Digital Media PRIMER

Digital Audio, Video, Imaging and Multimedia Programming

Third Edition

YUE-LING WONG

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Yue-Ling Wong

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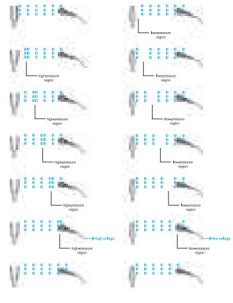

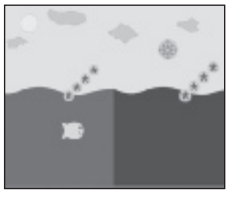

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Preface

Welcome to the third edition of *Digital Media Primer*. This book continues with the spirit of its previous editions. It emphasizes both conceptual and production aspects of digital media. It adopts a conceptual approach and relates to digital media software applications. The coverage of software applications intends to show students a general picture of how the concepts are translated into the common commands found in software applications. Therefore, whenever possible, multiple software applications are used as examples. The intent is not about training of software application skills or providing a survey of these software applications. Digital media software applications of the same medium share common commands and features, which are based on the same technical concepts and principles. The differences may be that these concepts and principles are presented in the software applications using slightly different command names and user interfaces. It is the author's assumption that if the student understands the underlying concepts and principles and then sees examples of how they are actually translated into the commands or options found in application programs, the student can apply the knowledge to quickly pick up similar software applications and the ever-changing new versions of these software applications.

What's New in This Edition?

The main motivation of the new edition is to update the materials with new technology, especially those for mobile devices, and to expand the content to allow more different paths through this book for a wide range of digital media courses.

Most of the chapters are revised, but the significant changes in this edition fall into two categories. One is the revision of the multimedia authoring from Flash ActionScript programming to JavaScript programming with HTML5 Canvas.

The second category of changes is the revision of the video chapters to include ultra high-definition video in addition to high-definition video. The video chapters are revised to put more focus relevant to the Web and mobile connection.

Specifically, the new content and updates in this edition include:

- A new chapter introducing JavaScript programming (Chapter 10)
- A new chapter on adding images and drawing on HTML5 Canvas (Chapter 11)
- A new chapter on creating animation on HTML5 Canvas (Chapter 12)
- A new chapter on adding interactivity on HTML5 Canvas (Chapter 13)
- A new chapter introducing object-oriented JavaScript (Chapter 14)
- Revised Chapter 6 (video concepts) to include information on ultra high-definition video and H.264 compression standard
- Revised the information about data rate to be more relevant to wireless connection
- Revised Chapter 7 (video production) to include updates on digital video cameras, examples of high-definition video editing tools, and examples of video effects
- A new section on vector graphics for the Web (Chapter 3)

- A new section on cloud computing (Chapter 1)
- New screenshots of the latest digital media software applications

Coordinating Coursework with This Text

This book is written for introductory courses in digital media. It is for introductory students from all disciplines who are interested in learning the foundational scientific concepts and basic techniques in digital media production. There is no specific prerequisite to use this book. The courses in which this textbook will be useful include:

- Non-major introductory computer science courses that adopt a digital media theme, integrating both scientific concepts and hands-on production aspects of digital images, video, and audio, and giving students exposure to basic computer programming through animation and game programming
- Introductory computer programming courses that adopt the theme of game programming with JavaScript and HTML5 Canvas
- Introductory digital art courses intended to help students harness the digital media tools by learning the underlying scientific concepts, thereby achieving intended artistic results and improving confidence to experiment with creative uses of such tools
- Introductory media production courses that introduce students to a solid technical foundation of digital video and audio

After completing this book, students will understand the underlying concepts of computer terms common to digital media and be able to connect these concepts with the tools and techniques of digital media application programs. The connection between scientific concepts and applications will help students make educated decisions, rather than relying on defaults or recipes, in using tools and techniques in application programs. In addition, the approach of this book intends to instill in students the ability and confidence to explore and teach themselves new application programs. After completing Chapters 1 through 7, students will be able to create and edit digital images, audio, and video. Chapter 8 covers HTML basics to prepare students with a sufficient foundation to build upon in learning how to add HTML5 video and audio to Web pages. In addition, students will learn the structure, syntax, and semantics of HTML5. After completing Chapter 9, students will be able to construct a basic HTML5 document and embed video and audio on a Web page using the HTML5 video and audio tags. After completing Chapter 10, students will know how to read simple JavaScript programs and add JavaScript to HTML documents. Building upon the knowledge of JavaScript, students will learn how to add images, drawings, and animation to HTML5 Canvas (Chapters 11–12). In Chapter 13, students will learn how to add interactivity, including mouse, keyboard, and touch (for touch-enabled devices), to HTML5 Canvas in the context of game programming. Students may also continue on to the object-oriented programming in Chapter 14.

