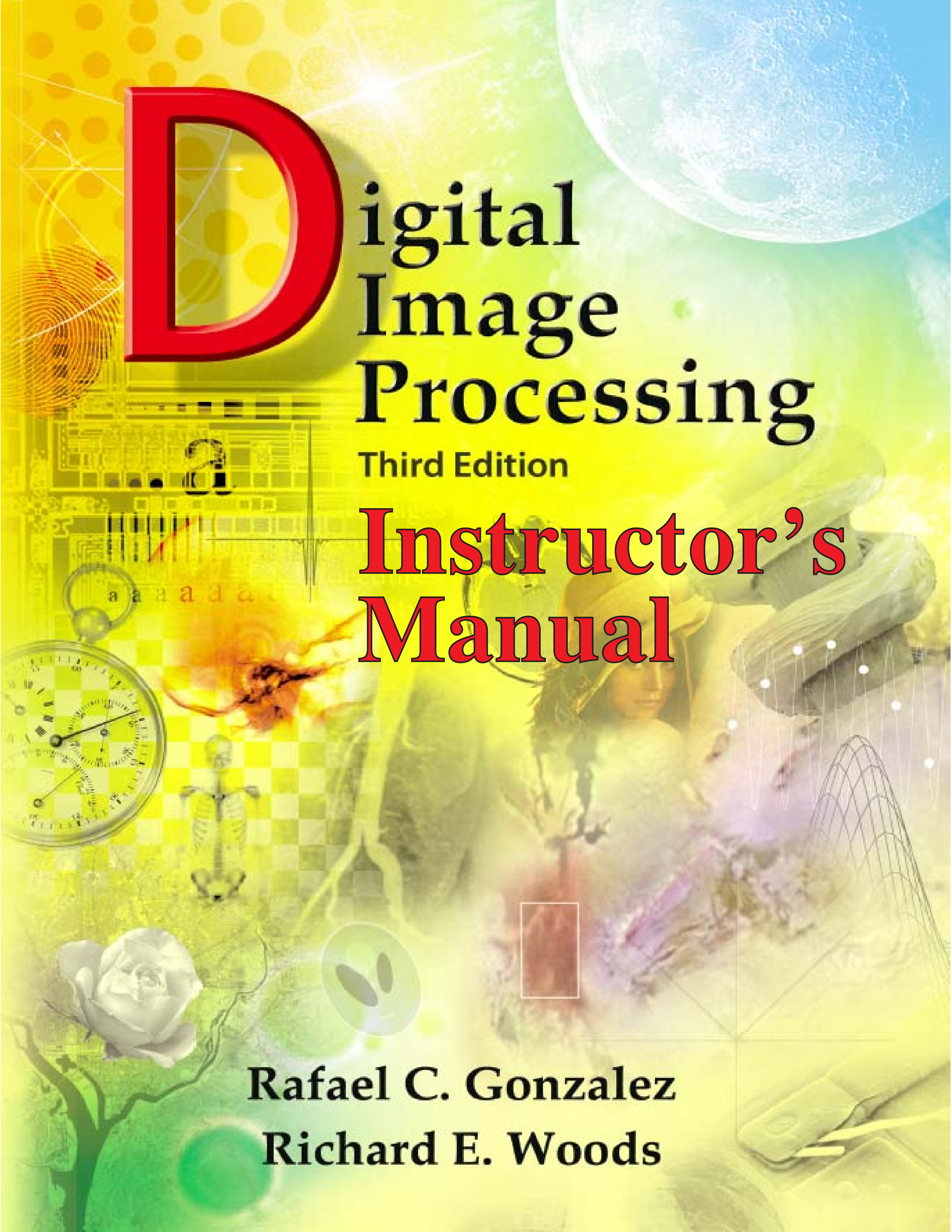

Digital Image Processing

Third Edition

Instructor's Manual

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Version 3.0

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Chapter 1

Introduction

The purpose of this chapter is to present suggested guidelines for teaching material from *Digital Image Processing* at the senior and first-year graduate levels. We also discuss use of the book web site. Although the book is totally self-contained, the web site offers, among other things, complementary review material and computer projects that can be assigned in conjunction with classroom work. Detailed solutions to all problems in the book also are included in the remaining chapters of this manual.

