

1051-716 Fourier Methods for Imaging

Website: <http://www.cis.rit.edu/class/simg716/>

If online students are registered for the class, the website will include links to lecture recordings and scanned notes from each class. Note that this is an open website that does not require a password; it is NOT part of the RIT “MyCourses” system (but may be reached therefrom).

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Meeting Rooms/Times: Quarter 20111: MW, 10:00AM – 11:50AM, Room 76-2155, possible supplemental (and optional) problem sessions

Prerequisites:

A complete course in undergraduate Calculus is expected, including exposure to complex numbers. Any additional experience with matrix algebra, linear algebra and complex analysis is very helpful.

Details: Homework will be assigned, and is to be handed in **on time** (extensions will be considered **in advance**, though cases of unforeseeable emergency will always be considered). Scores for assignments handed in late will be penalized heavily and homework will not be accepted after solutions have been posted. Problems (or some subset thereof) will be graded and solutions to all problems will be handed out as quickly as possible after the homework due date.

Homework – 30% (Assignments usually given Monday, usually due 1 week later at start of class.)

Midterm Exam (closed book, closed notes, 2 hours, anticipated date: W, 12 October) – 30 %

Final Exam (cumulative, closed book, closed notes, 3 hours if possible, room and time TBA) – 40%

This is challenging material for most students (and is supposed to be). Despite (or perhaps because of) its demanding nature, it is *essential* to master Fourier theory (sometimes called *linear systems theory*) if you plan to work in any area of imaging, which now includes most (if not all) disciplines of science. Fourier transforms appear in many (if not all) aspects of imaging, especially as a means to describe and/or predict the action of optical imaging systems and to filter digital or analog images. If you are not very familiar with the subject, you should expect to devote a significant amount of time to this course outside of class. Even if you have some preparation in the field (as from a linear systems course in electrical engineering), you likely will find that the different emphasis in this class will still require significant outside time. A rule of thumb for this class is that you will spend 2-3 hours outside of class *per hour* in class, which means that you should *plan* to spend 8-12 hours per week outside of class. Even if you finish the homework “early,” you can use the “extra” time to outside reading on the subject throughout the term.

In the past, I have generally scheduled supplemental and *optional* “problem sessions” each week during the term (often Fridays at 4PM) for students to ask questions and work on problems. These have generally been well received by students. The Friday schedule may not be possible on a regular basis this quarter due to family issues, so it may be necessary to investigate other options (perhaps Tuesdays at 4PM or Monday or Tuesday evenings). Again, I emphasize that these sessions are optional.

RIT remains on the quarter schedule until 2013 and one feature (actually much more of a “bug”) of this calendar is that time FLIES by (particularly for offsite students!). If you are having problems learning the material, **DON'T WAIT; ASK EARLY** for help – in and/or outside of class. Though I keep my office door closed, **PLEASE** knock; if I am not doing something urgent, I will set aside time to help – working with students individually or in small groups is the most enjoyable part of my job. I am often in the office on weekends, and spending some time to help students often is a nice break in those days.

My philosophy on exams is that they test *understanding* of material, which is the ability to assimilate concepts and synthesize useful results in applications. This is *not* the same as the ability to parrot discussions of concepts or replicate the solutions to homework problems. In other words, you need to know how to *apply* the material in the course. Be forewarned, my exams seem to have a reputation among students, and I make no apologies, since this is a graduate program and students must demonstrate *mastery* (not just “understanding”) of the material.

Grading:

I reserve the right for some flexibility, but the **approximate** mapping of numerical to letter grades likely will be:

Numerical Score	Letter Grade
88 - 100	A
76.0 - 87.9	B
68.0 - 75.9	C
60.0 - 67.9	D
< 60	F

Note that the histogram bins are a bit wider for higher scores and that the actual mapping may differ. Be advised that I tend to place scores near the margin into the lower grade. Also note that students with fellowships must maintain an average of “B” or better (GPA 3.0+) to maintain their support and that ALL graduate students must have this GPA or better to be in good standing for graduation – all the more reason to deal with difficulties early rather than late.

