Innovations and Experiences in a Multidisciplinary Course on Image Formation and Processing: Simulation of a Corporate Environment

Jim Farison
Baylor University

Introduction

For the past several years, the author's favorite specialization for teaching and research has been the field of imaging and image processing. Imaging technology and image processing methods have changed dramatically over that period; and, so have students. After joining Baylor University, a mid-sized private institution in Texas, ten years ago, the author initiated an elective engineering course in image formation and processing, and has sought to make the course more attractive, and relevant, each year. This paper describes the fall semester 2008 version of the course, called ELC 4353 Image Formation and Processing, also cross-listed as BME 4353, and reviews the development, innovations and assessment of the course. The issues addressed and evaluated include: the scope and balance; delivery, significant student involvement including three sets of student presentations; and a simulated company environment. These features of the course mechanics have been developed through experience over these years and to appeal to students with their diverse elective course selection criteria and technical interests.

PART I – Overview of the Course from a Traditional Perspective

Background of Course

For context, the standard mechanics of this "course" are outlined in this section. The course is at the senior level, and also carries graduate credit for graduate student enrollment (with an additional course requirement). The course was first offered as a trial Special Topics course in fall 2002; then, from Fall 2004 through Fall 2006, it was offered annually as the established course, EGR 4353 Image Formation and Processing. This author gave the initial fall 2002 introductory trial. The established version was given in 2004 by a colleague, then by the author for the past four years (fall 2005 through fall 2008). It is listed and offered as a three-credit course, and has been offered both on a three-times-a-week, 50-minute schedule, and a twice-a-week, 75 minute schedule. The fall 2007 and fall 2008 classes were on a 50-minute, three-times-a-week schedule. When Baylor University's multiple B.S. engineering programs went to distinct course prefixes in fall 2008, the course became dual listed, as ELC 4353 (for B.S. or M.S. ECE students) and BME 4353 (for students in the interdisciplinary B.S.E. program or the M.S. BME program). The current catalog description is:

> **ELC 4353 Image Formation and Processing (cross-listed with BME 4353)**
> Introduction to image formation systems that provide images for medical diagnostics, remote sensing, industrial inspection, nondestructive testing, materials evaluation, and optical copying. Image processing, including image enhancement, analysis, and compression. Student specialization through assignments and project.

The prerequisite is a three-credit, junior, engineering lecture course called ELC 3335 Signals and Systems. A three-credit, junior, lecture course STA 3381 Statistical Methods, taught by our Statistics Department, is a co-requisite. Both of those courses are offered both semesters and are currently required for our three B. S. engineering majors (ECE, ME, and Engineering).

Enrollment

Natural curricular and other influences have resulted, historically, in many enrollees having been undergraduate ECE students but, as noted, the prerequisites make the course enrollment available for all of our undergraduate engineering students (and, possibly, for others taking an engineering minor). An increasing diversity of enrollment has been encouraged and achieved. In an early semester, a mechanical engineering graduate student who needed to use images and image processing for his M.S. thesis research enrolled. While the annual enrollment (from 5 to 14 students) and academic diversity of students who select the course have varied considerably from year to year, the more recent classes (fall 2007 and fall 2008) were particularly diverse (with 9 and 14 students enrolled, respectively):

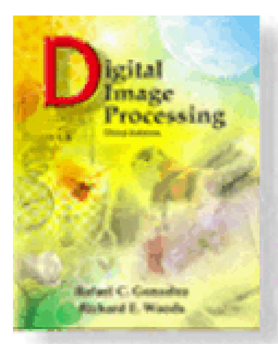
Enrolled Students by Major and Level – Fall 2007	Undergrad.	Masters	Total
Electrical and Computer Engineering	5	1	6
Biomedical Engineering		1	1
Engineering	1		1
Computer Science (w/engineering minor)	1		1
Total	7	2	9

Enrolled Students by Major and Level – Fall 2008	Undergrad.	Masters	Total
Electrical and Computer Engineering	5	4	9
Biomedical Engineering		1	1
Engineering (Biomedical Option)	3		3
Engineering		1	1
Total	8	6	14

Of the 14 fall 2008 students, four were enrolled in BME 4353 and 10 were enrolled in ELC 4253.

