



GPGN 404 Syllabus - Digital Signal Processing

Prerequisites: MATH 213, MATH225 and MATH348 or PHGN311

Instructor:

- Jeffrey Shragge, Associate Professor, Geophysics Department

Contact Information (O/P/E):

- Green Center Room 241
- 303.273.3552
- jshragge@mines.edu (<https://mail.google.com/mail/?view=cm&fs=1&tf=1&to=jshragge@mines.edu>)

Class meeting days/times/locations:

- Lectures: MW 1100-1150h; Brown Building W250
- Lab: Thur 1400-1600h; CoorsTek 130

Office hours:

- Wednesdays between 1.00-3.00pm
- Limited availability outside these hours by email request

Teaching Assistant:

- Brett Bernstein bbernstein@mymail.mines.edu (<https://mail.google.com/mail/?view=cm&fs=1&tf=1&to=bbernstein@mymail.mines.edu>)
- Office Hours: By appointment

Instructional Activity:

- 2 hours lecture
- 3 hours lab
- 3 semester hours

Course Designation:

- GPGN Major Requirement

Course Description from Bulletin

The fundamentals of 1D and 2D digital signal processing as applied to geophysical investigations are studied. Students explore the mathematical background and practical consequences of the

- Fourier Series and 1D/2D Fourier Transforms
- Linear Time-invariant (LTI) systems
- Convolution and Deconvolution
- Properties of Discrete Systems
- Sampling Theorem and signal reconstruction
- Z-Transform
- Discrete-time Fourier Transform
- Discrete Fourier Series and Discrete Fourier Transform

- Windowing and Spectrograms
- Realization of Digital Filters
- FIR filter design
- IIR filter design

Emphasis is placed on applying the knowledge gained in lecture to exploring practical signal processing issues. This is done through homework and in-class practicum assignments requiring the programming and testing of algorithms discussed in lecture.

Learning Outcomes

Conceptual Skills: This senior-level undergraduate course builds on analytical skills learned in previous years by applying those skills to the analysis of 1D and 2D digital signals. Major objectives of the course include:

1. Learning and exploiting similarities between concepts learned in calculus, differential equations, and elsewhere, and how they appear in the context of digital signal analysis.
2. Understanding how to use discrete Fourier transforms in the analysis and processing of digital signals.
3. Learning how to digitally sample continuous analog signals, reconstruct continuous signals from sampled ones, and the conditions under which this reconstruction is feasible.
4. Learning the pitfalls and tradeoffs in the design and application of common digital filters.

Practical Skills: To help meet these objectives students will:

1. Independently design, develop, validate and apply computer programs to solve digital signal analysis and processing tasks, largely using the Python language and its associated tool kits (i.e., Numpy, Scipy and Matplotlib).
2. Gain experience in choosing and applying 1D/2D filters to achieve specific filtering tasks through a range of numerical exercises and an independent project.

Course Assessment procedures

The course will be assessed according to the following:

- Quizzes (40%) - Online and due by Fridays at 2359h.
- Labs (40%) - Thursdays. Due following Friday at 2359h.
- Project (20%) - Due at end of term.

Course Schedule*

*Timeline subject to revision

- Week 1 (Jan 11-15)
 - No class Jan 11
 - Module 01 - Introduction
- Week 2 (Jan 18-22)
 - No class Jan 18 (MLK Day)
 - Module 02 - Terminology of Digital Signal Processing
 - Module 03 - Complex Numbers
 - Lab 1 (Jan 21) - Python Refresher and Complex Numbers
- Week 3 (Jan 25-29)
 - Module 03 - Complex Numbers
 - Module 04 - Fourier Series and Applications
 - Quiz 1 (by Jan 29) - Complex Numbers
 - Lab 2 (Jan 28) - Fourier Series
- Week 4 (Feb 01-05)
 - Module 04 - Fourier Series and Applications
 - Module 05 - Fourier Transform and Applications
 - Quiz 2 (by Feb 5) - Fourier Series
 - Lab 3 (Feb 4) - 1D/2D Fourier Transforms
- Week 5 (Feb 08-12)
 - Module 05 - Fourier Transform and Applications