All of that being said, I would give one (additional) word of warning: one pet peeve of mine is the student who does not ask questions, in class or out, until immediately before some deadline (exam or due date for homework), at which time questions are suddenly *urgent*. My advice is to ask questions in sufficient time to have a positive impact on your understanding.

Since it is very unlikely that this course will have a teaching assistant, it is possible that the time interval between submission and return of homework may be longer than desirable. For this reason, I also recommend that you keep a copy of your homework. If you have a scanner, you might make a pdf copy of your homework before submitting it. You also may submit pdfs (in color if necessary) and retain your original copy.

Online Students: You MUST have a document scanner and software, such as Adobe *Acrobat* with the full features (NOT the free *Acrobat Reader*), for converting the scanned files to PDF. You must e-mail the pdf file of your homework to me; do NOT use FAX (the image quality of faxed pages is often very poor and delivery of documents sent to the department FAX machine cannot be guaranteed). Also, please do not use the RIT “MyCourses” program to submit homework as I rarely (if ever) use it. MAKE SURE that your submissions are readable before e-mailing them to me by reading over the scanned files. The plan is to transmit online material simultaneously with the onsite class, though technological failures of transmission and recording are seemingly inevitable and should be anticipated. In the recent past, I have presented the lectures on a tablet that transmits handwriting on paper so that the online and onsite students see and hear the same material simultaneously. In recent years, these lecture notes have been scanned, converted to pdf, and uploaded to the course website (usually within an hour of the end of class). A warning: it will be difficult to respond to questions from online students in real time due to the difficulty of monitoring the website at the same time as presenting the material. Online students may find it more useful to ask questions offline before or after the class.

If there are no online students registered, I expect that the class presentation will revert to the traditional “blackboard” lectures with computer adjuncts for clarity.

Course Material:

This course introduces mathematical formalisms for describing imaging systems, with emphasis on systems with responses constrained to be linear in dynamic range and independent of spatial location in the scene. In other words, the course develops mathematical models of imaging systems and applies them to problems relevant to imaging.

Text Materials:

Text: *Fourier Methods in Imaging*, R.L. Easton, Jr., Wiley, 2010, ISBN 978-0-470-68983-7, list price \$165 from Wiley (<http://www.wiley.com/WileyCDA/WileyTitle/productCd-0470660112.html>, Adobe e-book format for the same price). The book is available from the usual suspects: the RIT Bookstore (B&N@RIT, <http://rit.bncollege.com/> and from [Amazon.com](http://www.amazon.com)). It likely is also available from the Society for Imaging Science and Technology at a substantial discount of \$120 including shipping (<http://www.imaging.org/ist/store/phypub.cfm?seriesid=34&pubid=944>) The book considers continuous and discrete imaging systems and optical imaging, and thus is relevant to the subsequent courses 1051-718 *Digital Imaging Mathematics* and 1051-733 *Optics for Imaging*. Note that MANY other books also are available that touch on aspects of mathematical models of imaging systems and parameters. You should peruse these and (at least) be aware of the treatments (see the bibliography list). Though my book may be considered to be expensive at \$165 list, it is cheaper than the alternatives listed below AND it is useful for at least two additional courses.

Other useful books include:

- 1 *Foundations of Image Science*, H.H. Barrett and K.D. Myers, Wiley-Interscience, 2004, ISBN 978-0471153009 (\$209.95 list, \$159.46 from Amazon.com) Catalog number TK8315 .B37 2004.
- 2 *Linear Systems, Fourier Transforms, and Optics*, Jack D.Gaskill, Wiley, 1978, ISBN 978-0471292883 (\$225.00 list), QC355.2.G37: (formerly the text for this class, provides the inspiration for some homework problems)

3 *Fourier Analysis and Imaging*, R.N. Bracewell, Prentice-Hall, 2004, ISBN 978-0306481871. (\$179.00 list) An earlier version, *Two-Dimensional Imaging*, is in the RIT Library at call number TA1637.B73.

