New in the Third Edition

In this third edition of the book, we have focused on making fixes and improvements as identified by teachers using the book and by anonymous reviewers.

1. General freshening of the references, for example Netscape Navigator and 40 Gb hard disks are so 2005.
2. Introducing more computer science terms (briefly) earlier in the book, such as *algorithm*, *identifier*, and *local and global scope*.
3. More thorough presentation of conditionals, earlier in the book, including *else* and *elif*.
4. A section on functions and parameters, with a discussion of when to use return and when it isn’t necessary.
5. More explanation of how variables work, especially with respect to objects.
6. More on mirroring pictures, with a more generalized example.
7. Updating the Web examples with references to accessing common, modern sites.
8. More on differences between image formats.
9. Removing some of the more trivial Turtle examples in Chapter 16, and adding a couple of sophisticated examples with turtles.
10. Updating the section on hardware and networks to reference newer hardware, including multi core processors and cell phones.
11. Making clearer what can be done in Jython and CPython, in comparison with JES.
12. Adding another steganography-related example.
13. Adding figures and additional explanation for the areas that reviewers saw as confusing for students.

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Changes Made in the Second Edition

We appreciate the interest in the first edition of the book, which has allowed us to prepare this second edition. We are grateful for the comments from our anonymous reviewers that guided our revision.

The major differences between the first edition and second edition are:

1. We increased our coverage of the Python language, including more of the standard libraries, global scope, and additional control structures.
2. There is an increased emphasis on abstraction and on creating reusable code.
3. The movie chapter includes instructions on how to create standard AVI and Quick-Time movies for sharing with others.
4. We increased the number of exercises at the end of each chapter significantly.
5. All indices start with zero instead of one. By starting with zero as the first index instead of one, we are more compatible with standard Python.
6. We removed the chapter on creating a user interface in Swing and the one on JavaScript.
7. We rewrote the chapter on design and debugging to include design and testing examples, with an emphasis on maintenance.
8. We split the chapter on creating and modifying text into two chapters. We added an example of steganography.
9. We split the language paradigms chapter (styles of programming) into two chapters to provide more content on functional (such as non mutable functions) and object-oriented programming (e.g., introducing objects through use of Logo-like turtles).
10. We have added in coverage of concepts that many teachers want to touch on in their introductory course, such as binary representations of negative numbers.
11. Overall, we have made the English clearer and removed some unnecessary detail. (We hope.)
12. There is no longer a CD in the back of the book. The latest versions of all software and materials can be found at http://mediacomputation.org.

The second edition adds a co-author who brings great experience to the project.

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Preface to the First Edition

Research in computing education makes it clear that one doesn’t just “learn to program.” One learns to program *something* [5, 22], and the motivation to do that something can make the difference between learning and not learning to program [8]. The challenge for any teacher is to pick a *something* that is a powerful enough motivator.

People want to communicate. We are social creatures and the desire to communicate is one of our primal motivations. Increasingly, the computer is used as a tool for communication even more than a tool for calculation. Virtually all published text, images, sounds, music, and movies today are prepared using computing technology.

This book is about teaching people to program in order to communicate with digital media. The book focuses on how to manipulate images, sounds, text, and movies as professionals might, but with programs written by students. We know that most people will use professional-grade applications to perform these type of manipulations. But, knowing *how* to write your own programs means that you *can* do more than what your current application allows you to do. Your power of expression is not limited by your application software.

It may also be true that knowing how the algorithms in a media applications work allows you to use them better or to move from one application to the next more easily. If your focus in an application is on what menu item does what, every application is different. But if your focus is on moving or coloring the pixels in the way you want, then maybe it’s easier to get past the menu items and focus on what you want to say.

This book is not just about programming in media. Media-manipulation programs can be hard to write or may behave in unexpected ways. Natural questions arise, like “Why is the same image filter faster in Photoshop?” and “That was hard to debug—Are there ways of writing programs that are easier to debug?” Answering questions like these is what computer scientists do. There are several chapters at the end of the book that are about *computing*, not just programming. The final chapters go beyond media manipulation to more general topics.

The computer is the most amazingly creative device that humans have ever conceived. It is completely made up of mind-stuff. The notion “Don’t just dream it, be it” is really possible on a computer. If you can imagine it, you can make it “real” on the computer. Playing with programming can be and *should* be enormous fun.

