing on a distinctly different problem as the base and illustrating the design cycle carried out on it. Each segment will be conducted by a different lecturer/s.
- Each segment will have a continual assessment (CA) component (25%) and a research project (RP) component (50%). The RP is typically an unsolved open-ended problem from that segment.
- 100% CA; <u>EE5110 students will do 4 out of 5 CA components from the five segments.</u>
- 100% CA; <u>EE6110 students will select any two CA components and 1 RP from any of the five segments, but they cannot be from the same segment. Note that Segments D & E only has 1 RP.</u>

Schedule

- Week 1: Overview and Segment A
  Week 2: Segment A
- Weeks 3 and 4: Segment B
- Weeks 5 and 6: Segment C
- RECESS WEEK
- Weeks 7 to 12: Segments D & E

Semiconductor Manufacturing (A)

Event-based Vision (B)

Control Optimization (C)

Autonomous Systems (D & E)

CA Distribution (EE5110)

Semiconductor Manufacturing (A)	
CA	RP

Event-based Vision (B)	
CA	RP

Control Optimization (C)	
CA	RP

Autonomous Systems (D & E)	
2 CAs	RP

1. Do all 4 out of 5 CA components from the 5 segments.

2. Each of the CA is given a deadline of 2 weeks to complete following the segment.

CA Distribution (EE6110)

Segment		
Semiconductor Manufacturing (A)	CA	RP
Event-based Vision (B)	CA	RP
Control Optimization (C)	CA	RP
Autonomous Systems (D & E)	2 CAs	RP

1. Choose any 2 CA components from available 5 segments + 1 RP from a different segment from the 2 CA.

2. Students will begin the RP, selected from week 3 and they can meet the individual staff members to find out the details. The RP are given a deadline of 10 weeks so they should be completed for examination by the end of week 12.

3. For RP from segments D & E, approach Dr Huang Sunan.

Brief Introduction to Five Segments

- Semiconductor Manufacturing (A)
- Event-based Vision (B)
- Control Optimization (C)
- Autonomous Systems (D & E)

Semiconductor Manufacturing

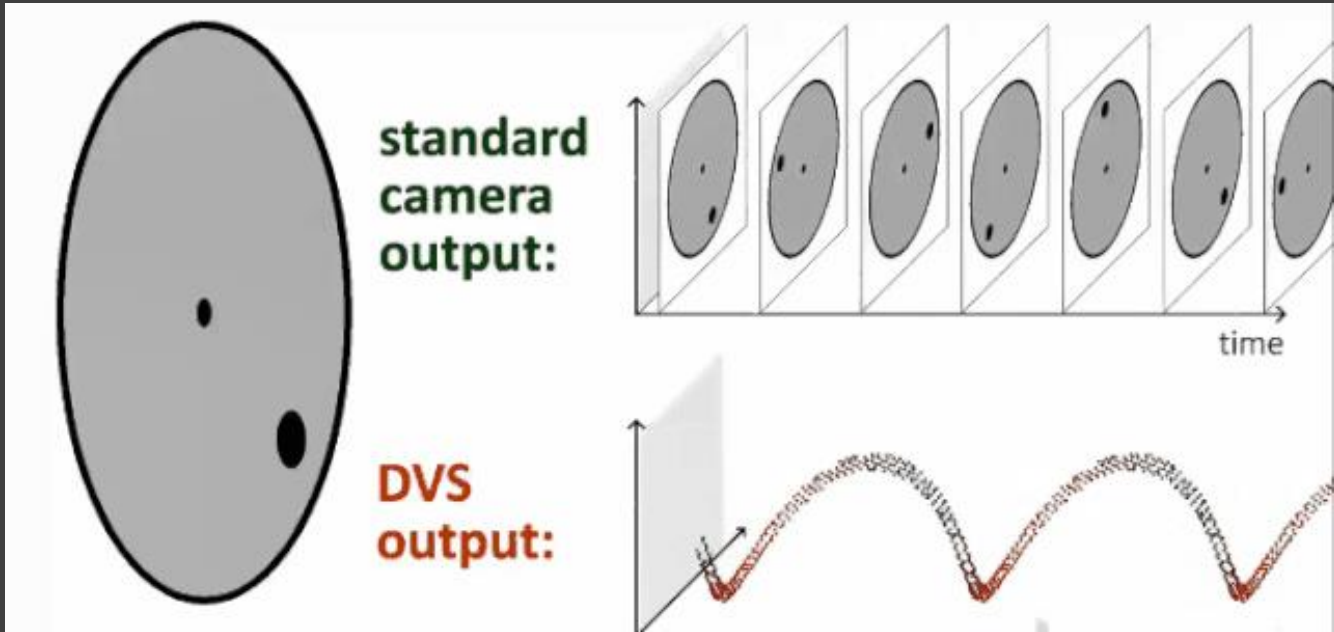
- A/Prof Arthur Tay
- ECE, NUS
- Email: eletaya@nus.edu.sg

Semiconductor Manufacturing

- **Brief Overview**: Students will get an overview of current semiconductor manufacturing. They will be introduced to process monitoring and control needed in this domain and will be brought through the design of a temperature control system in the manufacturing of ICs.
- **CA**: The students will be designing a controller for a thermal processing system in semiconductor manufacturing. The model of the system will be provided, the student will work on the controller design and simulation will be done in Matlab. A report of the results and analysis will have to be submitted together with the simulation codes and plots.
- **RP**: The students will discuss with lecturer to select a suitable semiconductor process. The work involves modeling, control and simulation in Matlab. A report of the results and analysis will have to be submitted together with the simulation codes and plots. In addition, the student will also need to provide a comprehensive literature review of the state-of-the-art systems.

