ELEC4410 Control Systems Design

Lecture 1: Introduction and course outline

Julio Braslavsky

Centre for Complex Dynamic Systems and Control
School of Electrical Engineering and Computer Science
The University of Newcastle

21 July 2008

Outline

1. Motivation for ELEC4410
   - Why study Control Systems Design?
   - Some application examples

2. Course Overview
   - Lecturers
   - Purpose and Objectives
   - Assessment
   - Lectures and communication

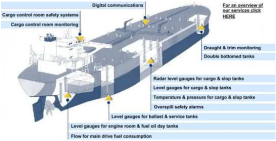
Why study Control Systems Design?

Advanced control systems are central to everyday technology applications

Microdrives

Engines

Aircrafts

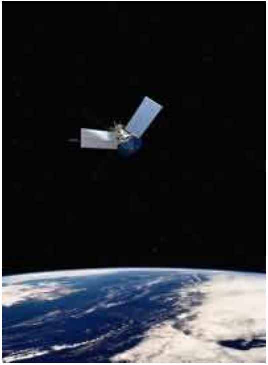


Ships

The University of Newcastle

Why study Control Systems Design?

Space communication and exploration would not be possible without control engineering technology



Satellites

Space exploration

Why study Control Systems Design?

Control engineering is key to

- high performance
- reduced waste and emissions
- energy efficiency
- safety of operation
- high quality production
- operation of complex systems

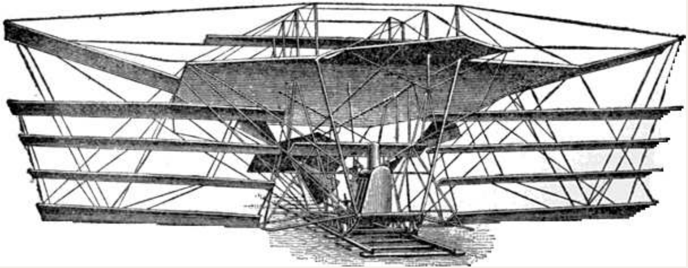
Example: Control of an aircraft

2005 Airbus 380: 680 ton maximum take-off weigth, 75,000 HP engines

The University of Newcastle

Example: Control of an aircraft

In the beginnings



1894 Hiram Maxim's flying machine: 3.5 ton, 360 HP engine was state-of-the-art technology. Aerodynamically unstable and uncontrollable, the project was soon abandonded.

Example: Control of an aircraft

Back in the 1890s. . .

- aerodynamic principles for wing design were well-understood
- lighter and more powerful internal combustion engines had been built
- Otto Lilienthal built wings capable of carrying him in flight

However. . .

- self-propelled flying machines remained an open challenge

Pioneers of aeronautics

- Orville and Wilbur Wright, bike designers in Indiana, realised the final problem was control

Example: Control of an aircraft

Back in the 1890s. . .

- aerodynamic principles for wing design were well-understood
- lighter and more powerful internal combustion engines had been built
- Otto Lilienthal built wings capable of carrying him in flight

However. . .

- self-propelled flying machines remained an open challenge

Pioneers of aeronautics

- Orville and Wilbur Wright, bike designers in Indiana, realised the final problem was control

Example: Control of an aircraft

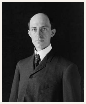
Back in the 1890s. . .

- aerodynamic principles for wing design were well-understood
- lighter and more powerful internal combustion engines had been built
- Otto Lilienthal built wings capable of carrying him in flight

However. . .

- self-propelled flying machines remained an open challenge

Pioneers of aeronautics



- Orville and Wilbur Wright, bike designers in Indiana, realised the final problem was control

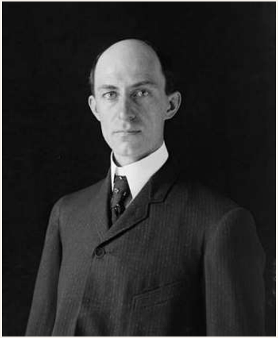
Example: Control of an aircraft

The flying problem

Wilbur Wright said in 1901:

- *Men know how to construct airplanes.*
- *Men also know how to build engines.*
- *Inability to **balance** and **steer** still confronts students on **the flying problem**.*
- *When this one feature has been worked out, the age of flying will have arrived, for all other difficulties are of minor importance.*

Wilbur Wright (1867–1912)



A control problem:

balance and steer = stabilise and control

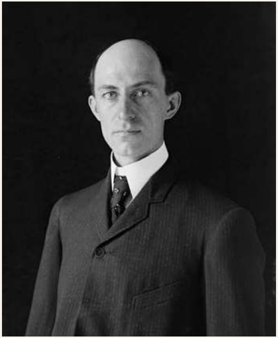
Example: Control of an aircraft

The flying problem

Wilbur Wright said in 1901:

