Aeronautical Systems - Guidance and Control

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Course Details

Description

This course was first held in Politecnico di Milano during April and July 2014, with the goal of teaching a practical approach to engineering. The lessons and models provide students both theoretical and practical tools to help them learn control theory and model based design. They will learn kinematics and dynamics and develop the equations of motion for a blimp. Using Simulink, they will model the dynamics of the blimp and design PID controllers for both altitude and yaw control. Using the Simulink Hardware Support Packge for Arduino and a custom Simulink toolbox developed specifically for this course, the students will deploy their controller designs to Arduino hardware.

In the first three lessons students are introduced to MATLAB, the non-linear six degree of freedom equations of motion are developed and used to describe the motion of the blimp, and the use of state space and linear transfer function models for calculating the frequency response of dynamic systems is demonstrated. In the fourth lesson, Simulink is used to model the dynamics of the blimp and examples of PID controllers are given. Students will learn to program an Arduino board to control the blimp using Simulink in the fifth lesson and Kalman filters are introduced in the final lesson to develop navigation equations for the blimp.

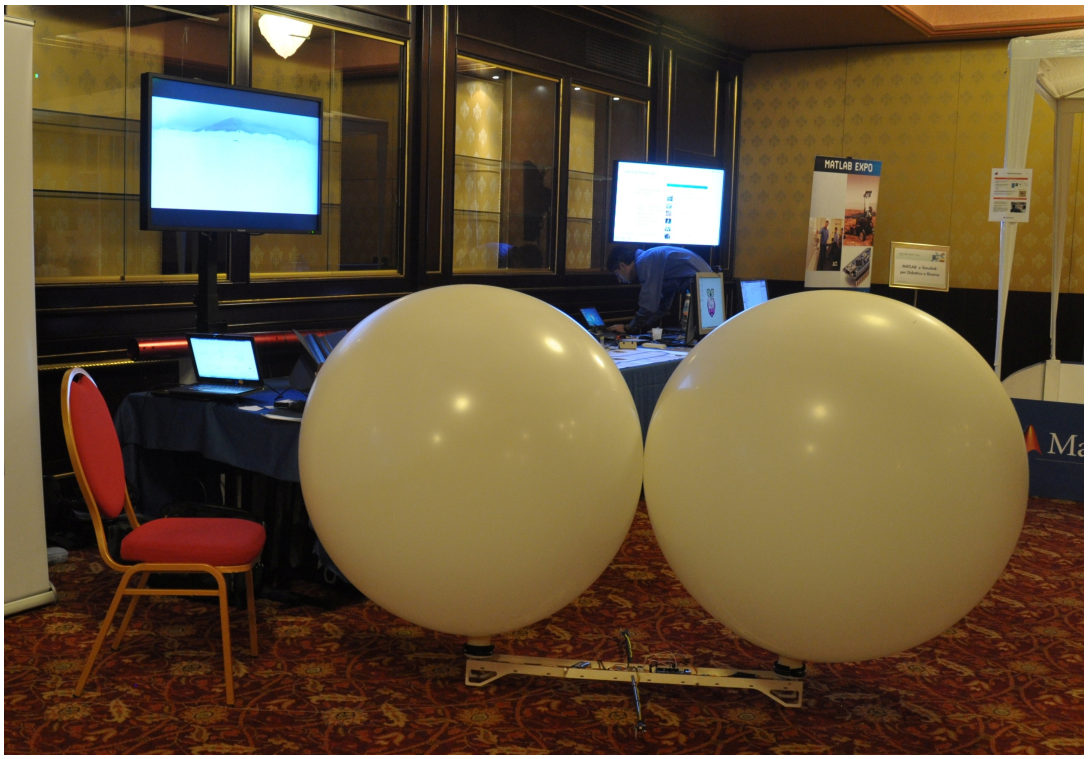

Figure 1: The blimp built for the course.

CAD models of the blimp and circuit design files for an Arduino sensor shield are packaged with the material for this course to allow the students to build a copy of the blimp used in the course.

Original Course Documents

BLIMP 2014

Course Contents

Lesson 1: MATLAB Tutorial

- Getting Started
- Examples
- Language Fundamentals
- Mathematics
- Graphics
- Programming

Lesson 2: Dynamics and Kinematics

- Reference Frames
  - Inertial Reference Frame
  - NED Reference Frame
  - Body Fixed Reference Frame
  - Coordinate Systems

- Law of Dynamics
  - Center of Mass
  - Linear Momentum Conservation
  - Angular Momentum Conservation
- Kinematics
  - Direction Cosine Matrix
  - Euler Angles
  - Quaternions
- Linear Systems and State Space Representation
  - Blimp Model

Lesson 3: System State, Transfer Function and Frequency Response

- State of a Dynamic System
  - The State Equation
  - Output Equations
  - State Equation Based Modeling Procedure
- Transformation From State-Space Equations to Classical form
- Transformation From Classical Form to State-Space Representation
- The Matrix Transfer Function
- Frequency Response
  - The Concept of Frequency Response
  - Analytical Expressions for the Frequency Response

Lesson 4: Introduction to Simulink

- Introduction
  - Simulink
  - Getting Started
  - Most Important Blocks
- Pulse Response
  - Simulink Model
- Blimp System's Stability
  - Altitude Stability
  - Yaw Stability
- Direct Integration
  - Alttude Time Domain

Lesson 5: Arduino Basics

- What is Arduino
- Programming Arduino with Simulink
  - A First Example
  - Traffic Light Controller
  - Servo Control
- Sensors Reading with Simulink and Arduino
  - What is a MEMs
  - MEMs Communication Interface

    - Skyward Blimp Target
    - Read Data from Sensors
    - PID Example

Lesson 6: Navigation

- Principles of Navigation
    - Determining Attitude
    - Determining Position
- Random Process (basics)
- Linear Systems: Observer
    - Observability
    - Observer Derivation
    - Kalman Filter
- Kalman filtering
    - Recursive Kalman Filter
    - Extended Kalman Filter
    - Optimal Control
- Blimp Navigation
    - Sensors
    - Choice of Sensors
    - Inertial Navigation System
    - Altimeter
    - Ranging Sensor

Course Materials

PID Simulators - Lesson 4

- Altitude Simulator
- Yaw Simulator

Arduino Examples - Lesson 5

- Drive Servo Motor
- Traffic Light Controller

Resources

Arduino Shield Circuit Diagram

- Circuit Design Files

Blimp CAD Models

- SOLIDWORKS® Files

Links

Skyward Experimental Rocketry

Learn more about MathWorks academic resources:

- MATLAB Courseware
- Hardware Resources
- Classroom Resources
- MATLAB Examples
- Books
- Tutorials
- Webinars
- Technical Articles