Digital media classes may be taught from different disciplinary perspectives, and the background of students taking digital media classes are also diverse. There are many paths through this book for a digital media course. Thus, this book covers more than a semester's worth of materials. For some courses, this book may offer more technical background than the course's expectations. The role of the instructor is integral in deciding the best path through this book for the course. For example, not all the topics in Chapter 1 have to be the first week's lectures; they could be in the middle or end of the semester as the instructor sees fit. Listed in Table 1 are several suggested treatments employing this book and the three-book digital media series.

TABLE 1 Suggested Treatments Employing This Book and the Series

	Suggested Chapter Coverage
A course that covers the breadth of all three media: images, audio, and video	• Chapters 1–7 (this book) • Chapters 8–9 (this book)
A course that covers only one medium	• Chapter 1 (this book) • Two chapters of the medium (this book) • Chapters 8–9 if the medium is video or audio • Chapter 1 (*Digital Art*) • Two chapters of the medium (*Digital Art*) For example, for a course that focuses on digital images from the art perspective, you could cover Primer Chapters 1, 2, 3, and Art Module Chapters 1, 2, 3.
A course that covers multimedia authoring or basic programming through animation and games	• Chapters 1–3 (this book) • Chapters 8–13 (this book)
An introduction to computer programming in the context of game programming	• Chapters 8–14 (this book) • Chapters 1–3 (this book) if time allows
A course that focuses on concepts with minimal hands-on practice	Concept chapters: • Chapters 1, 2, 4, 6 (this book) • Chapters 1, 2, 4, 6 (*Digital Art*)
A course that focuses on hands-on practice	• Chapters 1, 3, 5, 7, and 8–9 (this book) • Chapters 1, 3, 5, 7 (*Digital Art*) • The concepts chapters (Chapters 2, 4, and 6) are highly recommended. If it is not possible to go over the concepts in class, refer students to self-study these concepts chapters. You may want to assign the end-of-chapter review questions to ensure they understand the concepts.

Along with the first edition of this book, I wrote a companion volume that allows further specialization at the advanced level in digital visual arts. Also published by Pearson, the title is

- *Digital Art: Its Art and Science* ISBN: 0-13-175703-2

The two books maintain the same number of parallel chapters—one on background, two on each of the image, audio, and video, and several on multimedia/Web authoring. The third edition of this book preserves the structure of the parallel chapters, allowing students to easily look up relevant information across perspectives.

For courses with a stronger emphasis on the digital arts, using these two books in tandem will allow you to deepen your treatment of the art perspective.

Text Organization

This book follows the same organization as the previous editions. The digital media curriculum is organized around a core concept of digital media: the digitization process—sampling

and quantization (Figure 1). For example, the **sampling** process gives rise to the image resolution in digital images and the sampling rate in digital audio. The **quantization** process gives rise to the color depth in digital images and the bit depth in digital audio. Digital video also deals with frame size, which relates to image resolution. This way, students learn about image resolution, audio sampling rate, color depth, audio bit depth, and video frame size from the same central concepts applied in different contexts, rather than as separate bits and pieces of factual information for different media. The core concept of digitization also helps students understand the nature of digital media—their limitations and uses.