**OBJECTIVES, APPROACH AND ORGANIZATION**

The curricular content of this book meets the requirements of the “imperative-first” approach described in the ACM/IEEE *Computing Curriculum 2001* standards document [4]. The book starts with a focus on fundamental programming constructs: assignments, sequential operations, iteration, conditionals, and defining functions. Abstractions...
(e.g., algorithmic complexity, program efficiency, computer organization, hierarchical decomposition, recursion, and object-oriented programming) are emphasized later, after the students have a context for understanding them.

This unusual ordering is based on the findings of research in the learning sciences. Memory is associative. We remember new things based on what we associate them with. People can learn concepts and skills on the premise that they will be useful some day but the concepts and skills will be related only to the premises. The result has been described as “brittle knowledge” [9]—the kind of knowledge that gets you through the exam but is promptly forgotten because it doesn’t relate to anything but being in that class.

Concepts and skills are best remembered if they can be related to many different ideas or to ideas that come up in one’s everyday life. If we want students to gain transferable knowledge (knowledge that can be applied in new situations), we have to help them to relate new knowledge to more general problems, so that the memories get indexed in ways that associate with those kinds of problems [26]. In this book, we teach with concrete experiences that students can explore and relate to (e.g., conditionals for removing red-eye in pictures) and later lay abstractions on top of them (e.g., achieving the same goal using recursion or functional filters and maps).

We know that starting from the abstractions doesn’t really work for computing students. Ann Fleury has shown that students in introductory computing courses just don’t buy what we tell them about encapsulation and reuse (e.g., [13]). Students prefer simpler code that they can trace easily and they actually think that such code is better. It takes time and experience for students to realize that there is value in well-designed systems. Without experience, it’s very difficult for students to learn the abstractions.

The media computation approach used in this book starts from what many people use computers for: image manipulation, exploring digital music, viewing and creating Web pages, and making videos. We then explain programming and computing in terms of these activities. We want students to visit Amazon (for example) and think, “Here’s a catalog Web site—and I know that these are implemented with a database and a set of programs that format the database entries as Web pages.” We want students to use Adobe Photoshop and GIMP and think about how their image filters are actually manipulating red, green, and blue components of pixels. Starting from a relevant context makes transfer of knowledge and skills more likely. It also makes the examples more interesting and motivating, which helps with keeping students in the class.

The media computation approach spends about two-thirds of the time on giving students experiences with a variety of media in contexts that they find motivating. After that two-thirds, though, they naturally start to ask questions about computing. “Why is it that Photoshop is faster than my program?” and “Movie code is slow—How slow do programs get?” are typical. At that point, we introduce the abstractions and the valuable insights from computer science that answer their questions. That’s what the last part of this book is about.

A different body of research in computing education explores why withdrawal or failure rates in introductory computing are so high. One common theme is that computing courses seem “irrelevant” and unnecessarily focus on “tedious details” such as efficiency [31, 1]. A communications context is perceived as relevant by students.
(as they tell us in surveys and interviews [15, 27]). The relevant context is part of the explanation for the success we have had with retention in the Georgia Tech course for which this book was written.

The late entrance of abstraction isn’t the only unusual ordering in this approach. We start using arrays and matrices in Chapter 3, in our first significant programs. Typically, introductory computing courses push arrays off until later, because they are obviously more complicated than variables with simple values. A relevant and concrete context is very powerful [22]. We find that students have no problem manipulating matrices of pixels in a picture.

The rate of students withdrawing from introductory computing courses or receiving a D or F grade (commonly called the WDF rate) is reported in the 30–50% range or even higher. A recent international survey of failure rates in introductory computing courses reported that the average failure rate among 54 U.S. institutions was 33% and among 17 international institutions was 17% [6]. At Georgia Tech, from 2000 to 2002, we had an average WDF rate of 28% in the introductory course required for all majors. We used the first edition of this text in our course Introduction to Media Computation. Our first pilot offering of the course had 121 students, no computing or engineering majors, and two-thirds of the students were female. Our WDF rate was 11.5%.

Over the next two years (Spring 2003 to Fall 2005), the average WDF rate at Georgia Tech (across multiple instructors, and literally thousands of students) was 15% [21]. Actually, the 28% prior WDF rate and 15% current WDF rate are incomparable, since all majors took the first course and only liberal arts, architecture, and management majors took the new course. Individual majors have much more dramatic changes. Management majors, for example, had a 51.5% WDF rate from 1999 to 2003 with the earlier course, and had a 11.2% failure rate in the first two years of the new course [21]. Since the first edition of this book was published, several other schools have adopted and adapted this approach and evaluated their result. All of them have reported similar, dramatic improvements in success rates [37, 36].

