1051-716-20111 — FOURIER METHODS FOR IMAGING

website: http://www.cis.rit.edu/class/simg716/

Relevant Published Materials:
Though this list is meant to be fairly comprehensive, I am sure that there are others that should be included – feel free to suggest additions to the list. Library of Congress call numbers are included for books available in the RIT library. The comments are my own gauges of usefulness to this class and to imaging in general. You should spend some time in the library looking over these books!

Text:

1. ***Fourier Methods in Imaging***, Roger L. Easton, Jr., Wiley, 2010, ISBN 978-0-470-68983-7, available from RIT Library as e-book at http://site.ebrary.com/lib/rit/docDetail.action?docID=10381046

Other Textbooks (and very useful!):

2. ***Foundations of Image Science***, H.H. Barrett & K.D. Myers, Wiley, 2004, ISBN 0-471-15300-1, Catalog number TK8315.B37 2004
3. ***Linear Systems, Fourier Transforms, and Optics***, Jack D. Gaskill, Wiley, 1978, QC355.2.G37 (source of many homework problems)
4. ***Two-Dimensional Imaging***, R.N. Bracewell, Prentice-Hall, 1995, TA1637.B73
5. ***Fourier Analysis and Imaging***, R.N. Bracewell, Springer 2004, ISBN 978-030648187
6. ***Digital Image Processing***, K.R. Castleman, Prentice-Hall, 1996 (§1-2,§9-16), *(far more comprehensive than title implies; excellent for a variety of imaging systems, demonstrates relationship of linear systems to optical systems, I really like this book),* TA1632.C37

Mathematical Foundations of Linear Systems:

1. For review, Schaum's Outlines on Calculus, Linear Algebra, Vector Analysis, Matrices, Complex Variables; also Schaum's *Mathematical Handbook*
2. ***Advanced Mathematical Methods for Engineering and Science Students***, G. Stephenson, P.M.Radmore, Cambridge, 1990 (particularly §2 on special functions and §7 on Fourier transforms)
3. ***Linear Algebra and its Applications*** (3rd Edition), Gilbert Strang, Harcourt, Brace, Jovanovitch, 1988, (Chapters on orthogonal projections, eigenvectors, change of bases)
4. Any of several texts on mathematical physics, e.g., Kreysig and Kreysig, *Advanced Engineering Mathematics*, Arfken, *Mathematical Methods for Physicists*, Byron and Fuller *Mathematics of Classical and Quantum Physics*, etc. (Every scientist needs at least one of these) Byron and Fuller is available as a Dover paperback reprint for under $25 (www.doverpublications.com)
5. ***Handbook of Mathematical Functions***, M. Abramowitz and I. A. Stegun, standard reference on mathematical functions, available online for free at http://people.math.sfu.ca/~cbm/aands/

Fourier Transforms in Mathematics:

1. ***The Fourier Integral and Certain of its Applications***, N. Wiener, Dover Publications reprint, 1958 (first published in 1933 – *tediously mathematical*), QA404.W47
2. ***An Introduction to the Theory of Fourier's Series and Integrals***, H.S. Carslaw, Dover Publications reprint, 1950 (first published in 1930 -- *also mathematical, but easier to read than Wiener)* QA404.C32
3. ***A Handbook of Fourier Theorems***, D.C. Champeney, Cambridge, 1987, (*best of the three*) QA403.5.C47

Fourier Transforms in Physics/Engineering:

1. ***Fourier Series and Boundary-Value Problems***, R.V. Churchill, McGraw-Hill, 4th Edition, 1987, (*classic text with lots of physical applications*), QA404.C6
2. ***A First Course in Fourier Analysis***, D.M. Kammler, Prentice-Hall, 2000, (useful discussions of mathematical and computational aspects), QA403.5.K36
3. ***Fourier Transforms and their Physical Applications***, D.C. Champeney, Academic Press, 1973, *(excellent book),* QA403.5.C46
4. ***Fourier methods for mathematicians, scientists, and engineers***, M. Cartwright, Ellis Horwood, 1990, *(paperback, introductory, lots of physical applications),* QA403.5.C37
5. ***The Fourier Transform and Its Applications*** (2nd Edition, Revised), R.N.Bracewell, McGraw-Hill, 1986, *(the standard reference on 1-D Fourier, good discussion of discrete transforms and applications),* QA403.5.B7
6. ***Fourier Transforms, An Introduction for Engineers***, R.M. Gray and J.W. Goodman, Kluwer Academic Publishers, 1995, *(aimed at discrete transform, not as useful as I expected),* TK5102.9.G73