- *Men know how to construct airplanes.*
- *Men also know how to build engines.*
- *Inability to* ***balance*** *and* ***steer*** *still confronts students on* ***the flying problem****.*
- *When this one feature has been worked out, the age of flying will have arrived, for all other difficulties are of minor importance.*

Wilbur Wright (1867–1912)



A control problem:

balance and steer = stabilise and control

Example: Control of an aircraft

The flying problem

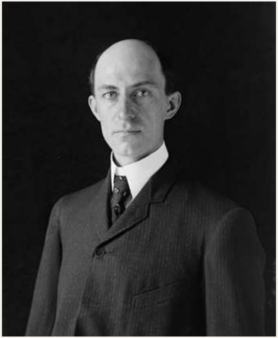
Wilbur Wright said in 1901:

- *Men know how to construct airplanes.*
- *Men also know how to build engines.*
- *Inability to **balance** and **steer** still confronts students on **the flying problem**.*
- *When this one feature has been worked out, the age of flying will have arrived, for all other difficulties are of minor importance.*

A control problem:

balance and steer = stabilise and control

Wilbur Wright (1867–1912)



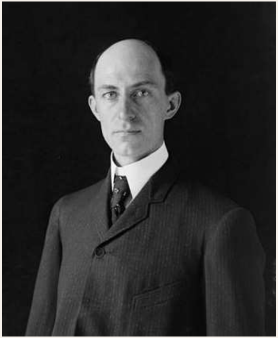
Example: Control of an aircraft

The flying problem

Wilbur Wright said in 1901:

- *Men know how to construct airplanes.*
- *Men also know how to build engines.*
- *Inability to* ***balance*** *and* ***steer*** *still confronts students on* ***the flying problem****.*
- *When this one feature has been worked out, the age of flying will have arrived, for all other difficulties are of minor importance.*

Wilbur Wright (1867–1912)



A control problem:

balance and steer = stabilise and control

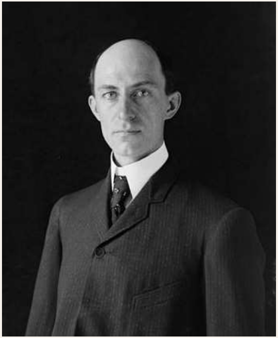
Example: Control of an aircraft

The flying problem

Wilbur Wright said in 1901:

- *Men know how to construct airplanes.*
- *Men also know how to build engines.*
- *Inability to* ***balance*** *and* ***steer*** *still confronts students on* ***the flying problem****.*
- *When this one feature has been worked out, the age of flying will have arrived, for all other difficulties are of minor importance.*

Wilbur Wright (1867–1912)



A control problem:

balance and steer = stabilise and control

Example: Control of an aircraft

Aircraft flight control

The control system of an aircraft consists basically of

- Flight control surfaces
- Cockpit controls
- Linkage systems
- Engine controls

Flight control surfaces

Allow the pilot to adjust aircraft attitude: rotation around vertical, longitudinal and lateral axes.

The flying problem

The Wright Brothers had to solve a complex multi-input multi-output (MIMO) control problem!

The UNIVERSITY of NEWCASTLE

Example: Control of an aircraft

Aircraft flight control

The control system of an aircraft consists basically of

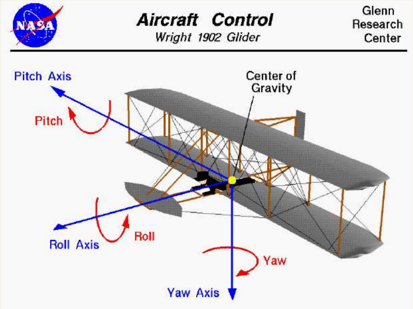
- Flight control surfaces
- Cockpit controls
- Linkage systems
- Engine controls

The flying problem

The Wright Brothers had to solve a complex multi-input multi-output (MIMO) control problem!

Flight control surfaces

Allow the pilot to adjust aircraft attitude: rotation around vertical, longitudinal and lateral axes.



Example: Control of an aircraft

Aircraft flight control

The control system of an aircraft consists basically of

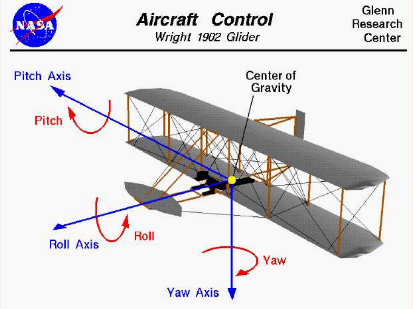
- Flight control surfaces
- Cockpit controls
- Linkage systems
- Engine controls

The flying problem

The Wright Brothers had to solve a complex multi-input multi-output (MIMO) control problem!

