ASEN 6091 / ECEN 5014
Global Navigation Satellite System (GNSS) Receiver Architectures

Spring Semester 2021
Scheduled Lecture Times: Mon & Wed: 16:10 – 17:25

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Course Overview

GNSS is a generic term describing the expanding field of satellite-based navigation/timing systems. The most prevalent of these systems currently is GPS which is owned and operated by the US. However, Russia maintains a system known as GLONASS. Both the European Union and China are developing their own GNSS system designated Galileo and Beidou (Compass), respectively. Lastly, there are a number of regional GNSS augmentation systems including but not limited to: WAAS (US), QZSS (Japan), EGNOS (EU), India (GAGAN) each of which provides GNSS corrections and, in some cases, ranging information.

There are a multitude of GPS receivers on the market today. Often times these receivers are embedded for monitoring and control and often, unfortunately, treated as a "black box". This course goes into the inner workings of a GPS receiver and also discusses features common to all GNSS receivers. The course will cover the analog radio frequency conditioning from the antenna to the analog-to-digital converter, then focus on the various signal processing algorithms used in GNSS receiver (acquisition, code tracking, carrier tracking, and navigation data decoding), as well as present the position/time solution. Such treatment of the operation of the receiver will provide insight into the trade-offs that go into GNSS receiver design.

The GNSS receiver is a specialized Code Division Multiple Access (CDMA) spread spectrum receiver. Thus those interested in CDMA technology will benefit from a "hands on" perspective and gain insight into the specifics of CDMA receivers designed for navigation and timing functionality.

Students interested in the course will be required to have a solid background in using Matlab. Some knowledge in signal processing, particular time/frequency domain transforms, and control theory would be helpful. Lastly, background on GPS or GNSS in general (such as ASEN 5090) is expected, but not required, and will definitely aid in the overall understanding of the technology.

Course Format

The course will follow a blend of traditional lectures with external independent lab/computing assignments. The traditional lectures will provide the basics of low-level GPS signal processing building on the internal operation of a GNSS receiver. Comprehensive assignments on the implementation of this receiver processing in Matlab will be given to the students. There will be a midterm which will be a take-home 24-hour exam. And then a final course project which will result in a presentation and report on the day of the final exam. This 2021 offering will also bring in the gitlab and slack collaborative tools for the class.

Textbook (not required)
A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach; K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. H. Jensen; 2007; ISBN-10: 978-0-8176-4390-4

Reference Material
1) Course Notes
2) Understanding GPS/GNSS: Principles and Applications; E.D. Kaplan (Editor); 3rd ed; 2017; ISBN13: 978-1630810580
3) Global Positioning System: Signals, Measurements and Performance, P. Enge, P. Misra, 2nd ed; 2010, ISBN-13: 978-0970954428
4) ICDs for GPS - http://www.gps.gov/technical/icwg/ (Also will refer to ICDs for other GNSS)
5) Global Positioning System: Theory & Applications; B. W. Parkinson (Editor), J. J. Spilker (Editor); Vol 1&2; 1996; ISBN13: 978-1563471063 & 978-1563471070 (new edition to be released shortly)
6) Fundamentals of Global Positioning System Receivers: A Software Approach; James Bao-Yen Tsui; 2000; ISBN13: 978-0471381549
7) Spread Spectrum Systems with Commercial Applications, R. C. Dixon, 3rd ed; 1994, ISBN13: 978-0471593423
8) Phase-Locked Loops : Design, Simulation, and Applications; R. Best; 6th ed; 2007; ISBN13: 978-0071493758

Course Schedule

Week(s)	1	Course Introduction & GPS Software Receiver Overview (Assignment 1)
Week(s)	2	Front End Design/Data Collection
Week(s)	3 & 4	GNSS Signal Acquisition (Assignment 2 & 3)
Week(s)	5 & 6	GNSS Signal Tracking (Assignment 4 & 5)
Week(s)	7	Navigation Data Decoding (Assignment 6)
Week(s)	8	Position Solution (Assignment 7)
Week(s)	9	Differential Position Solution (Assignment 8)
Week(s)	10	Midterm & Project Proposal
Week(s)	11-15	Project Work

Final Exam/Presentation Wed 5-May 7:30-10:00PM (based on final exam schedule)

Course /Grades/Evaluation

50% - Assignments
20% - Midterm (typically take-home 24 hour exam)
30% - Final (Course Project Presentation/Report)

Notes
1) Comprehensive assignments will be assigned approximately once per week at the beginning of the term, expected to be worked individually
2) Each assignment will be based on a 100 point scale
3) A midterm should be expected during the tenth week of the semester, typically format is an individual "take-home" 24 hour exam
4) A final project, based on the material from two thirds (approximate) of the course will replace a final exam. The project will require both a presentation and written report/code submission. It will be possible to work in groups of two, if preferred given sufficient scope for the project.

Material is preliminary and subject to change

SYLLABUS STATEMENTS

1) Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Code of Conduct.

2) Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- maintain 6-foot distancing when possible,
- wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders,
- clean local work area,
- practice hand hygiene,
- follow public health orders, and
- if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the "Accommodation for Disabilities" statement on this syllabus.
All students who are new to campus must complete the COVID-19 Student Health and Expectations Course. Before coming to campus each day, all students are required to complete the Buff Pass.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, please email Prof Dennis Akos as soon as possible.

3) Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

4) Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

5) Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to

academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

6) Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.
Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

7) Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please inform Prof Dennis Akos of any such holidays that may cause a conflict, over the semester, in the first wee of the semester. See the campus policy regarding religious observances for full details.