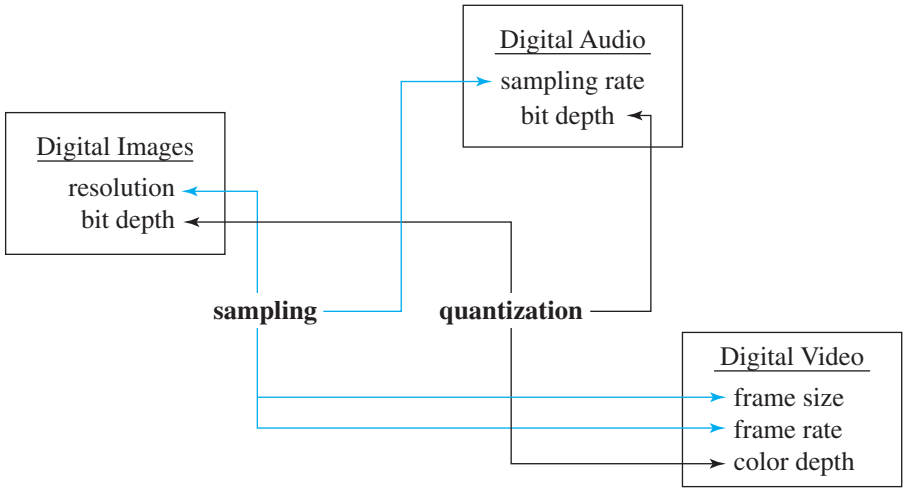

Figure 1 Sampling and quantization serve as the central concepts to unify the topics for different media.

Each of the image, audio, and video topics consists of two chapters: one on **concepts** and the second one on **application** of the concepts and the **production** of the media.

Chapter 1: Background

Chapter 2: Digital Image (concepts)
Chapter 3: Digital Image (application and production)

Chapter 4: Digital Audio (concepts)
Chapter 5: Digital Audio (application and production)

Chapter 6: Digital Video (concepts)
Chapter 7: Digital Video (application and production)

Chapter 8: HTML Basics

Chapter 9: HTML5 Video and Audio

Chapters 10–14: Introduction to Computer Programming in the Context of Game Programming with JavaScript

The scientific concepts and technical information are discussed in the concepts chapters (Chapters 2, 4, and 6). The applications of the concepts and the general techniques and tools of application programs are discussed in the production chapters (Chapters 3, 5, and 7). For example, Chapter 2 explains the concept of resolution of images. Correspondingly, Chapter 3 discusses how to estimate the scanning resolution and printing resolution. The determination of the scanning and printing resolution is an application of the concept of resolution.

For the multimedia authoring chapters, Chapter 10 provides an overview on programming fundamentals that are common to most programming languages. Chapter 11 introduces the HTML5 Canvas element and how to add images and drawings to the element. Chapter 12 introduces the basics of animation with HTML5 Canvas. Chapter 13 explains how to add interactivity, including touch events for touch-enabled devices. Chapter 14 introduces object-oriented programming, and the lab exercises are designed around programming computer games.

Features in the Textbook

There are several pedagogic elements used in the book:

- **Key terms:** Key terms are boldfaced. When a key term appears at several places in the text, the term is usually boldfaced where its definition is given.
- **Learning aids:** There are several types of learning aids accompanying this text (see the subsequent subsection). They are integral to the text and noted in the text in blue boxes. A title and a brief description are given for each learning aid. The learning aids can be found on the accompanying Web site of this text.
- **Boxed materials:** They intend to expand the discussion and explanation of the concept or terminology relevant to the current part of the text. The materials may be branched off from the main flow of the text. Thus, they are separated from the main text to avoid diversion from the flow of thoughts.
- **Margin notes:** They are generally used for a brief explanation of terminology, or for referring to the chapter that covers the basics that are needed for the current part of the text.
- **Self-test questions:** These questions are found in the text of some chapters. The answers are provided at the end of the question or the bottom of the page. These questions, unlike the end-of-chapter review questions, intend to provide the students an instant review of the topics. These topics are a little too involved to wait until the end-of-chapter review questions.
- **Summary:** Each chapter concludes with a summary of key concepts.
- **End-of-chapter review questions:** These are multiple-choice and short-answer questions to reinforce the retrieval of the learned foundational knowledge. They are to ensure that the student reaches the same level of competence of foundational knowledge.
- **Exploring the applications:** At the end of a production chapter, there is a list of suggested commonly used features and functionalities for the students to look up and explore in application programs. The goal is to help students to learn how to explore application programs in terms of tasks and then apply the basic concepts they have learned in the textbook. By taking this approach, the student is not tied to learning a particular software package or version.