1.1 Teaching Features of the Book

Undergraduate programs that offer digital image processing typically limit coverage to one semester. Graduate programs vary, and can include one or two semesters of the material. In the following discussion we give general guidelines for a one-semester senior course, a one-semester graduate course, and a full-year course of study covering two semesters. We assume a 15-week program per semester with three lectures per week. In order to provide flexibility for exams and review sessions, the guidelines discussed in the following sections are based on forty, 50-minute lectures per semester. The background assumed on the part of the student is senior-level preparation in mathematical analysis, matrix theory, probability, and computer programming. The Tutorials section in the book web site contains review materials on matrix theory and probability, and has a brief introduction to linear systems. PowerPoint classroom presentation material on the review topics is available in the Faculty section of the web site.

The suggested teaching guidelines are presented in terms of general objectives, and not as time schedules. There is so much variety in the way image processing material is taught that it makes little sense to attempt a breakdown of the material by class period. In particular, the organization of the present edition of the book is such that it makes it much easier than before to adopt significantly different teaching strategies, depending on course objectives and student background. For example, it is possible with the new organization to offer a course that emphasizes spatial techniques and covers little or no transform material. This is not something we recommend, but it is an option that often is attractive in programs that place little emphasis on the signal processing aspects of the field and prefer to focus more on the implementation of spatial techniques.

1.2 One Semester Senior Course

A basic strategy in teaching a senior course is to focus on aspects of image processing in which both the inputs and outputs of those processes are images. In the scope of a senior course, this usually means the material contained in Chapters 1 through 6. Depending on instructor preferences, wavelets (Chapter 7) usually are beyond the scope of coverage in a typical senior curriculum. However, we recommend covering at least some material on image compression (Chapter 8) as outlined below.

We have found in more than three decades of teaching this material to seniors in electrical engineering, computer science, and other technical disciplines, that one of the keys to success is to spend at least one lecture on motivation and the equivalent of one lecture on review of background material, as the need arises. The motivational material is provided in the numerous application areas dis1.2 One Semester Senior Coursecussed in Chapter 1. This chapter was prepared with this objective in mind. Some of this material can be covered in class in the first period and the rest assigned as independent reading. Background review should cover probability theory (of one random variable) before histogram processing (Section 3.3). A brief review of vectors and matrices may be required later, depending on the material covered. The review material in the book web site was designed for just this purpose.

Chapter 2 should be covered in its entirety. Some of the material (Sections 2.1 through 2.3.3) can be assigned as independent reading, but more detailed explanation (combined with some additional independent reading) of Sections 2.3.4 and 2.4 through 2.6 is time well spent. The material in Section 2.6 covers concepts that are used throughout the book and provides a number of image processing applications that are useful as motivational background for the rest of the book

Chapter 3 covers spatial intensity transformations and spatial correlation and convolution as the foundation of spatial filtering. The chapter also covers a number of different uses of spatial transformations and spatial filtering for image enhancement. These techniques are illustrated in the context enhancement (as motivational aids), but it is pointed out several times in the chapter that the methods developed have a much broader range of application. For a senior course, we recommend covering Sections 3.1 through 3.3.1, and Sections 3.4 through 3.6. Section 3.7 can be assigned as independent reading, depending on time.

