

COMP 576 (crosslisted as BMME 576), Spring 2022

Title: Mathematics for Image Computing

Credit: 3 credits

Target Audience: Undergraduates and graduates. The undergraduates may be in computer science, in biomedical engineering, majors in the mathematical sciences, or in any discipline using images. Graduates will be in disciplines using images, such as biomedical engineering; computer science graduate students may take this course, as well. This course can stand alone or be taken to provide background useful before taking COMP 775: Medical Image Analysis or COMP 776: Computer Vision. It also provides useful background for courses in biomedical imaging and image reconstruction.

Goal and Key Learning Objectives: To *present mathematics* relevant to image processing and analysis using real image computing objectives, as illustrated by computer implementations. The image computing objectives of concern include sharpening blurred images, denoising images, rotating or scaling objects in images, changing the number of image pixels, and locating object edges and bars in images. This mathematics is important in understanding methods that improve image quality, that find, recognize, or visualize objects in images, or that register images. The student who completes this course will be able to program in Matlab to accomplish image processing and will be prepared to learn the methods that go into computer vision and medical image analysis.

Catalogue description: Mathematics relevant to image processing and analysis using real image computing objectives and provided by computer implementations.

Prerequisites: the calculus of functions of multiple variables and enough linear algebra to understand matrix multiplication and determinants; programming such as that learned in COMP 116, 110, or 401. Matlab will be the course's main computer language, but you need not know that language going in. If you know C++ or Python and want to use that in place of Matlab, please see the instructor to understand the impediments that will cause and to record your choice.

Syllabus:

Spatial derivatives via tensors; numerical methods for derivative computation

Image representation: by pixels, by Taylor series

Shift-invariant linear operators: convolution and filtering

Fourier analysis and other orthogonal function decompositions; singular value decomposition

Imaging properties: point and line spread functions, resolution, distortion

Image sampling, esp. the Shannon theorem; resampling

Gaussian apertures, derivatives with apertures, and multiscale analysis; their use for finding edges and bars

Wavelets for multiscale analysis

Interpolation and least squares approximation of image intensities; splines

Height ridges; their use for finding edges and bars

Image translation, rotation, and scaling: quaternions and homogenous coordinates; perspective, affine transformations

Images as algebraic graphs; objects as graph cuts

Mathematics of deterministic optimization, Lagrange multipliers

As time permits: information theory and entropy; Levenberg-Marquardt optimization

The professor reserves the right to make limited changes to the syllabus, as well as to homework due dates and exam dates. These changes will be announced as early as possible.

Lectures:

Spring 2022 Course Delivery: The first week of instruction will be done remotely, at the following zoom site:

<https://unc.zoom.us/j/964026521>

After the first week of instruction, as long as it is possible to do so safely, we will be meeting in person this semester. I understand the ongoing COVID-19 pandemic may require changes to this plan and will be monitoring the situation closely. If I need to change the format of the course temporarily due to outbreaks of illness, I will announce this via email and the course Sakai site.

The course material will be taught largely through lectures and slides sets, though auxiliary book references will be provided. While there is no textbook, there is a book that covers much of the material rather well, but not with the same points of view as the course lectures in many cases. That book is *Image Processing and Analysis* by Stan Birchfield, Cengage Learning, 2016. A copy is on reserve at the Undergraduate Library. However, you may want to purchase your own copy; Amazon lists the paperback at just under \$80. With my lectures I will share what the appropriate sections of that book are. They will be recommended but not required reading, except as specified. The ppt slide sets forming the lectures are required “reading”. They will appear on the Sakai site for the course. You should arrange to be able to take notes on these sets, either online or by printing the document out on paper. When problems are found on a ppt slide, the slide will be corrected and the ppt will be reposted.

If you find something in a lecture unclear or in error, please interrupt and ask a question or indicate a correction. Doing so will help all the other students.

Except under limited circumstances for excusable reasons, attendance in person at all lectures delivered in person is required. For the few lectures that a student must attend remotely, at the above-specified zoom site, the lecture should be attended at the time of the lecture. In urgent circumstances the lecture may be attended via the recording, which will be placed in the COMP 576 folder at the Google Drive site of smp@cs.unc.edu.

Assignments: Assignments will largely involve writing Matlab programs that accomplish image processing or analysis, so as to provide a concrete understanding of the mathematics being taught, though there will be some problems that require you to do mathematics. You will need to have a particular version of matlab on your own computer; that version will be announced. If you do not have it, an LA will explain to you how to get it. If you do not know matlab, there is an online tutorial, which you should take immediately. Questions on matlab syntax and functions should be posed to the learning assistants, not to the instructor.

