IMGS 616 Fourier Methods for Imaging (RIT #11857)

Website: *http://www.cis.rit.edu/class/simg716/* (note the URL, the number refers to the former quarter course, but it was easier to just keep it)

The website will include links to lecture recordings and scanned notes from each class. The reliability of the recordings has improved substantially, but it is not foolproof and problems may crop up. My advice for "in-class" students is not to rely on the recording but to make it to the class. Note that this is an open website that does not require a password – it is NOT part of the RIT "MyCourses" system, but is linked from there.

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Meeting Rooms/Times: Quarter 20141: TTh, 9:30am – 10:45am, Bldg. 76 (Carlson), Room 2155.

Since there is much to cover in this course, I plan to offer supplemental classes and problem sessions that will be scheduled after we get the schedule worked out … probably by the second week.

NOTE: Foods and drinks/liquids are NOT allowed in the classroom – food because of the "mess" factor, liquids because of the electrical outlets on the tabletops – you must leave any such items on the table outside of the door

Also, turn off and put away any phones or other gadgets during class time –focus on the material, not on distractions.

Two off-campus events will affect this course in the first five weeks: I will be presenting a short course at the Sorbonne the week of September 15-19 and will be attending a conference in Malmö on October 1-3 (flights depart Monday 29 September and return Sunday 5 October). As we approach these dates, we will arrange to make up any missed classes either by prerecording lectures, guest lecturers, or rescheduling.

Prerequisites:
A full course in undergraduate Calculus is expected, including exposure to complex numbers. Any additional experience with matrix algebra, complex analysis, and linear algebra (especially eigenvectors and eigenvalues) should be very helpful.

Details: Homework will be assigned, and is to be handed in **on time** (extensions will be considered **in advance** for good reason, e.g., to attend a conference, though documented cases of unforeseeable emergency will always be accepted). Scores for assignments handed in late will be penalized heavily and homework will not be accepted after solutions have been posted, which ideally will be shortly after the due date. Problems (or some subset thereof) will be graded and returned as quickly as possible after the homework due date.

Homework – 30% (Assignments usually given Tuesday, usually due 1 week later *at start of class*).
Midterm Exams (closed book, closed notes, 75 minutes, anticipated dates: Tu 24 Sept and Th 31 Oct.) – 20% each
Final Exam (cumulative, closed book, closed notes, 3 hours, Tuesday 17 December, 8am-11am, 76-2155) – 30%

This is challenging material for most students (and is supposed to be). Despite (or perhaps because of) its demanding nature, Fourier or linear systems theory must be mastered and not just "understood" to do research in just about any area of imaging, which now is part of most (if not all) disciplines of science. Briefly put, Fourier transforms produce a different function that is equivalent to an image $f[x,y]$. The coordinates $[x,y]$ of the image have dimensions of "length" (e.g., millimeters), while the coordinates in the alternative representation have dimensions of "reciprocal length" ("cycles per millimeter"). The alternative representation provides an avenue to describe and/or predict the action of optical imaging systems and to filter digital or analog images. Though it is possible to find disagreement from uninformed parties, the continuous case (with integrals) is as important as the discrete case (with summations).

It is very valuable to be able to think about this material "visually" or "graphically" rather than just as "equations." In fact, I contend that it often is possible to solve problems completely just from the graphs while also avoiding "dumb mistakes." There are a number of available computational tools available, including two ("Signals" and "SignalShow") that were written specifically for this course. I strongly urge you to investigate the available packages and take advantage of them.

Since this is a course that applies mathematical tools to imaging situations, it is necessary to consider how to implement the applications. In part, this will require the student to be able to convert verbal descriptions into and solve the corresponding equations. For many students, this task seems to be challenging and therefore requires some practice. You can expect to be faced with such "word problems" during this course.

Time on Task: 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), expect that the different emphasis in this class likely will mean that you will have to spend significant outside time to master the material. 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. This time includes reading the text and related books as well as doing homework. Even if you finish the homework "early," you would be well advised to use "extra" time throughout the term for additional reading on the subject.

In the past, I have generally scheduled supplemental and *optional* "problem sessions" each week during the term for students to ask questions and work on problems. These have generally been well received by the students who attend, particularly those whose math preparation was farther back in time. Unfortunately, I may not be able to attend every Friday because of to family issues, so it may be necessary to investigate other options (perhaps midweek evenings).

The way the RIT semester schedule has been implemented, we now have somewhat less time to cover yet more material, so it will be even more of a challenge to keep up. 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. *Despite what you may hear from classmates who were too shy or otherwise afraid to ask, 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 from other activities on those days, so please knock then too.

My view about 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.

One issue that occasionally crops up due to the different cultural backgrounds of students is the question of whether working together is appropriate. I encourage you to consult with your peers on homework problems, since a good way to learn is to explain to a colleague. That said, your submission must be your own work (I have had students literally photocopy graphs and submit them, which is completely inappropriate). For example, if you are assigned work that requires submission of computer output, you may consult with colleagues about programming questions, but you must submit output from your own program and may not copy output from someone else. On examinations, all work must be your own from start to finish.