- Module 06 - 2D Fourier Transforms
- Quiz 3 (by Feb 12) - 1D Fourier Transforms
- Lab 4 (Feb 11) - 2D Fourier Transforms
- Week 6 (Feb 15-19)
 - No class Feb 15 (President's Day break)
 - Module 07 - Linear Time-Invariant (LTI) systems
 - Quiz 4 (by Feb 19) - 2D Fourier Transform
 - Lab 5 (Feb 18) - 1D/2D Convolution, Correlation and Deconvolution
- Week 7 (Feb 22-26)
 - Module 07 - Linear Time-Invariant (LTI) systems
 - Module 07a - Geophysical Applications of Correlation and Convolution (Can Oren)
 - Quiz 5 (by Feb 26) - Convolution
 - Lab 6 (Feb 25) - 2D Convolution, Linearity and Noise
- Week 8 (Mar 01-05)
 - Module 07a - Geophysical Applications of Correlation and Convolution (Can Oren)
 - Module 08 - Discrete-Time Signals
 - Quiz 6 (by Mar 05) - Correlation and Convolution
 - Lab 7 (Mar 04) - Matrix Operators, Invertability and Adjoints
- Week 9 (Mar 08-12)
 - Module 08 - Discrete-Time Signals
 - Module 09 - Digital Sampling and Reconstruction
 - Quiz 7 (by Mar 12) - Discrete-time Signals
 - Lab 8 (Mar 11) - Sampling, Reconstruction and Random Sampling
- Week 10 (Mar 15-19)
 - Module 09a - Higher-order Sinc Interpolation (Can Oren)
 - Module 10 - Discrete Fourier series and Discrete Fourier Transform (DFT)
 - Quiz 8 (by Mar 19) Digital Sampling and Reconstruction
 - Lab 9 (Mar 18) Discrete Fourier Transform (DFT)
- Week 11 (Mar 22-26)
 - Module 10 - Discrete Fourier series and Discrete Fourier Transform (DFT)
 - Module 11 - Windows and Spectrograms
 - Quiz 9 (by Mar 26) - Discrete Fourier Transform (DFT)
 - Lab 10 (Mar 25) - Spectrograms and Time-Frequency Processing
- Week 12 (Mar 29-Apr 02)
 - Spring Break (no classes)
- Week 13 (Apr 05-09)
 - Module 11a - Wavelet Transform (Can Oren)
 - Module 12 - The Z Transform
 - Quiz 10 (by Apr 09) - Windows and Spectrograms
 - Lab 11 (Apr 08) - Wavelet Transform
- Week 14 (Apr 12-16)
 - Module 12 - The Z Transform
 - Module 13 - Practical Filtering
 - Quiz 11 (by Apr 16) - The Z Transform
 - Lab 12 (Apr 15) - Z Transforms and FIR Filtering
- Week 15 (Apr 19-23)
 - Module 13 - Practical Filtering
 - Quiz 12 (by Apr 23) - FIR and IIR Filtering
 - Lab 13 (Apr 22) - Z Transforms and IIR Filtering
 - Project work in lab
- Week 16 (Apr 26-30)
 - Intentionally left blank!
 - Project work in lab

- Week 17 (May 03-07)
 - No classes
 - **FINAL PROJECTS DUE: Friday May 07 @ 2359h**

Recommended Resources

- **Course Materials:** You can clone a copy of **Jupyter Notebooks** containing the course notes and reproducible DSP Python code examples that use the powerful Numpy, Scipy and Matplotlib packages. You can "git clone" the course notes by running this in the location where you want to "install" the files:
 - git clone https://github.com/jshragge/CSM_GP_DIGSIG.git (https://github.com/jshragge/CSM_GP_DIGSIG.git)
 - You will receive "handouts" for lab assignments in electronic format.
- *Discrete-Time Signal Processing*, 3rd Edition, by A.V. Oppenheim and R.W. Schaffer.
 - **Optional:** This is very comprehensive textbook on the subject; however, it may be somewhat abstract and difficult to access to some people since it is written from an electrical engineering perspective.
- *The Scientist's and Engineer's Guide to Digital Signal Processing*, 2nd Edition, by Steve Smith. Available [free online here](http://www.dspguide.com/pdfbook.htm) (<http://www.dspguide.com/pdfbook.htm>).
 - **Optional:** This textbook is aimed at a upper undergraduate level and is written with a balance of science and engineering in mind.
- *A Student's Guide to Python for Physical Modelling*, by Jesse M. Kinder and Philip Nelson
 - **Optional:** This book is a helpful guide to those starting down the path of Python programming. If you are at the point in life, I'd strongly recommend picking this up (currently available at the CSM bookstore).