Flight control surfaces

Allow the pilot to adjust aircraft attitude: rotation around vertical, longitudinal and lateral axes.

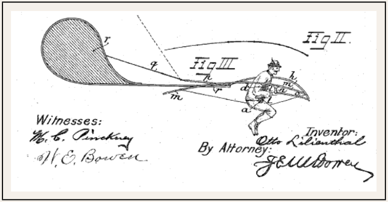


Example: Control of an aircraft

Otto Lilienthal (1848–1896)

Pioneered the idea of increasing pilot control authority to achieve flight stability: he used his body weight to steer and stabilise

Otto Lilienthal's glider



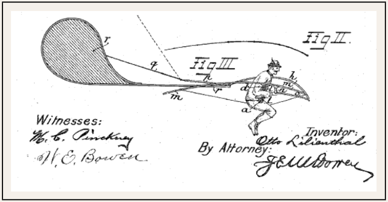
Wright's wing warping idea

Example: Control of an aircraft

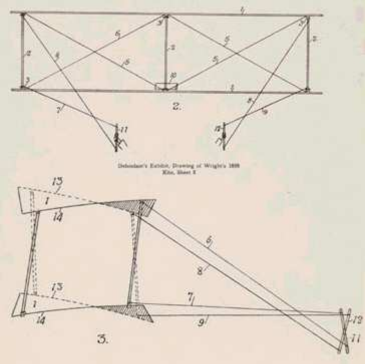
Otto Lilienthal (1848–1896)

Pioneered the idea of increasing pilot control authority to achieve flight stability: he used his body weight to steer and stabilise

Otto Lilienthal's glider



Wright's wing warping idea

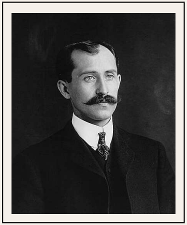


The Wright brothers improved on Lilienthal's idea using **wing-warping** and **anhedral wings** to increase controllability

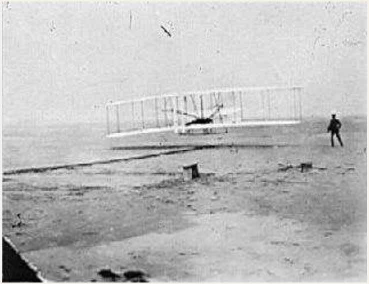
Example: Control of an aircraft

The Wright Brothers solved the flight control problem and flew their glider at Kitty Hawk on December 17, 1903.

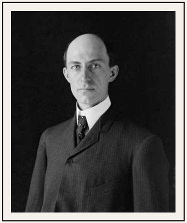
Orville Wright



The Wright Flyer I at Kitty Hawk



Wilbur Wright



Example: Control of an aircraft

Consequences of inadequate control design

- Flight control problems are still current
- 1993 crash of SAABs air-fighter Gripen illustrates the potential dramatic consequences of bad control design
- The control design failed to include **antiwindup** compensation for rate limitations, which originated **pilot induced oscillations**

Saab JAS 39 Gripen

Outline

1. Motivation for ELEC4410
   - Why study Control Systems Design?
   - Some application examples

2. Course Overview
   - Lecturers
   - Purpose and Objectives
   - Assessment
   - Lectures and communication

The ELEC4410 lecturers

Lecturer	Office	Availability
Greg Adams	EAG03d	Wednewsdays 10:00 to 12:00
Gregory.Adams@newcastle.edu.au		Phone: 4921 6033
Julio Braslavsky	EAG02	Thursdays, 15:00 to 17:00
Julio.Braslavsky@newcastle.edu.au		Phone: 4921 5740
Alejandro Rojas	EF07e	Mondays, 15:00 to 17:00
Alejandro.Rojas@newcastle.edu.au		Phone: 4921 6023
James Welsh	EAG15	Mondays, 15:00 to 17:00
James.Welsh@newcastle.edu.au		Phone: 4921 6087

Purpose and objectives

ELEC4410 builds on ELEC4400 introducing modern control techniques and practical implementation issues. It gives:

- An exposure to modern control tools
- An in-depth introduction to the fundamental concepts of linear system theory
- A basic understanding of various factors which limit the achievable control system performance
- Experience in lab implementations of control systems.
- An initial exposure to control implementation issues
- Knowledge of case studies of successful modern control implementations.

Purpose and objectives

ELEC4410 builds on ELEC4400 introducing modern control techniques and practical implementation issues. It gives:

- An exposure to modern control tools
- An in-depth introduction to the fundamental concepts of linear system theory
- A basic understanding of various factors which limit the achievable control system performance
- Experience in lab implementations of control systems.
- An initial exposure to control implementation issues
- Knowledge of case studies of successful modern control implementations.