7. ***A student's guide to Fourier transforms, with Applications to Physics and Engineering***, J.F. James, Cambridge, 1996, QC20.7.F67J36, (reissued 2011, *thin, cheap as paperback, useful)*
8. ***The Fourier Integral and its Applications***, A. Papoulis, McGraw-Hill, 1962, *(old, pre-FFT, though good mix of mathematical theory and practical applications),* QA404.P32
9. ***Fourier Transforms***, I.N. Sneddon, Dover Publications, 1995 (first published in 1951), *(similar comments to Papoulis),* QA404.S53
10. ***Fourier Analysis***, T.W. Körner, Cambridge, 1988, *(potpourri of Fourier from nonconventional point of view -- historically driven),* QA403.5.K67
11. ***Exercises for Fourier Analysis***, T.W. Körner, Cambridge, 1993, *(see comment above)* ,QA403.5.K66
12. ***Integral Transforms in Science and Engineering***, K.B. Wolf, Plenum, 1979, *(mathematical reference),* QA432.W64
13. ***Probability, Statistical Optics, and Data Testing***, 2nd Ed. B.R. Frieden, Springer-Verlag, 1991 (particularly §4 on Fourier methods – *excellent discussion of applications of statistical principles to many types of imaging problems, not just optics),* QA273.F89
14. ***Statistical Optics***, J.W. Goodman, Wiley, 1985, *(applications of Fourier theory to statistics, particularly in optics),* QC355.2.G66
15. ***Who is Fourier? A Mathematical Adventure***, Transnational College of LEX, Language Research Foundation, 1995. *($25 paperback translated from Japanese, very introductory, lots of pictorial examples. usefulness limited by lack of index)*
16. ***The Hartley Transform***, R.N. Bracewell, Oxford, 1986, (*describes a special case of Fourier transform that is real valued for real-valued inputs, a favorite of Bracewell)* QA403.5.B73

Discrete Fourier Transforms: (more relevant to course 1051-718 *Digital Imaging Mathematics*)

1. ***The FFT, Fundamentals and Concepts***, R.W. Ramirez, Prentice-Hall, 1985, *(graphical introduction to discrete Fourier transform)* QA403.5.R36
2. ***The Fast Fourier Transform and its Applications***, E.O. Brigham, Prentice-Hall, 1988, *(excellent),* QA403.B75
3. ***Fast Fourier Transforms***, J.S. Walker, 2nd Edition, CRC Press, 1996, *(w/ DOS software),* QA403.W33
4. ***Multidimensional Digital Signal Processing***, D.E. Dudgeon and R.M. Mersereau, Prentice-Hall, 1984 (§1-§2), *(written for EEs, but good discussion of 2-D discrete transform)* TK5102.5.D83

Linear Systems and Optical Imaging:

1. ***Introduction to Fourier Optics,*** J.W. Goodman, (3rd Edition), Roberts and Co., 2005, (updated classic, the BEST book on applications of Fourier transforms in optical imaging), QC355.G65
2. ***Fourier Optics, An Introduction*** (2nd Edition), E.G. Steward, Wiley, 1987, (useful introduction, lower level than Goodman), QC454.F7S83
3. ***Introduction to the Optical Transfer Function***, C.S. Williams and O.A. Becklund, Wiley, 1989, (specialized topic of linear systems in optics), QC367.W55
4. ***Systems and Transforms with Applications in Optics***, A. Papoulis, McGraw-Hill, 1968, (another classic, though showing its age; Papoulis has LOTS of useful things to say!), QC383.P23
5. ***Applications of Optical Fourier Transforms***, H. Stark, ed., Academic Press, 1982, (as implied, discussions of specific applications), TA1632.A68
6. ***Quantitative Coherent Imaging: Theory, Methods, and Some Applications***, J.M.Blackledge, Academic Press, 1989, (nice description of subject, unusual notation/spellings), QC476.C6.B553
7. ***The New Physical Optics Notebook***, Reynolds, DeVelis, Parrent, and Thompson, SPIE Press, 1989, *(applications of linear systems to optics/holography; though I am not fond of the notation, this is a very useful book that considers applications of optics to imaging),* QC395.2.N48
8. ***Fourier Series and Optical Transform Techniques in Contemporary Optics***, Raymond Wilson, John Wiley & Sons, Inc, 1995. QC454.F7 W55 (ISBN 0-471-30357-7)

Image Recovery:

1. ***Image Restoration and Reconstruction***, R.H.T.Bates and M.J.McDonnell, Oxford University Press, 1986, *(application of linear systems to imaging),* TA1632.B36
2. ***Image Recovery, Theory and Application***, (H.Stark, ed.), Academic Press, 1987, *(similar to Bates but more applications, multiple authors, fragmented),* TA1632.I4824