Student Learning Aids and Supplementary Materials

For access to the Learning Aids and Supplementary Materials, please go to: http://www.pearsonhighered.com/digitalmedia.

There are several types of online learning aids accompanying this text. They appear in blue boxes with a small icon ( or ) followed by a title and a brief description. The computer mouse icon indicates that the learning aid is interactive or has a hands-on component. These include interactive tutorials and demonstrations, labs, and worksheets. The filmstrip icon means that the learning aid is a movie (for example, the screen-captured movies that show how to use a tool in an application program), video files that demonstrate the effect of different compression settings, or supplementary reading materials.

- **Tutorials**

  The tutorials are used for various purposes:

  - Conceptual: To explain concepts, such as sampling and quantizing
  - Software tool how-to's: Short screen-captured movies showing how-to's of application programs
  - Example files: Files that you can download to open and see how they work
  - Visualization: To help visualize difficult concepts
  - Explanation of terminology
  - Step-by-step guide to solve a problem: such as Chapter 1's binary-decimal conversion

  All of the tutorials can be used as outside class review by students. Some of the tutorials can be used by the instructor as interactive animated presentations during lecture—for example, Chapter 1's "Converting Analog to Digital—Sampling and Quantizing," Chapter 2's "Sampling and Quantizing in Digital Images," Chapter 3's "Understanding and Applying Histograms," and Chapter 4's "Sound as a Pressure Wave" and "Sampling and Quantizing in Digital Audio."

- **Demonstrations:** For example, audio files that let you hear how different sampling rates and bit depths affect the audio quality, or video files that let you see how different compression settings affect the visual quality.
- **Worksheets:** Worksheets are question-based PDF files that can be downloaded and printed out. They require more thinking than the end-of-chapter review questions. Some may require exploration or experimentation to discover answers. The syntax review worksheets in the programming chapters are intended to help students to summarize the syntax and practice writing code, which are important to success in an introductory programming course.

  My game programming class surveys showed that students unanimously found the syntax review worksheets very helpful and that they used their graded worksheets for studying. Some students even suggested having more review worksheets on topics that were not included in the worksheets. However, it was also a common response that the syntax review worksheets were boring. Therefore, if the syntax review worksheets were made optional, students very likely will not complete the worksheets that are beneficial to their learning. I found that it worked well to make the syntax review worksheets part of the homework assignments. I also advised students to keep the graded worksheets for use as syntax references in the lab and for studying for tests and the final exam. The intention of the syntax review worksheets is to help students create their own study aids and notes. Therefore, it would be best to help them to complete the worksheets correctly as much as possible.

  Some students may come to your office to ask questions on homework. However, many students may not be willing to do so. I have found that a short in-class Q&A

section right before the students turn in the worksheets provides a good opportunity for offering such help. During the Q&A section, students are encouraged to ask questions that they have been stuck on and to discuss their thoughts on the answers. They are allowed to make corrections before they turn in the worksheets. Being able to make corrections before turning in the worksheets is an incentive for students to ask questions. It is also as if they are grading their own homework. This provides an opportunity for students to take a critical look at their code answers. While they are asking homework questions in class, they more likely also ask you to clarify some lecture materials, in which case you will get student feedback on the lecture materials and be able to clarify any misunderstandings that were usually the root of the homework problems.

- **Labs:** These are lab manuals, with instructions to edit or create digital media files. They are designed to provide hands-on opportunities to process and manipulate digital images, sound, and video. The labs for multimedia authoring include creating animation. In developing the labs, I tried to emphasize the tasks rather than giving command-by-command, recipe-type instructions. For the computer programming chapters (Chapters 10–14), labs are an important component. From my experience, for a 3-credit course (three 50-minute lectures per week) plus a lab section (1.5 hours per week), it worked well to turn one of the lecture periods into an extra lab period. A lab briefing that gives students a big picture of the steps and demonstrates how the final product should look and work is also important.