Scope and Balance of Course

After trying other books, the textbook that has been used here in recent years is Digital Image Processing, Rafael C. Gonzalez and Richard E. Woods, Pearson/Prentice Hall ©. This past fall, the recently released third edition (2008) was used. The extensive and excellent visuals available with this textbook are not only a great resource but virtually a necessity for a visually-oriented image processing course. Various other valuable on-line resources are also available from the publisher at http://www.imageprocessingplace.com/. Because of some specific characteristics of this course, described in the next section, the instructor's lectures in recent offerings have covered only selected portions of the book's twelve chapters: Chapters 1-4, much of Chapter 5, and portions of Chapters 6, 8, and 9. Chapter titles are:



1. Introduction
2. Digital Image Fundamentals
3. Intensity Transformations and Spatial Filtering
4. Filtering in the Frequency Domain
5. Image Restoration and Reconstruction
6. Color Image Processing
7. Wavelets and Multiresolution Processing
9. Morphological Image Processing
10. Image Segmentation
11. Representation and Description
12. Object Recognition

One of the attractions of this textbook for our Image Formation and Processing course is the extensive coverage of the variety of imaging systems used for image generation in "Chapter 1 Examples of Fields that Use Digital Image Processing." The presentation in that chapter is arranged according to the transverse electromagnetic spectral band in which the image is generated. Also introduced are a few other imaging technologies such as the longitudinal waves of ultrasound. While this imaging application overview seems to be a very attractive feature for an image processing textbook for engineering students, it also provides the springboard for this course's inclusion of a considerable emphasis on other engineering issues involved in the operation and application of diverse contemporary imaging systems. That is, this course includes attention to some of the "practical issues" related to the physical imaging systems that generate the images. Because of the time devoted to imaging systems while going through Chapter 1, less of the remaining text can be completed.

PART II - Individualized Student Learning Component

One of the attractive features of the course, both to the instructor and to (most of) the students, is an individualized learning component. The students have generally responded with increasing enthusiasm each year, as the instructor has developed and refined this feature over the past several annual offerings. Currently, the course presentation emphasizes three distinct aspects of imaging systems and their applications that seem appropriate and valuable to senior and masters students, most of whom are about to graduate and enter the work force. Each of the three individualized components of the current course content involves a broad imaging subject area, within which each student selects the specific topic. These three varied and student-based learning components enrich the course in at least two significant ways.

First, for each of these three special components of the course, each student selects the subject of his or her own choosing (with instructor approval for appropriateness of the specific subject and level and to avoid duplication or overlap of topics). Each student then completes the full cycle of:

1) a literature search,
2) paper preparation and refinement for submission and distribution to the class members and instructor, and
3) the preparation and delivery of a live visual presentation to the class.

This gives a significant individualization of subject content according to each student's specific interests. Second, this pattern also gives a wide diversity of exposure for each student who learns from the intentional diversity of the other students' presentations.

The three presentation themes are:

1. Practical imaging system issues. – As we near the completion of the coverage of the variety of imaging system methods and applications in Chapter 1, each student selects a topic (a specific imaging system or major component). Upon approval or modification of the proposed topic by the instructor (for appropriateness and so that the group has a good variety), the student collects material, then organizes and presents a written paper and PP presentation for the class. Appropriate content for this initial presentation includes very practical and commercial engineering-oriented topics such as: who manufactures these systems or components, who uses them, how are they used, and what are their characteristics (applications, cost, physical size, resolution, lifetime, etc.).

2. Contemporary image processing R&D. – After we have covered some of the image processing topics from the text and the students have some vocabulary and perspective, each student selects a topic and paper from the reviewed and published professional research literature on some specific image processing algorithm and/or imaging application and, again, with approval, prepares and distributes a written paper and delivers a classroom presentation on that subject.

3. Each student's own applied image processing research project. – As late in the course as the preparation sequence involved allows, each student selects and upon approval for appropriateness of topic and level conducts an actual image processing project (normally, MATLAB Image Processing Toolbox-based). The project is designed to test and/or compare the image processing effectiveness of some desired imaging processing algorithm(s). Again, each student's project results are distributed in written form and presented orally to the class.

The extra requirement for graduate credit for graduate student enrollees is related to the presentations. While the expectations for the first presentation are about the same for all enrolled students, the second project (research literature) has a slightly higher expectation and the third project (MATLAB research project) requires a demonstrably higher expectation for the graduate students.

Because of the perceived inherent value of, and the time devoted to, these three individualized presentation assignments and the resulting diversity that the whole class receives, very few traditional homework problem assignments are used (none in the 2008 class).

Simulated Corporate Business Environment

Since the enrollment comprises mostly students who are planning to graduate that year, they are likely becoming tired of the traditional academic routine of lectures, homework, tests and final exams. Except for those planning on graduate school, the majority of students are eager to get on with their employment in industry. Realizing this tendency, the author decided to try an innovation that might be especially compatible with this type and level of elective course. In the offering during fall 2007 (and, again, in fall 2008), he sought to simulate a corporate business environment within the course and classroom. The context given by the instructor is:

> "I have been asked by our company to investigate the viability of our entering some aspect of the imaging industry, possibly in:
> 1) product development, sales, or service,
> 2) government- or industrially-sponsored image processing research, and/or
> 3) contract image processing service.
> In six months, I am expected to provide a report for our corporate vice president on our findings and a recommendation of appropriate action. Each of you is an important part of the team I have assembled from various units of our company to investigate that possibility."

