SIE 456/556: Fundamentals of Guidance for Aerospace Systems
Syllabus
Fall 2011

Course Instructor

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Office Hours: Tuesday 2-5pm, or by appointment

Course Meetings and Distance Learning

Monday & Wednesday 12-1:15pm, room ENGR 301 (Old Engineering Building).

The lectures will be broadcasted in real-time as well as videotaped and stored at webcast.engr.arizona.edu. Students will have the ability to view the lectures on-demand from the office or from home.

Course Description and Objectives

The main objective of the course is to introduce the students to the fundamental principles behind the development of guidance laws for aerospace systems. More specifically, the course will introduce basic and more advanced guidance concepts for aerospace vehicles and discuss their practical implementation on missiles, planetary landers, and reentry and launch vehicles. The first part of the course is focused on the intercept guidance problem and its application to guided missile systems. The basic ideas behind proportional navigation are introduced together with a detailed analysis of the PN law in both time and frequency domains. The guidance law design is viewed from a control theory standpoint and design methods using both time domain and frequency domain are introduced. Special emphasis is placed on non-linear control design techniques including sliding control mode and Lyapunov-based approach for a robust design and improvement of targeting performance. In the second part of the course, the optimal control theory is introduced as main tool to design guidance algorithms for planetary landers. More specifically, the design of guidance laws for powered descent landing on planetary bodies is discussed. Both numerical and analytical methods to determine targeting reference trajectories are presented together with real-time guidance algorithms that close the loop on the planned path. The third part of the course will be focused on a) guidance algorithms for hypersonic reentry vehicles and b) ascent guidance for Launch Vehicles (LV). In this context, guidance algorithms available to control the bank angle for low lift-to-drag ratio capsules will be discussed together with powered exo-atmospheric guidance algorithms for LV orbit targeting. Particular emphasis will be given to the practical implementation of the guidance algorithms.

At the end of the course the student is expected to:

1. Master the design and analysis process for missile guidance in both time and frequency domains.
2. Simulate planar and three-dimensional engagement scenarios to analyze a variety of missile guidance algorithms.
3. Understand the principles of optimal guidance for planetary landers, reentry and launch vehicles. Have the ability to generate both analytically and numerically optimal open-loop trajectories for ascent and landing vehicles.
4. Design and analyze, via 3-DOF simulations guidance algorithms, for powered terminal landing and launch vehicle orbital targeting.

Semester assignments, midterm and final project

During the semester, students will be required to submit approximately 8 (eight) homework assignments on a bi-weekly basis. The homework will be a combination of theoretical analysis and computer simulations for guidance design, analysis and performance verification. In addition, the student will be required to take a midterm exam testing the understanding of missile guidance principles. At the end of the course, students will be required to submit a final project, which will be evaluated in place of a final exam. The final project will be an extensive analysis and a 3-DOF simulation of a guidance system for planetary landers and ascent vehicles, or a combination of both. Graduate students will be required to answer additional questions during the midterm, as well as perform additional analysis and more extensive simulations on the final project.

Grades Distribution

A regular grade (A, B, C, D, E) will be assigned. The grade will be established as function of class performance. Each student will receive a numerical value according to his/her performance on the following items:

Homework (30%)
Midterm Exam (30%)
Final Project/Exam (40%)

The final grade will depend on the overall class performance.

Class Schedule

The following class schedule is tentative and assumed to be developed over a course of 14 weeks.

Week 1: Introduction to the problem of guidance for aerospace vehicles. The basics of missile guidance

Week 2: Fundamental principles of Parallel Navigation. The PN guidance law

Week 3: Time domain analysis of the PN guidance for guided missiles systems

Week 4: Frequency domain analysis of the PN guidance for guided missile systems

Week 5: Missile guidance design using the time domain approach

Week 6: Missile guidance design using the frequency domain approach

Week 7: Guidance laws performance analysis under stochastic inputs. Overview of the integrated missile guidance design process.

Week 8: Fundamentals of optimal control theory. Guidance as optimal control problem.

Week 9: Principles of guidance for planetary landers. The Apollo guidance for lunar landing.

Week 10: Optimal guidance for planetary landers. Analytical and numerical approach.

Week 11: Non-linear techniques for terminal powered landing guidance on planetary bodies. Sliding mode control and Lyapunov approach.

Week 12: Hypersonic guidance for Reentry vehicles.

Week 13: Principles of guidance for launch vehicles. The Powered Exo-atmospheric Guidance (PEG, shuttle guidance).

Week 14: Advanced guidance laws for launch vehicles.

Textbooks

Rafael Yanushevsky, Modern Missile Guidance, Boca Raton : CRC Press, ©2008. (Required).

Paul Zarchan, Tactical and Strategic Missile Guidance, *Progress in Astronautics and Aeronautics Series*, 219 © 2007, 5th Edition, 889 pages, (Recommended)

Instructor class notes and relevant research papers (the instructor will make them available through the D2L course website at d2l.arizona.edu)

Software

MATLAB (full version available for download to UA students)