Event-based Vision

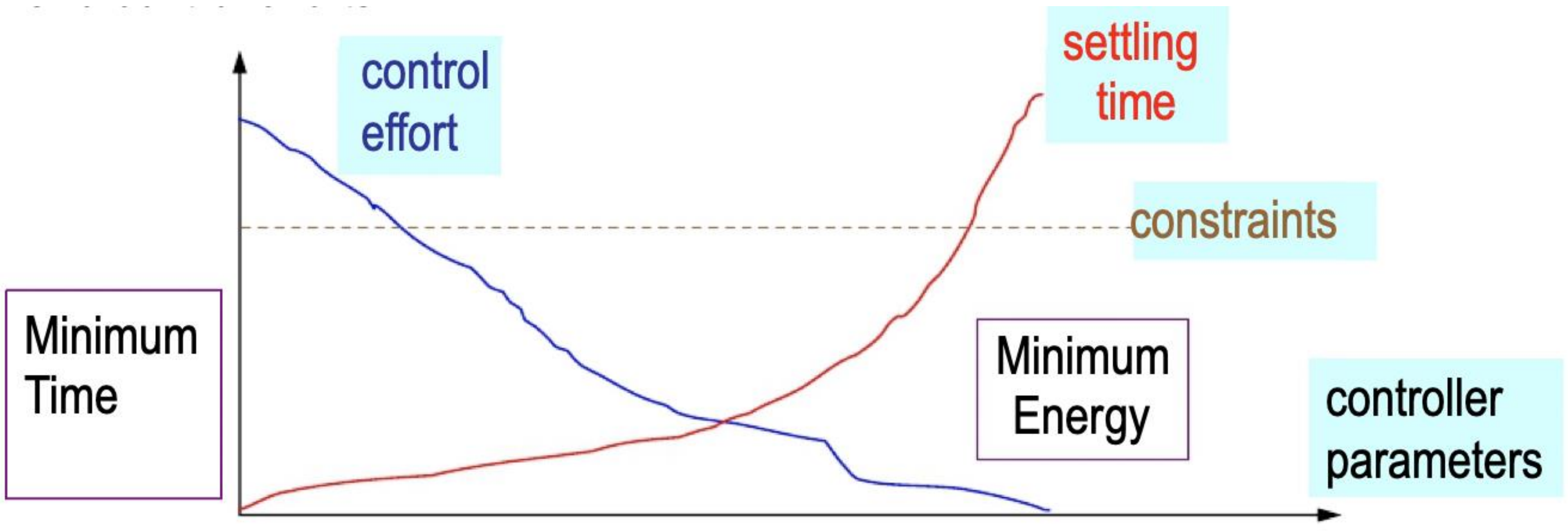
- Dr Jiang Rui
- Adjunct Lecturer, ECE, NUS
- OmniVision Technologies
- elejiangrui@nus.edu.sg



Event-based Vision

- **Brief Overview**: We all know the camera.
  An event camera (or Dynamic Vision Sensor, DVS) works differently by outputting asynchronized data when detecting motion or intensity change. This lecture will give you a comprehensive review on event-based machine vision systems (e.g. event-based sensors and cameras, event data representation, event data simulation and datasets), algorithms, and applications (detection and tracking, optical flow estimation, pose estimation and SLAM, image reconstruction, motion segmentation, recognition).
- **CA**: Design an Event Data Simulator. Based on the principles of the event cameras, the students are required to design a simulation framework to generate events, given high frame-rate images as inputs.
- **RP**: Event-based High Frame-Rate Video Reconstruction. Students are required to design and implement a video reconstruction framework to interpolate high frame-rate videos from events.