The key objectives of Chapter 4 are (1) to start from basic principles of signal sampling and from these derive the discrete Fourier transform; and (2) to illustrate the use of filtering in the frequency domain. As in Chapter 3, we use mostly examples from image enhancement, but make it clear that the Fourier transform has a much broader scope of application. The early part of the chapter through Section 4.2.2 can be assigned as independent reading. We recommend careful coverage of Sections 4.2.3 through 4.3.4. Section 4.3.5 can be assigned as independent reading. Section 4.4 should be covered in detail. The early part of Section 4.5 deals with extending to 2-D the material derived in the earlier sections of this chapter. Thus, Sections 4.5.1 through 4.5.3 can be assigned as independent reading and then devote part of the period following the assignment to summarizing that material. We recommend class coverage of the rest of the section. In Section 4.6, we recommend that Sections 4.6.1-4.6.6 be covered in class. Section 4.6.7 can be assigned as independent reading. Sections 4.7.1-4.7.3 should be covered and Section 4.7.4 can be assigned as independent reading. In Sections 4.8 through 4.9 we recommend covering one filter (like the ideal lowpass and highpass filters) and assigning the rest of those two sections as independent reading. In a senior course, we recommend covering Section 4.9 through Section 4.9.3 only. In Section 4.10, we also recommend covering one filter and assigning the rest as independent reading. In Section 4.11, we recommend covering Sections 4.11.1 and 4.11.2 and mentioning the existence of FFT algorithms. The $\log_2$ computational advantage of the FFT discussed in the early part of Section 4.11.3 should be mentioned, but in a senior course there typically is no time to cover development of the FFT in detail.

Chapter 5 can be covered as a continuation of Chapter 4. Section 5.1 makes this an easy approach. Then, it is possible to give the student a "flavor" of what restoration is (and still keep the discussion brief) by covering only Gaussian and impulse noise in Section 5.2.1, and two of the spatial filters in Section 5.3. This latter section is a frequent source of confusion to the student who, based on discussions earlier in the chapter, is expecting to see a more objective approach. It is worthwhile to emphasize at this point that spatial enhancement and restoration are the same thing when it comes to noise reduction by spatial filtering. A good way to keep it brief and conclude coverage of restoration is to jump at this point to inverse filtering (which follows directly from the model in Section 5.1) and show the problems with this approach. Then, with a brief explanation regarding the fact that much of restoration centers around the instabilities inherent in inverse filtering, it is possible to introduce the "interactive" form of the Wiener filter in Eq. (5.8-3) and discuss Examples 5.12 and 5.13. At a minimum, we recommend a brief discussion on image reconstruction by covering Sections 5.11.1-5.11-2 and mentioning that the rest of Section 5.11 deals with ways to generated projections in which blur is minimized.

Coverage of Chapter 6 also can be brief at the senior level by focusing on enough material to give the student a foundation on the physics of color (Section 6.1), two basic color models (RGB and CMY/CMYK), and then concluding with a brief coverage of pseudocolor processing (Section 6.3). We typically conclude a senior course by covering some of the basic aspects of image compression (Chapter 8). Interest in this topic has increased significantly as a result of the heavy use of images and graphics over the Internet, and students usually are easily motivated by the topic. The amount of material covered depends on the time left in the semester.

1.3 One Semester Graduate Course (No Background in DIP)

The main difference between a senior and a first-year graduate course in which neither group has formal background in image processing is mostly in the scope of the material covered, in the sense that we simply go faster in a graduate course and feel much freer in assigning independent reading. In a graduate course we add the following material to the material suggested in the previous section.

Sections 3.3.2-3.3.4 are added as is Section 3.3.8 on fuzzy image processing. We cover Chapter 4 in its entirety (with appropriate sections assigned as independent readying, depending on the level of the class). To Chapter 5 we add Sections 5.6-5.8 and cover Section 5.11 in detail. In Chapter 6 we add the HSI model (Section 6.3.2) , Section 6.4, and Section 6.6. A nice introduction to wavelets (Chapter 7) can be achieved by a combination of classroom discussions and independent reading. The minimum number of sections in that chapter are 7.1, 7.2, 7.3, and 7.5, with appropriate (but brief) mention of the existence of fast wavelet transforms. Sections 8.1 and 8.2 through Section 8.2.8 provide a nice introduction to image compression.