Purpose and objectives

ELEC4410 builds on ELEC4400 introducing modern control techniques and practical implementation issues. It gives:

- An exposure to modern control tools
- An in-depth introduction to the fundamental concepts of linear system theory
- A basic understanding of various factors which limit the achievable control system performance
- Experience in lab implementations of control systems.
- An initial exposure to control implementation issues
- Knowledge of case studies of successful modern control implementations.

Purpose and objectives

ELEC4410 builds on ELEC4400 introducing modern control techniques and practical implementation issues. It gives:

- An exposure to modern control tools
- An in-depth introduction to the fundamental concepts of linear system theory
- A basic understanding of various factors which limit the achievable control system performance
- Experience in lab implementations of control systems.
- An initial exposure to control implementation issues
- Knowledge of case studies of successful modern control implementations.

Purpose and objectives

ELEC4410 builds on ELEC4400 introducing modern control techniques and practical implementation issues. It gives:

- An exposure to modern control tools
- An in-depth introduction to the fundamental concepts of linear system theory
- A basic understanding of various factors which limit the achievable control system performance
- Experience in lab implementations of control systems.
- An initial exposure to control implementation issues
- Knowledge of case studies of successful modern control implementations.

The University of Newcastle

Purpose and objectives

ELEC4410 builds on ELEC4400 introducing modern control techniques and practical implementation issues. It gives:

- An exposure to modern control tools
- An in-depth introduction to the fundamental concepts of linear system theory
- A basic understanding of various factors which limit the achievable control system performance
- Experience in lab implementations of control systems.
- An initial exposure to control implementation issues
- Knowledge of case studies of successful modern control implementations.

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Topics and assumed knowledge

Topics

- Internal model control (16 hours),
- Fundamental Limitations in Control Design (5 hours),
- Introduction to System Identification (2 hours),
- State Space System Theory (21 hours),
- State Space Control Design (14 hours),
- Optimal Estimation (5 hours),

Assumed Knowledge

- ELEC4400
- Linear algebra and Laplace transforms
- Complex variables and linear ODE

Assessment and workload

The course will be assessed as follows:

- Assignments (15%)
- Labs (10%)
- Quiz (15%)
- Exam (60%)

Weekly assignments (individual or group of 2) (10%)
Paper review presentation (group of 2) (5%)

Groups of at most 3 students
1 compulsory lab, 4 elective labs

17 September 2008, 8am-10am, EF14
open book, covering first 8 weeks

40% min required to pass final exam

Assessment and workload

The course will be assessed as follows:

- Assignments (15%)
- Labs (10%)
- Quiz (15%)
- Exam (60%)

Weekly assignments (individual or group of 2) (10%)
Paper review presentation (group of 2) (5%)

Groups of at most 3 students
1 compulsory lab, 4 elective labs

17 September 2008, 8am-10am, EF14
open book, covering first 8 weeks

40% min required to pass final exam

Assessment and workload

The course will be assessed as follows:

- Assignments (15%)
- Labs (10%)
- Quiz (15%)
- Exam (60%)

Weekly assignments (individual or group of 2) (10%)
Paper review presentation (group of 2) (5%)

Groups of at most 3 students
1 compulsory lab, 4 elective labs

17 September 2008, 8am-10am, EF14
open book, covering first 8 weeks

40% min required to pass final exam

Assessment and workload

The course will be assessed as follows:

- Assignments (15%)
- Labs (10%)
- Quiz (15%)
- Exam (60%)

Weekly assignments (individual or group of 2) (10%)
Paper review presentation (group of 2) (5%)

Groups of at most 3 students
1 compulsory lab, 4 elective labs

17 September 2008, 8am-10am, EF14
open book, covering first 8 weeks

40% min required to pass final exam

The University of Newcastle

Contact

Lecture times

Activity	Day	Time	Room
Lecture	Monday	10:00–12:00	EAG01
Tutorial	Wednesday	08:00–10:00	EF14/ES204
Lecture	Thursday	13:00–15:00	EAG01

Communication

Course information, assignments, timetables, announcements and materials, will be regularly posted in Blackboard.

Enrolled students should visit **Blackboard** regularly!

Contact

Lecture times

Activity	Day	Time	Room
Lecture	Monday	10:00–12:00	EAG01
Tutorial	Wednesday	08:00–10:00	EF14/ES204
Lecture	Thursday	13:00–15:00	EAG01

Communication

Course information, assignments, timetables, announcements and materials, will be regularly posted in Blackboard.

Enrolled students should visit **Blackboard** regularly!

Contact

Lecture times

Activity	Day	Time	Room
Lecture	Monday	10:00–12:00	EAG01
Tutorial	Wednesday	08:00–10:00	EF14/ES204
Lecture	Thursday	13:00–15:00	EAG01

Communication

Course information, assignments, timetables, announcements and materials, will be regularly posted in Blackboard.

Enrolled students should visit **Blackboard** regularly!