Delivery mode/Pedagogy

The material is presented through two one-hour lectures per week, and one two-hour lab session per week and through self-study. Student will be provided with the material (**Jupyter Notebook**) before classes and are expected to read through and reproduce worked examples before class. These notebooks use short **Python** examples to illustrate the concepts introduced in class. Class time is focused on clarification and going through worked examples – both as a whole class and in small groups.

How to get help?

You should not hesitate to seek my help, and can do this in the following ways:

1. Ask questions in class. Never hesitate to ask, even if I have explained material before. You can safely assume that if something is not clear to you, there are several classmates that have the same question. I will also answer questions related to homework.
2. Drop by in my office. I travel much and am busy, but you need not hesitate to come by with questions. You can see my schedule online by visiting [here](https://sites.google.com/site/jshragge/) (<https://sites.google.com/site/jshragge/>) and clicking on "Check my schedule for availability". I generally will not use email to answer questions about the material covered, but will use email to agree on a meeting time.
3. Seek the help of the teaching assistant.
4. I will not provide help for homework through email (but can arrange for a meeting time). If anything is not clear, or if you need help, ask in a timely way using any of the three options above.

Coursework Return Policy

Quiz and lab results will be returned within one week.

Absence Policy (e.g., Sports/Activities Policy)

All students are advised to be familiar with CSM's policy regarding the make-up of work missed due to excused absences. This policy may be found in the Bulletin. If a student is ill and exhibits flu-like symptoms, they should not attend class, labs, or exams. In order for an absence based on illness to be excused, the student must normally communicate directly with the Associate Dean of Students or his/her instructors. In all cases of unexcused absences the faculty member has the right to deny the student the opportunity to make up all or part of the missed work. **Coursework must be turned in before it is due to be graded – plan ahead.**

Diversity and Inclusion

At Colorado School of Mines, we understand that a diverse and inclusive learning environment inspires creativity and innovation, which are essential to the engineering process. We also know that in order to address current and emerging national and global challenges, it is important to learn with and from people who have different backgrounds, thoughts, and experiences. Our students represent every state in

the nation and more than 90 countries around the world, and we continue to make progress in the areas of diversity and inclusion by providing [Diversity and Inclusion programs and services \(https://www.mines.edu/about/diversity-and-inclusion/\)](https://www.mines.edu/about/diversity-and-inclusion/) to support these efforts.

Students with Disabilities

The Colorado School of Mines is committed to ensuring the full participation of all students in its programs, including students with disabilities. If you anticipate or experience any barriers to learning in this course, please feel welcome to discuss your concerns with me. Students with disabilities may also wish to contact Disability Support Services (DSS) to discuss options to removing barriers in this course, including how to register and request official accommodations. Please visit their website at disabilities.mines.edu (disabilities.mines.edu) for contact and additional information. If you have already been approved for accommodations through DSS, please meet with me at your earliest convenience so we can discuss your needs in this course.

Discrimination, Harassment and Title IX

All learning opportunities at Mines, including this course, require a safe environment for everyone to be productive and able to share and learn without fear of discrimination or harassment. Mines' core values of respect, diversity, compassion, and collaboration will be honored in this course, and the standards in this class are the same as those expected in any professional work environment. (More information can be found [here \(http://inside.mines.edu/UserFiles/File/FacultySenate/Documents/ValuesAndAspirationsStatement2-14-17.pdf\)](http://inside.mines.edu/UserFiles/File/FacultySenate/Documents/ValuesAndAspirationsStatement2-14-17.pdf).) **Discrimination or harassment of any type will not be tolerated.** As a participant in this course, we expect you to respect your instructor and your classmates. As your instructor, it is my responsibility to foster a learning environment that supports diversity of thoughts, perspectives and experiences, and honors your identities.