Useful References from Magazines and Journals:

1. "The Fourier Transform," R.N. Bracewell, in ***Scientific American***, June 1989, pp.86-95
2. "Numerical Transforms," R.N. Bracewell, in ***Science*****, v.248**, 11 May 1990, pp.697-704

3. "Fourier Analysis Using a Spreadsheet," R.A. Dory and J.H. Harris, in ***Computers in Physics***, Nov.-Dec. 1988, pp. 83-86
4. "A Plain Man's *(sic)* Guide to the FFT," P. Kraniauskas, in ***IEEE Signal Processing Magazine***, v.**11**, April 1994, pp. 24-35
5. "Tom, Dick, and Mary Discover the DFT," J.R. Deller, Jr., in ***IEEE Signal Processing Magazine***, v.**11** April 1994, pp. 36-50
6. "SIGNALS, Interactive Software for One-Dimensional Signal Processing," R.L. Easton, Jr., in ***Computer Applications in Engineering Education***, v.**1**, December 1993, pp.489-501
7. "Fast Fourier Transforms for Fun and Profit," W.M. Gentleman and G. Sande, in *Proceedings - Fall Joint Computer Conference*, 1966, pp.563-578
8. "Gauss and the History of the Fast Fourier Transform," Michael T. Heideman, Don H. Johnson, C. Sidney Burrus, **IEEE ASSP Magazine**, v.1, #4October 1984, pp. 14-21.

Other books containing useful discussions of imaging subjects:

1. ***Principles of Digital Image Synthesis***, Andrew Glassner, Morgan-Kauffman, 1995 (two volumes), *(very nice discussion of broad range of imaging topics, relevant material in §4-5,§8-10*), T385.G585
2. ***Image Reconstruction in Radiology,*** J. Anthony Parker, CRC Press, 1990, (*excellent book of much more general application than title implies; written for medical students and radiologists, does not require a "high" level of mathematical knowledge, useful intuitive discussions of imaging principles*) RC78.7.D53 P36
3. ***Radiological Imaging***, H.H. Barrett and W.Swindell, Academic Press, 1981, *(terrific book, also much more general than indicated by its title),* (§2, §4 on Linear Systems, §3 on Random Processes, §7 on Computed Tomography) RC78.B337

Computing Resources:

Many computational software packages are available that are helpful when learning the material in this class. CIS uses ***IDL™*** from ITT Visual Information Solutions (http://www.ittvis.com/) as its "standard" package. It is installed on the *UNIX* workstations in the Center, and also is available for purchase at a substantial student discount from CIS. Other packages exist, including ***Mathematica™*** (available on RIT VAX), ***MathCad™***, ***Matlab™***, and ***Scientific Workplace™***, **IDL®**, and **ENVI®**. All these packages allow computations involving most aspects of matrix algebra and complex analysis to be evaluated quickly and (more or less) painlessly. They also have graphing routines which may assist in visualizing concepts. In my opinion, most of the packages have a fairly steep learning curve – you cannot do much that is useful "out of the box." The programs also have their respective advantages and disadvantages, *e.g.*, my opinion is that the interfaces to ***Mathematica™*** and ***MathCAD™*** are not very intuitive, which means that new users have to travel the learning curve. Conversely, experienced users are rewarded by quicker answers.

Two free programs are available for illustrating the concepts of linear systems. My (very old) DOS program, "***Signals***" for 1-D functions runs in DOS and in Windows up through XP. By using the "DOSBox" utility (an x86 emulator available from http://www.dosbox.com/), it will run in Windows Vista, Windows 7, Apple OS X, and Linux. The ***Signals*** program was written with the intent of being easy to use (though you must decide for yourself whether it succeeds), particularly in a classroom lecture environment. It is may be downloaded for free from the CIS website at:

http://www.cis.rit.edu/resources/software/index.html

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

SignalShow

Juliet Bernstein has written a new Java counterpart of ***Signals***, called ***SignalShow***, that illustrates both 1-D and 2-D cases. The beta releases for Windows, Macintosh OSX, and Linux) are available online at http://www.signalshow.com/. This site includes links to instructional videos posted on YouTube. This program is useful for visualizing concepts in this course, as well as in 1051-718 "Digital Imaging Mathematics" and in 1051-733 "Optics for Imaging."

Other Software Tools

Other programs are available that are helpful in this course and the followup 1051-718 "Digital Imaging Mathematics."

- *ImageJ* is a freely available open-source program 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*, available on many computers in the Carlson Center
- *Matlab*