If additional time is available, a natural topic to cover next is morphological image processing (Chapter 9). The material in this chapter begins a transition from methods whose inputs and outputs are images to methods in which the inputs are images, but the outputs are attributes about those images, in the sense defined in Section 1.1. We recommend coverage of Sections 9.1 through 9.4, and some of the algorithms in Section 9.5.

1.4 One Semester Graduate Course (with Student Having Background in DIP)

Some programs have an undergraduate course in image processing as a prerequisite to a graduate course on the subject, in which case the course can be biased toward the latter chapters. In this case, a good deal of Chapters 2 and 3 is review, with the exception of Section 3.8, which deals with fuzzy image processing. Depending on what is covered in the undergraduate course, many of the sections in Chapter 4 will be review as well. For Chapter 5 we recommend the same level of coverage as outlined in the previous section.

In Chapter 6 we add full-color image processing (Sections 6.4 through 6.7). Chapters 7 and 8 are covered as outlined in the previous section. As noted in the previous section, Chapter 9 begins a transition from methods whose inputs and outputs are images to methods in which the inputs are images, but the outputs are attributes about those images. As a minimum, we recommend coverage of binary morphology: Sections 9.1 through 9.4, and some of the algorithms in Section 9.5. Mention should be made about possible extensions to gray-scale images, but coverage of this material may not be possible, depending on the schedule. In Chapter 10, we recommend Sections 10.1 through 10.4. In Chapter 11 we typically cover Sections 11.1 through 11.4.

1.5 Two Semester Graduate Course (No Background in DIP)

In a two-semester course it is possible to cover material in all twelve chapters of the book. The key in organizing the syllabus is the background the students bring to the class. For example, in an electrical and computer engineering curriculum graduate students have strong background in frequency domain processing, so Chapter 4 can be covered much quicker than would be the case in which the students are from, say, a computer science program. The important aspect of a full year course is exposure to the material in all chapters, even when some topics in each chapter are not covered.

1.6 Projects

One of the most interesting aspects of a course in digital image processing is the pictorial nature of the subject. It has been our experience that students truly enjoy and benefit from judicious use of computer projects to complement the material covered in class. Because computer projects are in addition to course work and homework assignments, we try to keep the formal project reporting as brief as possible. In order to facilitate grading, we try to achieve uniformity in the way project reports are prepared. A useful report format is as follows:

Page 1: Cover page.

- Project title
- Project number
- Course number
- Student's name
- Date due
- Date handed in
- Abstract (not to exceed 1/2 page)

Page 2: One to two pages (max) of technical discussion.

Page 3 (or 4): Discussion of results. One to two pages (max).

Results: Image results (printed typically on a laser or inkjet printer). All images must contain a number and title referred to in the discussion of results.

Appendix: Program listings, focused on any original code prepared by the student. For brevity, functions and routines provided to the student are referred to by name, but the code is not included.

Layout: The entire report must be on a standard sheet size (e.g., letter size in the U.S. or A4 in Europe), stapled with three or more staples on the left margin to form a booklet, or bound using clear plastic standard binding products.1.2 One Semester Senior Course

Project resources available in the book web site include a sample project, a list of suggested projects from which the instructor can select, book and other images, and MATLAB functions. Instructors who do not wish to use MATLAB will find additional software suggestions in the Support/Software section of the web site.

1.7 The Book Web Site

The companion web site

www.prenhall.com/gonzalezwoods

(or its mirror site)

www.imageprocessingplace.com

is a valuable teaching aid, in the sense that it includes material that previously was covered in class. In particular, the review material on probability, matrices, vectors, and linear systems, was prepared using the same notation as in the book, and is focused on areas that are directly relevant to discussions in the text. This allows the instructor to assign the material as independent reading, and spend no more than one total lecture period reviewing those subjects. Another major feature is the set of solutions to problems marked with a star in the book. These solutions are quite detailed, and were prepared with the idea of using them as teaching support. The on-line availability of projects and digital images frees the instructor from having to prepare experiments, data, and handouts for students. The fact that most of the images in the book are available for downloading further enhances the value of the web site as a teaching resource.