Control Optimization



- A/Prof Xiang Cheng,
- ECE, NUS
- Email: elexc@nus.edu.sg

Control Optimization

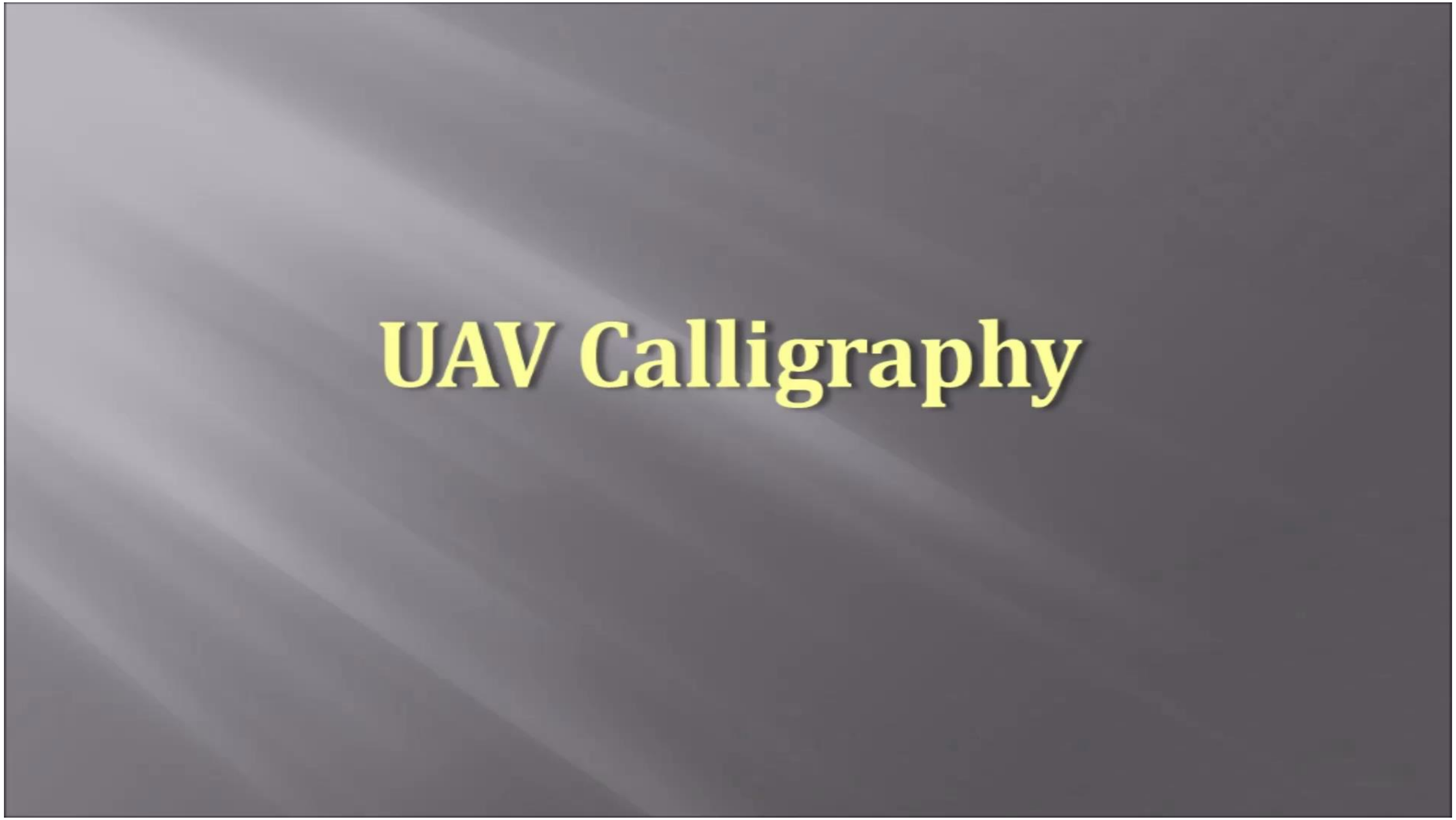
- **Brief Overview**: Two approaches will be introduced to deal with the optimization problem. The first one is the calculus of variations, in which the minimization function is regarded as a point in a function space. The second one is the dynamic programming approach, in which the optimal policy is computed at every state. Due to time constraint, only scalar case will be discussed in the class.
- **CA**: A set of four problems related to calculus of variations and dynamic programming will be given.
- **RP**: “How effective is approximate dynamic programming?"
  Students will carry out a critical evaluation of the latest technique of data-driven control: approximate dynamic programming. The technical report should consist of at least three parts:
  1. A comprehensive literature study of approximate dynamic programming (ADP)
  2. A critical evaluation of the strength and weakness of the ADP.
  3. Simulation studies to validate the analysis in part 2.

Autonomous Systems: Unmanned Aerial Vehicles

Segments D & E:

- Dr Huang Sunan
  Senior Research Scientist, Temasek Lab, NUS
  Email: tslhs@nus.edu.sg
- Dr Wang Fei
  Adjunct Lecturer, ECE, NUS
  CEO, Aerolion Technologies
  Email: elewf@nus.edu.sg

UAVs



Autonomous Systems: UAVs

- **Brief Overview**: Students will be introduced to UAV systems and the unmanned system structure adopted. The first half will focus on the design of the UAV platform and the details behind the modeling and control system design. The second half will focus on motion planning concepts and its development in unmanned vehicles, focusing on two algorithms: path planning and trajectory generation.
- **CAs**: students are required to propose a small-size UAV to navigate in a GPS-denied unknown environment, considering its hardware constraints such as footprint, payload, onboard computation resources, power consumption and communication bandwidth. The other CA focuses on motion planning and algorithms for UAVs.
- **RP**: students are required to solve a problem of a single UAV with multiple obstacles. Find an optimal path from the starting point to the goal for avoiding obstacles, and then generate a trajectory reference for driving the vehicle to the destination using PID. You can use MATLAB, Python or C language for programming.