Ways to Use This Book

This book represents what we teach at Georgia Tech in pretty much the same order. Individual teachers may skip some sections (e.g., the section on additive synthesis, MIDI, and MP3), but all of the content here has been tested with our students.

However, this material has been used in many other ways.

- A short introduction to computing could be taught with just Chapters 2 (introduction to programming) and 3 (introduction to image processing), perhaps with some material from Chapters 4 and 5. We have taught even single-day workshops on media computation using just this material.

- Chapters 6 through 8 basically replicate the computer science concepts from Chapters 3 through 5 but in the context of sounds rather than images. We find the replication useful—some students seem to relate better to the concepts of iteration and conditionals when working with one medium than with the other. Further, it gives us the opportunity to point out that the same algorithm can have similar effects in different media (e.g., scaling a picture up or down and shifting
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• a sound higher or lower in pitch are the same algorithm). But it could certainly be
  skipped to save time.
• Chapter 12 (on movies) introduces no new programming or computing concepts.
  While motivational, movie processing could be skipped to save time.
• We recommend getting to at least some of the chapters in the last unit, in order to
  lead students into thinking about computing and programming in a more abstract
  manner, but clearly not all of the chapters have to be covered.

Python and Jython
The programming language used in this book is Python. Python has been described as
"executable pseudo-code." We have found that both computer science majors and non
majors can learn Python. Since Python is actually used for communications tasks (e.g.,
Web site development), it’s a relevant language for an introductory computing course.
For example, job advertisements posted to the Python Web site (http://www.python.
org) show that companies like Google and Industrial Light & Magic hire Python
programmers.

The specific dialect of Python used in this book is Jython (http://www.jython.
org). Jython is Python. The differences between Python (normally implemented in C)
and Jython (which is implemented in Java) are akin to the differences between any
two language implementations (e.g., Microsoft vs. GNU C++ implementations)—the
basic language is exactly the same, with some library and details differences that most
students will never notice.

TYPOGRAPHICAL NOTATIONS
Examples of Python code look like this: x = x + 1. Longer examples look like this:

```python
def helloWorld():
    print "Hello, world!"
```

When showing something that the user types in with Python’s response, it will have
a similar font and style, but the user’s typing will appear after a Python prompt (»>):

```plaintext
>>> print 3 + 4
7
```

User interface components of JES (Jython Environment for Students) will be spec-
ified using a small caps font, like SAVE menu item and the LOAD button.
There are several special kinds of sidebars that you’ll find in the book.
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Common Bug: An Example Common Bug
Common things that can cause your program to fail appear like this.

Debugging Tip: An Example Debugging Tip
If there’s a good way to keep a bug from creeping into your programs in the first place, it’s highlighted here.

Making It Work Tip: An Example How to Make It Work
Best practices or techniques that really help are highlighted like this.

INSTRUCTOR RESOURCES
The instructor resources are available on the author’s website http://mediacomputation.org or the Pearson Education’s Instructor Resource Center at www.pearsonhighered.com/guzdial:

- PowerPoint® Presentation slides

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About the Authors

Mark Guzdial is a professor in the School of Interactive Computing in the College of Computing at Georgia Institute of Technology. He is one of the founders of the ACM’s International Computing Education Research workshop series. Dr. Guzdial’s research focuses on learning sciences and technology, specifically, computing education research. His first books were on the programming language Squeak and its use in education. He was the original developer of “Swiki” (Squeak Wiki), the first wiki developed explicitly for use in schools. Mark has published several books on the use of media as a context for learning computing, which have influenced undergraduate computing curricular around the world. He serves on the ACM Education Board and the ACM SIGCSE (Special Interest Group for Computer Science Education) Board. He is on the editorial boards of the Journal of the Learning Sciences and Communications of the ACM.

Barbara Ericson is a research scientist and the director of Computing Outreach for the College of Computing at Georgia Tech. She has been working on improving introductory computing education since 2004.

She has served as the teacher education representative on the Computer Science Teachers Association board, the co-chair of the K-12 Alliance for the National Center for Women in Information Technology, and as a reader for the Advanced Placement Computer Science exams. She enjoys the diversity of the types of problems she has worked on over the years in computing including computer graphics, artificial intelligence, medicine, and object-oriented programming. Mark and Barbara received the 2010 ACM Karl V. Karlstrom Award for Outstanding Computer Educator for their work on Media Computation including this book.