Module 1a

Modern Navigation Systems

Introduction to the Course:
Summary, Emphasis, Motivation, & Objectives

Course summary

- In Modern Navigation Systems, you will explore the use of satellite, terrestrial, celestial, radio, magnetic, and inertial systems for the real-time determination of
  - o Position
  - o Velocity (speed and direction)
  - o Acceleration
  - o Attitude (e.g. pitch, roll, and yaw)
  - o Time (the most important of them all…)

Areas of Emphasis

- The historical importance of navigation systems
- Avionics navigation systems for high performance aircraft (and UAVs)
- GPS
- The relationships between navigation, cartography, surveying, and astronomy
- Emerging trends for integrating multiple navigation techniques into tightly coupled systems

Motivation for developing this Course

- The instructor took the graduate course, *Air Traffic Control* (ATC), at MIT in the Aero & Astro Department in 1974
  - ATC used the first (pre-GPS) edition of the textbook by Kayton & Fried; we will be using the second (post-GPS) edition
  - This course brought together the information and skills that underlie many of the engineering and scientific disciplines
    - This information and the related skills developed to utilize it have **withstood the test of time** and have proven invaluable from a career perspective
- The history of the topics covered in Modern Navigation Systems parallels the history of the United States, and breathes life into the importance of STEM and STEAM (where A = arts)
- The material is also, simply put, interesting

There is also the competitive aspect…

- From Wikipedia:
  - "The US Naval Academy announced that it was discontinuing its course on celestial navigation, considered to be one of its most demanding course, from the formal curriculum in the spring of 1998 stating that a sextant is accurate to a three-mile (5 km) radius, while a satellite-linked computer can pinpoint a ship within 60 feet (18 m) as long as the satellites are functioning correctly. Presently, midshipmen continue to learn to use the sextant, but instead of performing a tedious 22-step mathematical calculation to plot a ship's course, midshipmen feed the raw data into a computer." http://en.wikipedia.org/wiki/Celestial_navigation
- The contrasting view, taken herein, it that since GPS uses the same "tedious … mathematical calculation(s)," it is more essential than ever that these calculations be widely understood

Course learning objectives

- Anyone can be a spectator; in this course you will learn to do things for real
- The next pages list some of the “things” that *you will be able to* “do” upon completion of the course

Objective 1

- Describe, compare, and reproduce the historical measurements and computations of Newton, Mason & Dixon, Lewis and Clark and others with respect to astronomy, surveying, and navigation.

Objective 2

- Derive the Keplerian orbital parameters and equations from the basic physics of force and momentum and compute the locations versus time, in spherical and Cartesian coordinate systems, of earth orbiting satellites, the earth's moon, the moons of Jupiter and other planets, and the orbits of the planets around the sun.

Objective 3

- Use angle measurements obtained from sextant observations of the stars to solve these equations and determine one's position on the surface of the earth. Convert the Keplerian orbital equations into the navigation equations of the Global Positioning System, and use measurements of time and distance, to solve these equations and determine one's position on the surface of the earth.

Objective 4

- Use the Keplerian equations to create algorithms applicable to the navigation, guidance, and control avionics of a typical (e.g., Cessna 172) small civil aircraft.

Objective 5

- Explain to others the historical and modern technologies used for radio, optical, inertial, magnetic, and celestial navigation

Objective 6

- Define and execute an original research project that builds on and extends the skills learned above.
  - In fact, you will have done this by the end of the term

Objective 7

- Although not a “formal” objective from a curriculum and credit perspective, the final course objective has three parts
  - o Learn new ways of approaching and solving problems by merging historical concepts with modern technology
  - o See and do things that are completely new to you
  - o Have fun

End of Mod 1A