Worksheets and labs are different. Worksheets are question-based homework intended to help students review and summarize a topic at a time. Labs are hands-on instruction-based activities that create or modify media files. Labs provide opportunities for students to apply multiple learned concepts and techniques in practice.

eText with Online Learning Aids

I encourage you to explore the eText with online learning aids and supplementary materials that are noted in the text. These materials can be accessed through the publisher's Companion Web site for this text at http://www.pearsonhighered.com/digitalmedia. You will need to redeem the access code provided at the front of your new textbook. Some learning aids require Shockwave plug-in, some require Flash player, some require QuickTime player, and some require JavaScript enabled. For those who have trouble getting Shockwave plug-in installed on the lab computers, the Shockwave supplementary materials are now also available as standalone .exe (Windows) and .app (Mac OS) files. The file format and requirements of each of these learning aids are noted with its link on the Companion Web site.

Instructor Resources

Protected instructor resources are available on the Pearson Instructor Resource Center (IRC). Please contact your local Pearson sales representative to gain access to this site. Instructors will find the following support material on the IRC:

- Lecture PowerPoint slides
- Answers to the end-of-chapter questions
- Answers to the worksheets
- Completed lab files

Software Tools for Practice and Labs

Although this book's approach of teaching media production application tools emphasizes identifying tasks and tries not to tie to any particular software, it is inevitable that you must

select some representative application programs to demonstrate the tools and techniques in the text and in the practice exercises, such as labs and worksheets. Table 2 lists the different application programs used as examples in this book. The application programs that appear the most in the text, tutorials, labs, and worksheets are in bold.

TABLE 2 Application Programs Used in This Text

Media Topic	Application Programs Used as Examples in the Text (The main programs used the most in the text, tutorials, labs, and worksheets are boldfaced.)
Digital Image	**Adobe Photoshop**, Adobe Illustrator
Digital Audio	**Adobe Audition**, **Audacity**, **Apple Garage Band**, Sony Sound Forge, SONAR, Sony ACID Pro
Digital Video	**Adobe Premiere Pro**, Apple Final Cut Pro, Sony Vegas, Adobe Encore DVD, Sony DVD Architect
Multimedia Authoring and Introduction to Computer Programming in the Context of Game Programming	**Adobe Dreamweaver, plain text editors** (such as Notepad for Windows and TextEdit for Mac OS)

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There would not have been a third edition without the previous editions, especially the first edition, to serve as a basis. Thus, my thanks again go to the professors who participated in pilot-testing of the first edition of the three-book series: Julie Carrington of Rollins College, Kristian Damkjer of University of Florida, Ian Douglas of Florida State University, Edward A. Fox of Virginia Polytechnic Institute and State University, Martha Garrett of Bishop McGuinness High School (North Carolina), Kim Nelson of University of Windsor (Ontario, Canada), Naomi Spellman of The University of California San Diego and San Diego State University, Christopher Stein of Borough of Manhattan Community College, and Mark Watanabe of Keaau High School (Hawaii).

I would also like to thank my student assistants, who helped in developing and suggesting some of the learning aids, and my former students who let me include their class work as demonstrations and chapter openers in the book: Cory Bullock, Kevin Crace, Emma Edgar, Gretchen Edwards, Robert May, Lindsay Ryerse, Caldwell Tanner, and Daniel Verwholt.

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Digital Media
PRIMER

Digital Audio, Video, Imaging and Multimedia Programming

CHAPTER 1

Background

TABLE OF CONTENTS

CHAPTER

1

KEY CONCEPTS

- Analog information versus digital data
- Converting analog data to digital data: sampling and quantizing
- Bits and bytes
- Base-10 versus base-2
- File size calculation
- File compression

GENERAL LEARNING OBJECTIVES

In this chapter, you will learn

- The computer terms common to digital media fundamentals.
- The difference between analog information and digital data.
- What the binary system means.
- The basic steps of digitization: sampling and quantization.
- The general strategies for reducing digital media file sizes.
- The reasons for file compression and types of file compression.

1.1 INTRODUCTION

Digital media studies rely on both conceptual and creative knowledge. Although knowing how to use digital media application programs, such as Adobe Photoshop and Corel PaintShop Pro for digital imaging, Adobe Premiere Pro and Apple Final Cut for digital video, and Adobe Audition and Sony Sound Forge for digital audio, is required, understanding the underlying principles and concepts helps to realize a creative idea with predictable results. Simply learning a particular version of a particular program restricts your creativity to what that version of that program can do. If you generalize by associating the task you want to accomplish with the basic concept behind the tool, then when you have to switch to another program or a new version, you can easily look up the information associated with the task in the program's Help menu.