Homework will be expected to be the student's own work. Students are encouraged to ask each other questions of interpretation on homework, but any use of other material from another person or document in homework passed in must be acknowledged in writing in the answer. A Piazza website will be available for communication among students and the professor.

Because of the large number of students in the course, I expect assignment evaluation to be in two forms: 1) by students evaluating each other's homeworks; 2) by running example inputs and automatically evaluating whether the answer is correct or not. You will be given the ability to run your program via the grading system on your own inputs, and when you are ready, you will then be asked to run it on inputs not known to you that will be provided by the program. If I look at the programs at all, they will be judged on the quality of your internal documentation.

Exams: There will be a midterm exam, given roughly 60% of the way through the course, and a final exam. Example exams will be provided, with solutions. The questions on the exams will be about concepts and methods; they will not involve writing matlab programs. The course final will be given in compliance with UNC final exam regulations and according to the UNC Final Exam calendar.

Grading: Grading will depend on the two exams (2/3), the programming assignments (1/3), and class participation, incl. visits to the professor's office (as possible upgrade when the grade calculated is near a boundary between grade levels). In parentheses are the weight given to the respective items. The exams grade will be computed as the final exam grade if that is higher than the midterm exam grade and as the average of the midterm grade and exam grade if the final exam grade is lower than the midterm exam grade. The assignments will occur roughly biweekly. Grading them will be based on the performance of your program on inputs I provide and not known to you beforehand; as well, the programs may be evaluated for documentation. Late assignments will be docked 10% if no more than one week late, after one free such late. Assignments passed in later will be docked 50%.

Class attendance is required; this is critical due to the lack of a textbook for the course. If you must miss a class due to illness or another emergency, you must first look at the slides for that lecture on Sakai, then look at the recording of the lecture, and then immediately attend an office hour or make an appointment with the instructor to go over the material. Class participation expected includes asking questions in class and making suggestions for alternative interpretations. Students who see shortcomings in their understanding of course material will be credited with coming intermittently to the twice-per-week office hours with the instructor (or by appointment).

Instructor information: The instructor will be Kenan Professor of Computer Science, Stephen Pizer. He has decades of experience in the area of the course. Office: 222 Sitterson Hall. Email: pizer@cs.unc.edu. Phone: 919-590-6085; home phone: 919-929-3641. Office hours will be at 2:30-3:30 on Tuesday and 3:30-4:30 on Fridays (in my office, or as announced via the above-specified zoom site), and in the 15-minute periods before and after each class (in the classroom). However, if more office hours are needed, I will schedule more. In particular, if you have a conflict at both of the office hours above, please email me with the times of your class conflicts. In addition, you are welcome to ask by email or phone for a separate appointment during the course. If you have an appointment or it is an office hour, please knock on my office door even if someone is with me.

My email usage is as follows: I try to read email within 24 hours. Do not expect email to be read within minutes or a few hours from when you send it; thus, it cannot be used for urgent matters. Likewise with Piazza.

Likewise, I listen to my voicemail on both by office phone and on my home phone (919-929-3641), but within 24 hours of when it was placed. I do not allow students to call me or text me on my cellphone, nor do I listen to voicemail on it.

Books on Reserve: At Undergraduate Library

Image Processing and Analysis by Stan Birchfield, Cengage Learning 2016

Digital Image Processing by Rafael Gonzales and Richard Woods, Pearson Prentice-Hall 2008

Wavelets, applications of the mathematics we will be discussing

Front-End Vision and Multi-Scale Image Analysis by BM ter Haar Romeny, Kluwer 2003 (This book is available as a Mathematica program on a CD that you can borrow from me to copy)

Spatial scale, noise: Chapters 1-8; Geometry-limited diffusion: Chapter 21

Fundamentals of Digital Image Processing by Anil Jain, Prentice-Hall 1989

Especially Fourier transform and spatial sampling

Learning Assistants: Office hours place and times TBA.

Andrew Chun (achun@live.unc.edu), Alan Li (byli2223@live.unc.edu), Mike Zhang (ningliz@live.unc.edu). They will be able to help with questions about matlab and will have office hours where they can answer such questions. For course substance material, I encourage you to ask most of that kind of question from the instructor.

Classroom: FB (Frederick Brooks) 007