# Syllabus, Math 994-002
## Applied and Computational Harmonic Analysis
## Spring 2020

**Course Description:** This course will cover aspects of modern computational harmonic analysis at the interface of signal processing. A central theme of the course is to find good representations of functional data (e.g., time series, images, etc), where the quality of the representation is measured through notions of sparsity, characterization of certain functional classes, and empirical performance.

The prologue of the course will cover the rudiments of Fourier analysis and discrete signal processing. The shortcomings of the Fourier transform will motivate us to study localized time-frequency representations of functions, which will introduce the windowed Fourier transform as well as the continuous and dyadic wavelet transforms. Unlike the Fourier transform, which characterizes only the global regularity of a function, wavelet transforms characterize the local regularity of functions, and we will prove fundamental results along these lines. Windowed Fourier and wavelet transforms will be placed in a more general mathematical context via the study of redundant dictionaries and frame theory. Wavelet bases will be introduced via multiresolution analyses, which in turn will lead to efficient (sparse) linear and nonlinear signal approximations.

The course will assume knowledge of linear algebra and real analysis (Lebesgue integration, $\mathbf{L}^p$ spaces, Banach and Hilbert spaces).

**Instructor Information:**

- **instructor:** Matthew Hirn
- **office:** 2507F, Engineering Building
- **email:** `mhirn@msu.edu`
- **phone:** (517) 432-0611
- **course webpage:** `https://matthewhirn.com/teaching/spring-2020-mth-994-002/`

**Meeting Time and Location:**

- Tuesday and Thursday, 12:40 PM – 2:00 PM
- A118, Wells Hall

**Office Hours:**

- Monday – Thursday, 4:00 PM – 5:00 PM (some Monday ones may need to be moved/cancelled starting in March, stay tuned to the announcements)

**Prerequisites:**

- Linear algebra
- Real analysis (Lebesgue integration, $\mathbf{L}^p$ spaces, Banach and Hilbert spaces)

**Resources:**

- *A Wavelet Tour of Signal Processing: The Sparse Way*, 3rd edition, by Stéphane Mallat (required)
- *Wavelets and Operators*, by Yves Meyer (we may use some parts, we will see, not required)
- *Harmonic Analysis and Applications*, by John Benedetto (detailed background on Fourier analysis, not required)
- *Foundations of Time Frequency Analysis*, by Karlheinz Grchenig (not required)

**Grading:**

- Homework: 80%
- Attendance: 20% (This is a small class! So it is important we attend and participate)

**How the course will work:** We will use *A Wavelet Tour of Signal Processing* as the primary source material for the course (see the tentative course outline below). We will not be able to cover every detail in lecture, so it will be up to you to read the book outside of class to fill in gaps. These readings will be part of the exercises, and will be clearly noted in the course notes. At a few points in the course I will add in some material from the other resources listed above, but this will be done in a self-contained way that does not require you to have those books. Course notes will be posted online after each lecture.

**Exercises** will be posted on the course website every Thursday, and a subset of the (non-reading) exercises will be graded. Each week there could be anywhere from zero to several new exercises; generally they will be due one week after they are posted (so the following Thursday). Exercises will be a mix of mathematical proofs and some programming. Each person is required to submit their own exercises, although you may discuss them with your classmates.

**Attendance** will be noted each class. Each unexcused absence will incur a 1% deduction from your final grade (maximum of 20%).

There will be no **Final Exam**.

**Course announcements** will be sent via email and posted on the course website.

***Tentative* course outline:**

- Chapter 2: The Fourier Kingdom
- Chapter 3: Discrete Revolution
- Chapter 4: Time Meets Frequency
- Chapters 5 & 6: Frames and Wavelet Zoom (we will jump back and forth)
- Chapter 7: Wavelet Bases
- Chapter 9: Approximation in Bases

**Academic Honesty:** Cheating in any form will not be tolerated and will be reported. You will receive a zero on any assignment in which there is a case of cheating. This includes, but is not limited to, plagiarism, failure to give proper citations, and copying another's work.

If you are preparing an assignment and have a question about whether you are adhering to this policy, please ask me. If you work on an assignment with other students, you must give credit to your collaborators.

MSU's policy on academic integrity can be found at the following URL:
`https://msu.edu/unit/ombud/academic-integrity/`

**Disability Services:** Accommodations for persons with disabilities can and will be made in this course. All arrangements will be organized through the RCPD office as MSU. Persons with disabilities who are interested in the available services should contact the MSU Resource Center for Persons with Disabilities (RCPD) at (517) 884-7273 or online at `http://www.rcpd.msu.edu`.