Many application programs provide default settings to create digital media products, allowing you to create a file without any knowledge of digital media fundamentals. For example, it is possible to apply a special effect with a filter without considering how its many settings affect the image. No error message will prevent you from applying the effect and saving the file, but achieving a desired effect often requires some trial-and-error experimenting. Understanding the concepts behind the tools helps you to make rational, educated decisions in using these tools to produce predictable and effective results.

1.1.1 Relevance of Binary Notation, Bits, and Bytes to Digital Media Studies

This chapter provides the foundational knowledge that is required to understand the digital media concepts introduced in the later chapters. Because computers handle data in the units of bits and bytes, it is inevitable that you will encounter these terms in studying digital media. This chapter will explain the meaning of bits and bytes. It also will explain the conversion between decimal and binary notations. The direct relevance of these concepts to digital media may not be obvious within this chapter alone, but these fundamentals will help you comprehend the terminology you will encounter in studying digital media. For example:

- *File size* and *prefixes*. Digital files—image, sound, and especially video files—can be very large. The file size is often an important consideration that affects your decisions in the creation and export steps. You often will need to monitor your file's size, which is reported in bits and bytes using prefixes (such as kilo, mega, and giga). In addition, later chapters have examples on file size calculations in bits, which then are converted to megabytes or gigabytes. Thus, you will need to know how to read a file's size and understand these units.
- *Binary notation*. By learning binary notation and decimal-to-binary conversion, you will see how information actually can be stored and handled on a computer as bits. Understanding the conversion of decimal to binary notations helps you understand why a number, representing a piece of information, requires a certain number of bits to store.
- *Bit depth*. You may have encountered the term *bit depth* or *color depth* (Chapters 2 and 3) if you have worked with digital images. Understanding binary systems helps you comprehend the connection between the bit depth or color depth of an image and the number of colors; for example, 8-bit refers to 256 colors and 24-bit refers to millions of colors.

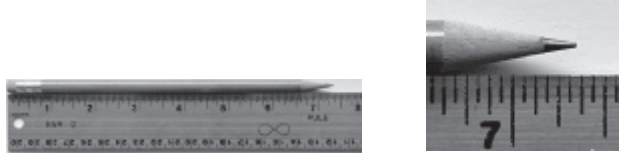
  With an understanding of bits, you will understand why an image with more colors or higher bit depth has a larger file size.
- *Bit rate*. In working with digital video, you will often encounter the term *bit rate* (Chapters 6 and 7). The bit rate of a video affects the smoothness of its playback. Understanding bits helps you comprehend what bit rate is, its significance, and how you can calculate your video's average bit rate to predict its playback.
- In Web page creation, you use hexadecimal notation to designate a color for text color and background color. For example, #FF0000 represents red. The conversions from decimal to binary and decimal to hexadecimal notations are similar. What you learn in the conversion of decimal to binary notations also will help you learn how the hexadecimal notation of a color is obtained.

1.2 ANALOG VERSUS DIGITAL REPRESENTATIONS

It is often said that we live in a digital age. However, the natural world we live in is an analog world. For example, the sounds and music we hear are ***analog*** signals of sound waves. Computers store and transmit information using ***digital*** data. To connect our analog world with computers, analog and digital information must be converted from one form to the other and back again. Unfortunately, the conversion process may sacrifice the exactness of the original information. We will discuss the conversion process—sampling and quantization—in more detail later in this chapter. In order to understand the process, we must first understand the nature of analog and digital representations of information.

1.2.1 Analog Information

Most information that we perceive in the natural world is in analog form. To illustrate, let's try to measure the length of a pencil (Figure 1.1). The ruler shows that the pencil is between 7¼ and 7½ inches long, but the point is a little less than halfway between 7¼ and 7½ inches. Would you round it down to 7.25? You cannot reproduce the exact length of this pencil with 7.25 inches. But wait—the pencil tip is about midway between 7¼ and 7½. So should we say it is 7⅜ or 7.375? This measurement is a little closer to the pencil length than 7.25, but the pencil is shorter than 7⅜ inches. So, is it 7.374, 7.373, 7.3735, 7.37355, . . .? An infinite number of divisions exist between two points. How small should the divisions of a ruler be to allow us to make an exact measurement? Infinitely small, because there is always another value between two values!