To help accomplish this:

- Course rosters are provided to the instructor with the student's legal name. I will honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records.
- If something is said or done in this course (by anyone, including myself) that made you or others feel uncomfortable, or if your performance in the course is being impacted by your experiences outside of the course, please report it to:
 - Me (if you are comfortable doing so)
 - [Wellness Center - Counseling \(https://www.mines.edu/counseling-center/\)](https://www.mines.edu/counseling-center/)
 - [Speak Up - Anonymous Option \(https://www.mines.edu/speak-up/\)](https://www.mines.edu/speak-up/)

In this course, we will cultivate a community that supports survivors, prevents interpersonal violence, and promotes a harassment free environment. Title IX and Colorado State law protects individuals from discrimination based on sex and gender in educational programs and activities. Mines takes this obligation seriously and is committed to providing a campus community free from gender and sex-based discrimination. Discrimination, including sexual harassment, sexual violence, stalking, and domestic violence, is prohibited and will not be tolerated within the Mines campus community. If these issues have affected you or someone you know, you can access the appropriate resources on the [Mines Title IX website \(https://www.mines.edu/title-ix/\)](https://www.mines.edu/title-ix/). You can also contact the Mines Title IX Coordinator, Camille Torres, at 303.384.2124 or titleix@mines.edu (titleix@mines.edu) for more information.

It's on us, all of the Mines community, to engineer a culture of respect

CARE @ Mines

If you feel overwhelmed, anxious, depressed, distressed, mentally or physically unhealthy, or concerned about your wellbeing overall, there are resources both on- and off-campus available to you. If you need assistance, please ask for help from a trusted faculty or staff member, fellow student, or any of the resources below. As a community of care, we can help one another get through difficult times. If you need help, reach out. If you are concerned for another student, offer assistance and/or ask for help on their behalf. Students seeking resources for themselves or others should visit care.mines.edu.

Additional suggestions for referrals for support, depending on comfort level and needs include:

- [CARE at Mines \(care.mines.edu\)](https://care.mines.edu) – for various resources and options, or to submit an online “CARE report” about someone you’re concerned about (email: care@mines.edu (care@mines.edu)).
- [CASA \(https://www.mines.edu/casa\)](https://www.mines.edu/casa) – for academic advising, tutoring, academic support, and academic workshops.
- [Counseling Center \(https://www.mines.edu/counseling-center/\)](https://www.mines.edu/counseling-center/) – for students to call 303-273-3377 for an appointment. There are also online resources for students on the website. Located in the Wellness Center 2nd floor at 1770 Elm St.
- [Health Center \(https://www.mines.edu/student-health/\)](https://www.mines.edu/student-health/) – students may call 303-273-3381 for appointment. Located in Wellness Center 1st floor at 1770 Elm St.
- [Colorado Crisis Services \(http://coloradocrisisservices.org\)](http://coloradocrisisservices.org) – for crisis support 24/7, either by phone, text, or in person. Colorado Crisis Services is a great confidential resource, available to anyone by calling 1-844-493-8255, or texting “TALK” to 38255. Walk-in location addresses are posted on the website.

All of these options are available for free for students. The Counseling Center, Health Center, and Colorado Crisis Services are confidential resources. The Counseling Center will also make referrals to off-campus counselors, if preferred.

In an emergency, you should call 911, and they will dispatch a Mines or Golden PD officer to assist.

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. Furthermore, please notify your professor if you are comfortable in doing so. This will enable your professor to provide resources that may be available.

Policy on academic integrity and misconduct

The Colorado School of Mines affirms the principle that all individuals associated with the Mines academic community have a responsibility for establishing, maintaining and fostering an understanding and appreciation for academic integrity. In broad terms, this implies protecting the environment of mutual trust within which scholarly exchange occurs, supporting the ability of the faculty to fairly and effectively evaluate every student's academic achievements, and giving credence to the university's educational mission, its scholarly objectives and the substance of the degrees it awards. The protection of academic integrity requires there to be clear and consistent standards, as well as confrontation and sanctions when individuals violate those standards. The Colorado School of Mines desires an environment free of any and all forms of academic misconduct and expects students to act with integrity at all times.

Academic misconduct is the intentional act of fraud, in which an individual seeks to claim credit for the work and efforts of another without authorization, or uses unauthorized materials or fabricated information in any academic exercise. Student Academic Misconduct arises when a student violates the principle of academic integrity. Such behavior erodes mutual trust, distorts the fair evaluation of academic achievements, violates the ethical code of behavior upon which education and scholarship rest, and undermines the credibility of the university. Because of the serious institutional and individual ramifications, student misconduct arising from violations of academic integrity is not tolerated at Mines. If a student is found to have engaged in such misconduct sanctions such as change of a grade, loss of institutional privileges, or academic suspension or dismissal may be imposed.

The complete policy is [online \(http://inside.mines.edu/POGO-Student\)](http://inside.mines.edu/POGO-Student)

In []: