

Preface to *The Science of Digital Media* Emphasizing Science While Enabling Practice and Art

The purpose of *The Science of Digital Media* is to explain the essential mathematics, algorithms, and technology that are the foundation of digital media tools. What do we mean by *digital media*? This is, in fact, a broad term used in different ways in different contexts. In our view, the term describes itself. *Digital media* is defined as media – images, sound, and video – that are represented and manipulated digitally. Thus, this book begins with a chapter on fundamentals, covering topics that are relevant across-media; it continues with chapters on digital imaging, digital audio, digital video; and it concludes with a final chapter on multimedia authoring, to tie the media together.

And what do we mean by digital media tools? We mean application programs for manipulating digital images, audio, and video – for example, Photoshop, GIMP, Illustrator, Audition, Audacity, Sound Forge, Reason, Max/MSP/Jitter, Premiere, and Final Cut. We also mean the programming languages and authoring tools that make it possible for you to put together your images, audio, and video in a dynamic, interactive production – for example, Director, Flash, and Java.

Digital media application programs are the basis for the topics chosen in *The Science of Digital Media*. This is *not* to say that the book is about how to use specific application programs. To choose topics for the book, I looked at the features of application programs and the activities you do when you use these features, choosing the mathematical and scientific topics accordingly. In digital image processing, you decide on a color mode, shift to indexed color, change resolution, choose a file type, and decide whether or not to compress. In digital audio processing, you choose a sampling rate and bit depth, dither if necessary, look at spectral views of your audio file, and filter out unwanted frequencies. In digital video, you shoot and capture video footage, edit it and apply special effects, compress, and prepare the video appropriately for distribution. But the question is not “what’s the right button to click or menu item to select?” The question is “what makes these things work?”

This book is accompanied by a variety of supplementary learning aids, including interactive online demos, problem-solving and concept-testing worksheets, MATLAB exercises, programming assignments, and suggestions for creative or term projects. The interactive demos “act out” concepts, activities, mathematical operations, and algorithms in a way that brings them alive and makes the concepts much easier to grasp. The worksheets give you an opportunity to test your understanding. Students do not need to have MATLAB in order to benefit from the MATLAB-based exercises. Solutions are provided for the instructor, and these solutions can be the basis for instructor lectures and demonstrations. The programming assignments show you how algorithms are implemented “from scratch.” The suggestions for projects tie science to both practice and art. Pre- and post-tests, solutions to worksheets and programming exercises, and example projects are made accessible on-line to instructors.

The Audience for *The Science of Digital Media* Level

The Science of Digital Media was written primarily for college-level courses taught to computer science students. However, it is targeted at a middle ground that makes it useful to students at multiple levels. Some of the material in the book is not

beyond the reach of high school students with sufficient background in mathematics and computer programming. At the other end of the spectrum, graduate students could use this book as an introduction to digital media, image processing, or digital signal processing, going into more depth in the mathematical and algorithmic complexities.

The mathematics for digital media ranges from high school to college level. The essential mathematical foundation for the book would include numeric bases (particularly base 2), exponents, logarithms, summations, functions, graphs of functions, and matrices. (See Table 1.) A few sections assume some knowledge of calculus – for example, the sections on transforms. However, mathematical details that are beyond the grasp of students in a course could be skipped without loss of continuity in the use of the book. For example, the section on FIR and IIR filters and Z-transforms could be omitted, or the essential concepts could be explained without the details, and the chapter in which the section is contained would still be coherent.

Concept in digital media	Mathematical foundation
sampling and quantization	base 2, conversion between bases
waveforms	trigonometric functions
color model conversions	linear and non-linear transforms
image filtering	convolutions and matrix operations
vector graphics, splines	parametric functions
examining image or audio data	histograms and statistical analysis, mean, median, mode, root-mean-square
audio dithering	graphing functions, summing functions
decibels	logarithms, exponents
transforms	functional domains
Fourier transform	summations and integrals
Z-transform	complex numbers, summations, integrals

Table 1. Mathematical foundations for digital media

The presentation of algorithms in the book assumes that students have some programming experience. At a minimum, they should understand procedural problem solving and be able to read pseudo-code. Chapter 8 focuses on a comparison of multimedia authoring environments and thus assumes some programming experience. However, instructors can use this book for a course without requiring students to write any programs.

Computer Science or Interdisciplinary Digital Media Courses

As implied in the title, *The Science of Digital Media* was written particularly as a textbook for computer science or interdisciplinary courses that treat digital media as a science. The book contains more than enough material for a single course. My goal in writing the book was to make it possible for you to select topics relevant to your curriculum, with the remainder available to you as reference. There are more worksheets, tutorials, and programming exercises than you'll need for a single course. The intent was to provide you with a repertoire of assignments so that you can choose those that best fit your needs.

Here are four ways that *The Science of Digital* could be used as a textbook. You may find other ways that work for you:

- A course that emphasizes breadth would make a pass over the entire book, with the instructor focusing only on the topics of most interest to him or her.
- If a course covers only one medium, only the chapters on that medium would be used and covered in detail.
- The book could be used over two semesters, one semester emphasizing algorithms and one semester emphasizing mathematics.
- The book could be used over two semesters, each semester making a pass over the entire book. The first semester would focus on basic concepts; the second semester would go into more depth on the mathematics.

The Science of Digital Media tries to be true to its name and keep the focus clearly on science, of which mathematics is a fundamental part. At the same time, I believe that what makes digital media such an exciting area is that it springs from *doing things* and *making things*: pictures, sound, videos, interactive games, educational software, and the like. If a digital media course doesn't return to its roots and give students opportunities to use the software and create something of their own, it will probably be a great disappointment. Thus, I envision a course in which classroom instruction focuses on science and mathematics, but the term project gives the students hands-on experience. For example, I often have my students implement game programs for their final projects, pulling together digital images, sound, and video by means of a multimedia programming language.

Practitioners and Hobbyists Working in Digital Media

The Science of Digital Media could also be of interest to practitioners and hobbyists working in digital media. The term “hobbyist” may seem to imply someone who is just in digital media for fun – but mathematics and science actually *are* fun for some people. There are people who just like to know how things work. If you're this type, it isn't enough to poke around on menu items and click buttons by trial and error until you get the effect you're looking for. You want to know what's *really* going on. Understanding the mathematics and science behind digital media tools gives you a mastery over the tools that is hard to achieve by hands-on experience alone. For practitioners of digital media brave enough or curious enough to “look under the hood,” *The Science of Digital Media* can be a helpful and, we hope, even an interesting reference book.

Whatever your reason for reading this book, I encourage you to dig in, find answers to questions that have always puzzled you, and realize there are questions that never even occurred to you. The practice of digital media can fascinate the eyes and ears with images, sound, motion, and interactivity. The science, mathematics, and technical ingenuity of digital media can equally dazzle the mind.