The first of these by Barrett and Myers (the authors are my research advisor and a contemporary colleague from graduate school) considers much of the same material up through optical imaging at a more theoretical level. I learned from Gaskill's book and class; the book is still an excellent reference, though it does not consider the discrete case. Other books and resources are listed in the bibliography posted on the course website: http://www.cis.rit.edu/class/simg716/Bibliography_716-20111.pdf

Obviously much material on the subject is available on the internet, but I very seriously doubt that anyone can master Fourier methods without becoming familiar (and spending time) with the standard texts. I STRONGLY advise that you locate the shelves in the library where this material is concentrated (Library of Congress call numbers beginning with TA, TK, QC) and USE the books you find there.

One electronic resource you might consult are the course lectures by Brad Osgood for EE261 at Stanford University, which are available for free on "iTunes U" at the iTunes store. Though aimed in a slightly different direction, the discussion may be helpful.

Signals Software:

For demonstrations in lectures, I shall often use my (ancient) program "*SIGNALS*" for PCs (which was written before some of you may have been born!). It is keystroke driven from menus, so it is typically more flexible, as well as much faster to use in class, than other available software tools, such as MatLab. Interested students may download it from the CIS website:

<http://www.cis.rit.edu/people/faculty/easton/signals/signals.zip>.

An old (but still valid) "user manual" is available at: http://www.cis.rit.edu/resources/software/sig_manual/index.html.

The free DOS emulator *DOSBoX* (<http://www.dosbox.com/>) allows the program to run (and quite well) on a wide range of computer platforms including Windows (95, 98, XP, Vista, and Win7), the Macintosh OS, and Linux. If you use *DOSBoX*, the graphics display appears in windows rather than full screen, which is a significant advantage over the old full-screen DOS display, particularly when running several applications simultaneously.

Any version of *DOSBoX* may be optimized for "Signals" by editing the configuration file (see instructions on the *DOSBoX* website or (in Windows) go to "Start → Programs → DOSBoX → Configuration → Edit Configuration"; then go to the bottom of the file to the section labeled [autoexec] and insert the lines listed below after "**Lines in this section will be run at startup:**"

#Lines in this section will be run at startup

mount c (*insert location of root directory for Signals here, e.g., "mount c c:\2d"*)

c: (*switches to the drive letter defined in the previous "mount" command*)

cycles=30000 (*you may want to experiment with this value – faster computers can make use of larger numbers to speed up processing*)

signals /c (*starts the program with the "color" display switch*)

SignalShow:

A new Java counterpart of *Signals*, called *SignalShow*, which was written as an undergraduate senior project by Juliet Bernstein a few years back. *SignalShow* goes beyond the original program in several ways, including illustration of the 2-D case. The beta releases of *SignalShow* for the three primary computing platforms (Windows, Macintosh OSX, and Linux) are available online at <http://www.signalshow.com/>. This site includes links to help videos that are posted on YouTube. You may find this program very helpful in your quest to visualize the concepts in this course, as well as in 1051-718 "Digital Imaging Mathematics," and in 1051-733 "Optics for Imaging."

Other Software Tools

There are plenty of other software available that may be helpful in this course and the followup 1051-718 "Digital Imaging Mathematics." *ImageJ* is available for free for all personal

- *ImageJ* is a freely available open-source program Windows, Linux and Mac OS X that has evolved from former versions *NIHImage* and *ScionImage*. Written in Java, the basic program and "plugins" for more advanced routines are available from the website <http://rsbweb.nih.gov/ij/>. Plugins are available for advanced processing relevant to this course, including the Radon transform and statistical analysis.
- *IDL / ENVI* are available on many computers in the Carlson Center
- *Matlab* is available from RIT for faculty and staff at reduced cost, but this offer does NOT extend to students.