A bit of philosophy here – my primary role in this whole picture is to present the material in a manner that is understandable and that relates the subject(s) to imaging. My secondary role is to assess the knowledge of students after the course is completed (i.e., I file "grades"). I occasionally get inquiries, usually towards the end of term, from students who ask "What grade am I going to get?" This question really asks for my assessment of the student's level of understanding, which the student always knows much better than I do. A better strategy would be to ask for help in understanding the material. I am much better able (and much more willing) to help with the latter case than the first question.

Grading:

The new RIT grade policy allows "±" grades, e.g., "B+". Note that these affect the GPA (e.g., 3 points for "B", 3.33 for "B+", 2.67 for "B–". Since this is a new policy, thresholds have not been determined and we will be playing it "by ear." The documented policy is posted at http://www.rit.edu/~w-policy/sectionD/D5.html

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 decision points for the bins are a bit wider for higher scores and that the actual mapping may differ. Be advised that scores at the margins tend to be placed in the lower grade. You likely are already aware that students with fellowships must maintain an average of "B" or better (GPA 3.0+) to continue their financial 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 asks no questions (in class or out) until immediately before some deadline (exam or homework due date), at which time questions are suddenly *urgent*. My advice is to ask questions in sufficient time to have a positive impact on your understanding.

This course may have a teaching assistant for grading, so I hope that the time interval between submission and return of homework will be one week or less. I do recommend that you scan your homework and keep a copy – the CIS copier has this capability – before submitting it. If you wish, feel free to submit a hard copy of the scanned file and retain your original.

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. To allow consideration of more of the basic material, including linear algebra with eigenvectors and eigenvalues, the class will have a fourth scheduled hour this year.

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 ~$140). The book is available from the usual suspects: the RIT Bookstore (B&N@RIT, http://rit.bncollege.com/), from Barnes and Noble as a printed book for ~$140 or in "Nook" e-format for ~$100, and from Amazon.com as printed book or in "Kindle" format for ~$135. It is available from the Society for Imaging Science and Technology at a substantial discount of $120 including shipping (http://www.imaging.org/ist/store/physpub.cfm?seriesid=34&pubid=944)

The book considers continuous and discrete imaging systems and optical imaging, and thus is very relevant, even essential, to the subsequent courses IMGS-633 *Optics for Imaging* and IMGS-682 *Digital Image Processing*. Note there is a long list of other books that touch on aspects of mathematical models of imaging systems. 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 many alternatives listed below and is useful for at least two additional courses. **In past years, some students have been caught using electronic copies that were downloaded from offshore websites, which is illegal under U.S. copyright law, as well as violating the RIT code of conduct.** Legal electronic copies of the book are available as described above and from the RIT library.

Other useful books include:

1 *Foundations of Image Science*, H.H. Barrett and K.D. Myers, Wiley-Interscience, 2004, ISBN 978-0471153009 ($230 list, $161.48 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 – a good metric of the inflation index is the fact that I bought this book for $30 in 1980), QC355.2.G37: This formerly was the text for this class and provides the inspiration for some homework problems.

3 *Fourier Analysis and Imaging*, R.N. Bracewell, Prentice-Hall, 2004, ISBN 978-0306481871. ($209.00 list) An earlier version, *Two-Dimensional Imaging*, is in the RIT Library at call number TA1637.B73.

The book by Barrett and Myers (my research advisor and a colleague from graduate school, respectively) considers much of the same material up through optical imaging, though at a more theoretical level and without figures and homework problems. Even with that constraint, you should be aware of this book. I took and graded Jack Gaskill's class and used his book in this class for many years. Its primary shortcoming is that it does not explicitly consider the discrete case.

The bibliography lists other books and resources: http://www.cis.rit.edu/class/simg716/Bibliography_616-20141.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 that you review and USE the books you find there.

One electronic resource you might consult is the set of lectures by Brad Osgood for EE261 at Stanford University, which is available on "iTunes U" for free and on YouTube (first lecture at http://www.youtube.com/watch?v=gZNm7L96pfY). Though aimed in a different direction, his discussion may be helpful.

Online Students: You MUST have a document scanner and software for converting the scanned files to PDF (such as Adobe *Acrobat* with full features – not the free *Acrobat Reader*). You should 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). Send the e-mail directly to me rather than using the RIT "MyCourses" program to submit homework. MAKE SURE that your submissions are readable before e-mailing them to me by checking the scanned files. The plan is to transmit lecture material live and simultaneously with the onsite class and the lectures will be recorded for later viewing. Recognize that technological failures of transmission and recording are seemingly inevitable and should be anticipated. Since I will have no assistant to monitor the system during lectures, it likely will not be possible to respond to online questions in real time. I expect that online students will find it more useful to ask questions offline before or after the class during scheduled office hours or at some prearranged time. If you call without an appointment, I pledge to respond at that moment if at all possible unless I am engaged in something "urgent."

25 August 2014