(a) (b)

Figure 1.1 (a) Measuring the length of a pencil with a ruler. (b) Close-up view of the pencil tip.

Examples of continuous information are time, weight, temperature, lines, waves (such as sound waves), and planes (such as photographs). Analog clocks, thermometers (Figure 1.2a), and weighing scales are examples of analog devices.

(a) (b)

Figure 1.2 (a) Analog thermometer and its close-up view. (b) Digital thermometer.

1.2.2 Digital Data

Computers are built from electronic devices that have only two possible states because they are only stable at one of two voltages. Thus, they operate on a binary system, also called base-2. Regardless of the actual voltages of these two states, we might denote them as *off* and *on* or *false* and *true*. In computer science, we denote this pair of states numerically as 0 and 1, respectively.

Most people associate the binary system exclusively with computers. It is true that computers use it, whereas in our daily lives, we use many other numbers. For this reason, many people think it's difficult to understand the binary concept.

However, the binary system is not that difficult. For example, imagine using eye signals to communicate with your friends. Each eye has closed and open positions (Figure 1.3). When you want to signal your friend, you first will have to assign meaning to the various combinations of open and closed eyes—***encode*** the message. Of course, your friend would have to know how to ***decode*** your signal—that is, interpret the meaning associated with each signal. For example, you may assign "yes" to "closed left eye, open right eye" and "no" to "both eyes closed." There are four open and closed combinations for two eyes. Therefore, you can send four different messages using eye signals. If we assign a numeric value to each of the open and closed eyes—say, open eye as 1 and closed eye as 0—then the four combinations can be represented as 00, 01, 10, and 11.

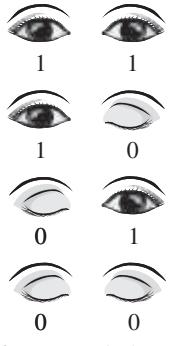


Figure 1.3 The four combinations of open and closed eyes.

Suppose you want to use eye signals to send your friend a message about a color—one out of 16 different choices. You would need another friend to help because you would need four eyes—a 4-bit system, as in Figure 1.4. Using two eyes lets you signal your friend a color out of only four different choices.

Let's look at another example using hand signals. Suppose we consider only two possible positions for each finger: raised up or bent down. The number of different combinations with five fingers is $2^5 = 32$. How about with both hands using 10 fingers? $2^{10} = 1024$. Wow! This means that you can send your friend 1024 different messages using the hand signals with each finger either up or down. Of course, some combinations of the raised and bent fingers are quite challenging to make, if not impossible.

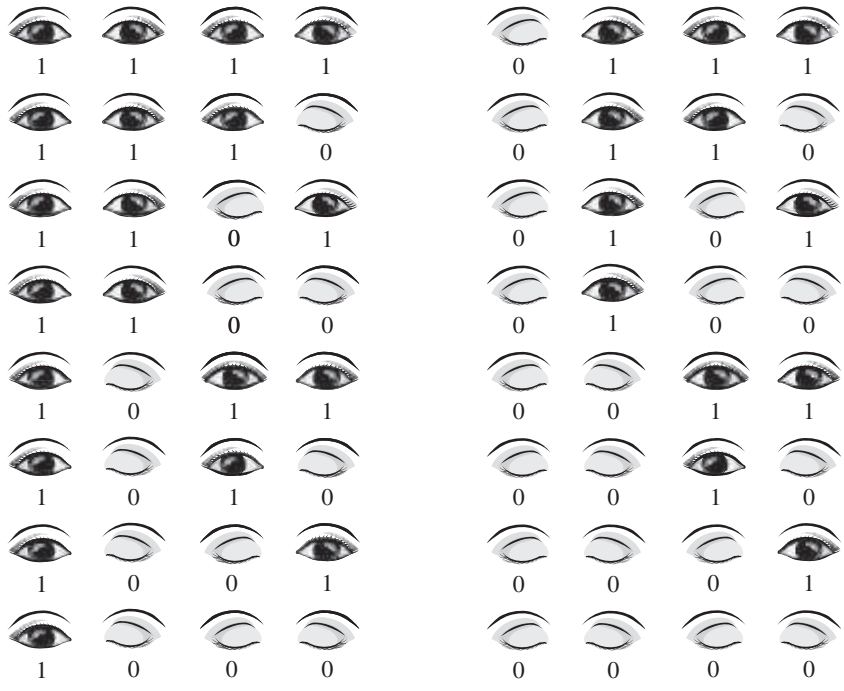


Figure 1.4 Sixteen different open and closed eye patterns created using four eyes.

