EECE 5698 - GNSS SIGNAL PROCESSING

Northeastern University
Department of Electrical and Computer Engineering

Spring 2018

Instructor:	Prof. Pau Closas	**Place:**	Kariotis Hall 302
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Office:	529 ISEC		2:50pm - 4:30pm

Office Hours: After class on Wednesdays (4:30pm to 5:30pm), or by appointment. If emails are sent, please always include [EECE5698] in subject line for filtering.

Prerequisites: An undergraduate-level understanding of probability, statistics, calculus, and linear algebra is assumed. Exposure to signal processing concepts is desirable. In terms of courses: EECE 2410, MATH 2341, and EECE2520.

Course Catalog Description: The course provides an introduction to Global Navigation Satellite Systems (GNSS), covering the fundamental aspects of operation. The emphasis of the course is on receiver design, although onboard satellite aspects are also discussed such as the different signals and GNSS constellations (focus on GPS and Galileo). Students taking this course will gain basic knowledge of the underlying principles of GNSS, while learn how to apply tools of statistical signal processing from detection, estimation, and filtering theories to a real-world engineering application. The syllabus includes notions in GNSS history; constellations and signals; propagation channel and main impairments; RF front end architectures; signal acquisition; signal tracking; position calculation and integrity measures; sensor hybridization and data fusion; and identification of the most challenging scenarios of operation.

Grading Policy:

- Homework (40%), matlab-based exercises and questions.
- In-class Quizzes (20%), quick questionnaires about course topics.
- Final project (40%), on selected research topics*.

* including a class presentation and a report on selected research articles complementing course topics.

Class Policy: Regular attendance is essential and expected.

Academic Honesty: Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation.

Summary of Course Objectives: Students should be able to:

1. Classify and identify the various GNSS systems that are available, including frequency bands, bandwidths, signals, and main characteristics.
2. Understand and explain the basic positioning principles that are used in satellite-based navigation, including ranging and Doppler estimation, and their use in multilateration algorithms.
3. Analyze GNSS signals in both continuous and discrete time, including characterization of spread-spectrum modulations and pseudo-random noise sequences. Interpretation of the propagation channel as a linear time-invariant (LTI) system with random perturbations.
4. Provide basic design requirements for RF front-ends, enabling downconversion and sampling of GNSS signals. Appropriate application of sampling theorem and manipulation of discrete-time signals.
5. Describe and analyze the main signal processing of a GNSS receiver, including acquisition, tracking and navigation. Application of detection (acquisition) and estimation (tracking) theories.
6. Recognize the main vulnerabilities and limitations of GNSS technology, including interference sources such as intentional jamming, unintentional interferences, spoofing, or ionospheric scintillation. Analyze the most common detection methods and countermeasures strategies. Interpret anti-jamming techniques in the context of robust signal processing theory.
7. Understand the alternatives for indoor positioning, including taxonomy of available technologies, classification of positioning strategies and methods. Trade-off between model-based and model-free schemes.
8. Present engineering problems in mathematical terms, allowing for technically sound solutions.
9. Be convinced that GNSS is not only an awful naming for EECE5698.

Topics Covered/Syllabus:

1. **Course introduction:** positioning is everywhere; GNSS is a key technology; main GNSS components; GNSS limitations; relation to syllabus topics; review of mathematical tools.

2. **Fundamentals of satellite-based navigation:** historical remarks on navigation; positioning concepts; system segments; space segment; ground segment; user segment.

3. **GNSS signals in space:** overview of the main signal characteristics: GPS, Galileo, Glonass, Beidou; focus on GPS L1 C/A signal; focus on Galileo E1 signal; BPSK vs BOC modulations.

4. **GNSS channel model:** propagation delay; Doppler effect; multipath and non-line-of-sight; ionospheric and tropospheric delays.

5. **GNSS receiver:** antenna and RF front-end; signal sampling; signal acquisition as a detection problem; signal tracking as a filtering problem; observables' computation.

6. **Navigation solution:** Code-based positioning; Code- and carrier-based positioning; least squares solution; weighted least squares solution; Kalman filtering solution; basic schemes for GNSS/inertial hybridization.

7. **Vulnerabilities of GNSS:** intentional interferences and jammers; unintentional interferences; spoofing attacks; ionospheric scintillation; detection and mitigation techniques.

8. **Indoor positioning:** basic measurements; positioning approaches: model-based versus model-free methods; hybridization and data fusion; main technologies.

Useful Books:

- K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. Jensen, A software-defined GPS and Galileo receiver: a single-frequency approach. Springer Science & Business Media; 2007.

- E. Kaplan and C. Hegarty, Understanding GPS: principles and applications. Artech house; 2005.

- P. Groves, Principles of GNSS, inertial, and multisensor integrated navigation systems (Second ed.) GNSS technology and applications series, Artech House; 2013.

- J. B. Tsui, Fundamentals of global positioning system receivers: a software approach. John Wiley & Sons; 2005.

Other Useful/Free References:

- European Space Agency's Navipedia, `www.navipedia.net`

- GNSS-SDR open source project, `gnss-sdr.org`

- Inside GNSS, `www.insidegnss.com`

- GPS World, `gpsworld.com`