This scenario, with the three specific emphases, is the context that gives specific meaning to the three projects and presentations listed in the Individualized Student Learning Component section above. The author believes this is a valuable idea to provide novelty to the classroom and motivation to the assignments. Unfortunately, in the initial 2007 implementation of this scenario, the instructor failed to convert his vocabulary and classroom environment sufficiently to make it seem much more than a relatively novel idea, gradually lapsing back into the more conventional vocabulary of the traditional college classroom, with only occasional references to the idea after the first project.

To gain more specific student feedback about the unique features of the course than the standard university teaching evaluation form could provide, the instructor also distributed a supplementary survey directed specifically to the unique features of this course at the end of the 2007 course. The room we use is arranged with the writing board and screen along the wider side of the room, with three end-to-end long tables in each of two parallel rows, facing the screen. The instructor has the space between the screen and the tables, with a computer desk to the side (out of the line of sight to the screen) and open space to roam between the screen and the students. The focused survey response was quite helpful, with 8 of the 9 enrolled students responding. One of the most practical and insightful suggestions from the students was that, if we wanted to simulate a business environment, why didn't we rearrange the room so we could sit more like a business meeting.

Given another opportunity in fall 2008, the author was convinced that the "corporate business environment" idea had considerable merit and could be developed much more fully. The students' "business environment" idea was implemented in fall 2008, with the instructor sitting (most of the time) at a smaller table making a three-sided "|___|" seating pattern, open toward the screen, with the instructor on the left side. This provided a much better environment, with everyone easily able to see the screen, the instructor, and each other. And, rearranging the room before and after each session gave the instructor some useful exercise.

As noted above, the fall 2007 class had an enrollment of only 9. The fall 2008 class, a group of 14, presented both positive (more variety) and negative features. One of the most challenging impacts of the larger number was the amount of time for each set of individual presentations. In 2007, the group of 9 students provided a very comfortable schedule of three meetings (class sessions; one week) with three presentations in each of three consecutive scheduled class periods of 50 minutes each. Each presentation had a quite comfortable 15 minute slot for getting the PP set-up, giving the presentation, and responding to questions. In 2008, with 14 students and considering going to more sessions as not viable, we continued with the three class period (one week) schedule. The class was scheduled for 9:05-9:55 am, MWF, and, very fortunately, no one had an 8:00 am class. So, the class agreed (but unclear as to how willingly) to start at 8:45 am on the first two days (70 minutes, to support with five presentations) and at the regular 9:05 am on the third day (with four presentations). This made the presentations shorter and more rushed than desirable, but the students seemed to take the timing in stride. The greatest disadvantage, at least in the instructor's judgment, was the weakening of the focus of the class on the respective presentations by having five different presentation topics in a single session on two of the days. To compensate, each student received a copy of the full papers and the PP slides for each of the three distinct topical sets of 14 presentations at the time of the respective presentations.

Fall 2008 Final Presentations

The student-selected student project titles for the third set of presentations, those representing the participants' own MATLAB image processing "research" projects, were:

First day	Image Rotation using MATLAB Corrupting and Recovering an Image Image Corrupted using Log-Polar Transform Deblurring Images using Constrained Least-Squares Filtering
Second day	Wiener Filter Texture Segmentation and Filtration Contract Enhancement of Medical Images Wavelet Transform and Its Application on Digital Image Processing Using MATLAB to Partially Reconstruct a Skeletonized Image
Third day	Using Noise to Enhance Images Iterative Projections onto Convex Surfaces in Image Reconstruction and Noise Reduction Shape Detection and Identification Lucy-Richardson Filtering Object Tracking with a USB Camera

Evaluation/Grading of Students

In accordance with the unique balance of course learning components and objectives in the delivery of this course, the evaluation for generating the necessary letter grade for each student is matched to the emphasis and components. Specifically, half of the course grade is determined by components common to most courses and half of the course grade is unique to this project/paper/presentation format:

Traditional grading components - classroom tests (50%)	
Midterm test	20%
Final exam (comprehensive)	30%

Individual student project reports and presentations (50%)

1. Applied/practical - imaging systems and hardware	15%
2. Peer-reviewed image processing research material	15%
3. Student-formulated image processing "research" project	20%

Conclusion

With the relatively favorable evaluation of the delivery of the course by both the students and the instructor, it is planned to continue the scope, structure and delivery of the course largely as described above. The primary change, which comes through clearly from the assessment by last years' students, will be to be much more intentional and consistent in developing the "corporate business format" throughout the course, as a potentially significant motivating environment for stimulating student initiative and learning in the course. Perhaps the instructor will even call the traditionally academic "midterm test and final exam" our "interim and final team-member assessments."

JIM FARISON
After a nine-year term as department chair (1998-2007), plus a year as associate chair (2007-2008), Dr. Farison is now teaching part-time as professor emeritus in the department of electrical and computer engineering, all at Baylor University. His teaching assignment is a spring-semester, required, junior-level course in Signals and Systems and a fall-semester, senior-graduate elective course in Image Formation and Processing, the latter being the subject of this paper.