1.3 BITS

In computer systems, data is stored and represented in *b*inary dig*it*s, called ***bits***. A bit has two possible values, 0 or 1. In the eye signal example, each eye can be considered a bit, as it can denote two possible states: open or closed. Although the two possible values of a bit are denoted numerically as 0 and 1, they can be used for much more than arithmetic.

One bit is not very useful in representing information, but a combination of bits forming larger sequences can represent content information, such as text characters, color information for digital images, and audio amplitudes.

In the eye signal analogy, each eye is like a bit—it has two states: closed and open, or 0 and 1. Using two eyes, we would call your system a 2-bit system. In the hand signal analogy, if you are using one hand, your system is 5-bit. As you see, the number of possible values corresponds to 2^{bit}.

1.3.1 Prefixes

Computer file sizes are reported in bits and bytes. Eight bits make a ***byte***. Digital files—image, sound, and especially video files—can be very large, and the file size is often an important consideration that affects your decisions in the file creation and export steps. You often will need to look up your files' sizes and monitor the available disk space on your computer's hard drive to make sure you have enough space for new files during the production process.

TABLE 1.1 The Relationship between Sizes and Prefixes under the Base-2 Definition

Prefix Name	Abbreviation	Size
Kilo	K	$2^{10} = 1{,}024$
Mega	M	$2^{20} = 1{,}048{,}576$
Giga	G	$2^{30} = 1{,}073{,}741{,}824$
Tera	T	$2^{40} = 1{,}099{,}511{,}627{,}776$
Peta	P	$2^{50} = 1{,}125{,}899{,}906{,}842{,}624$
Exa	E	$2^{60} = 1{,}152{,}921{,}504{,}606{,}846{,}976$
Zetta	Z	$2^{70} = 1{,}180{,}591{,}620{,}717{,}411{,}303{,}424$
Yotta	Y	$2^{80} = 1{,}208{,}925{,}819{,}614{,}629{,}174{,}706{,}176$

Because a file contains lots of bits and bytes, we use prefixes, such as ***kilo*** *(K),* ***mega*** *(M),* ***giga*** *(G),* and ***tera*** *(T),* to better conceive the size. In order for you to correctly interpret the size of your digital media file, you will need to have a clear idea of what these prefixes mean. Table 1.1 lists the prefixes, abbreviations, and sizes.

DOES A KILO EQUAL 1,000 OR 1,024?

Most people know that 1 kilo equals exactly 1,000 (e.g., 1 kilogram equals 1,000 grams), and the other prefixes imply a number based on 10 to the power of an integer. Notice that under the base-2 definition, a kilobyte (KB) is 1,024 bytes, a megabyte (MB) is 1,048,576 bytes, and so forth (Table 1.1). This discrepancy has caused confusion among manufacturers of computer storage devices, telecommunication engineers, and the general public.

To avoid such confusion, in December 1998, the International Electrotechnical Commission (IEC) approved the prefixes for binary multiples for use in the fields of data processing and data transmission (Table 1.2).[*] However, at the time of this writing, these new standard names are not widely used by or known to the public.

TABLE 1.2 IEC Prefixes for Binary Multiples

Original	Prefix Name	Symbol	Size
Kilo	Kibi	Ki	$2^{10} = 1{,}024$
Mega	Mebi	Mi	$2^{20} = 1{,}048{,}576$
Giga	Gibi	Gi	$2^{30} = 1{,}073{,}741{,}824$
Tera	Tebi	Ti	$2^{40} = 1{,}099{,}511{,}627{,}776$
Peta	Pebi	Pi	$2^{50} = 1{,}125{,}899{,}906{,}842{,}624$
Exa	Exbi	Ei	$2^{60} = 1{,}152{,}921{,}504{,}606{,}846{,}976$

[*] http://physics.nist.gov/cuu/Units/binary.html