READINGS FROM Programming with C++

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Programming with C++

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Australia • Brazil • Canada • Mexico • Singapore • United Kingdom • United States

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PREFACE

Welcome to *Readings from Programming with C++*. This text includes the stand-alone lessons and readings from MindTap for *Programming with C++* and is intended to be used in conjunction with the MindTap Reader for a complete learning experience.

MindTap Overview

Programming with C++ presents conceptual, language-agnostic narrative with language-specific assets, ungraded C++ coding Snippets, language-agnostic test banks, and additional instructor resources. The goal of this digital product is to develop content around the concepts that are essential for understanding Computer Science from a language-agnostic perspective. Learners will gain a foundational understanding of procedural programming, computer science concepts, and object-oriented programming. Instructors have identified the need for language-agnostic, conceptual content that can be paired with hands-on practice in a specific language. This 31-module text is designed to provide that conceptual content paired with language-specific examples and hands-on learning activities in C++.

Course Objectives:

- Develop a foundational knowledge of coding principles, vocabulary, and core concepts.
- Use new foundational knowledge to learn C++ programming skills.
- Practice emerging coding skills in a low-risk environment.
- Apply learned concepts and skills to assignments/activities that mimic real-world experiences and environments.

C++ Version

We recommend downloading the latest version of C++ before beginning this text. C++14 was used to test all C++ code presented in the module figures.

MindTap Features

In addition to the readings included within this text, the MindTap includes the following:

Course Orientation: Custom videos and readings prepare students for the material and coding experiences they will encounter in their course.

Videos: Animated videos demonstrate new programming terms and concepts in an easy-to-understand format, increasing student confidence and learning.

Coding Snippets: These short, ungraded coding activities are embedded within the MindTap Reader and provide students an opportunity to practice new programming concepts "in-the-moment." Additional language-specific "bridge content" helps transition the student from conceptual understanding to application of C++ code.

Language-specific Examples: Figures within the narrative illustrate the application of general concepts in C++ code.

Instructor & Student Resources

Additional instructor and student resources for this product are available online. Instructor assets include an Instructor's Manual, Teaching Online Guide, PowerPoint® slides, and a test bank powered by Cognero®. Student assets include source code files and coding Snippets ReadMe. Sign up or sign in at **www.cengage.com** to search for and access this product and its online resources.

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June Jamrich Parsons is an educator, digital book pioneer, and co-author of Texty and McGuffey Award-winning textbooks. She co-developed the first commercially successful multimedia, interactive digital textbook; one that set the bar for platforms now being developed by educational publishers. Her career includes extensive classroom teaching, product design for eCourseware, textbook authoring for Course Technology and Cengage, Creative Strategist for MediaTechnics Corporation, and Director of Content for Veative Virtual Reality Labs.

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June Jamrich Parsons: Computer programming can be a truly satisfying experience. The reward when a program runs flawlessly has to bring a smile even to the most seasoned programmers. Working with three programming languages for this project at the same time was certainly challenging but provided insights that can help students understand computational thinking. I've thoroughly enjoyed working with the team to create these versatile learning resources and would like to dedicate my efforts to my mom, who has been a steadfast cheerleader for me throughout my career. To the instructors and students who use this book, my hope is that you enjoy programming as much as I do.

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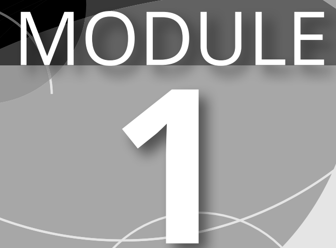

COMPUTATIONAL THINKING

LEARNING OBJECTIVES:

1.1 ALGORITHMS

1.1.1 Define the term "algorithm" as a series of steps for solving a problem or carrying out a task.

1.1.2 State that algorithms are the underlying logic for computer programs.

1.1.3 Define the term "computer program."

1.1.4 Provide examples of algorithms used in everyday technology applications.

1.1.5 Confirm that there can be more than one algorithm for a task or problem and that some algorithms may be more efficient than others.

1.1.6 Explain why computer scientists are interested in algorithm efficiency.

1.1.7 List the characteristics of an effective algorithm.

1.1.8 Write an algorithm for accomplishing a simple, everyday technology application.

1.1.9 Write an alternate algorithm for an everyday technology task.

1.1.10 Select the more efficient of the two algorithms you have written.

1.2 DECOMPOSITION

1.2.1 Define the term "decomposition" as a technique for dividing a complex problem or solution into smaller parts.

1.2.2 Explain why decomposition is an important tool for computer scientists.

1.2.3 Differentiate the concepts of algorithms and decomposition.

1.2.4 Identify examples of structural decomposition.

1.2.5 Identify examples of functional decomposition.

1.2.6 Identify examples of object-oriented decomposition.

1.2.7 Provide examples of decomposition in technology applications.

1.2.8 Explain how dependencies and cohesion relate to decomposition.

1.3 PATTERN IDENTIFICATION

1.3.1 Define the term "pattern identification" as a technique for recognizing similarities or characteristics among the elements of a task or problem.

1.3.2 Identify examples of fill-in-the-blank patterns.

1.3.3 Identify examples of repetitive patterns.

1.3.4 Identify examples of classification patterns.

1.3.5 Provide examples of pattern identification in the real world and in technology applications.

1.4 ABSTRACTION

1.4.1 Define the term "abstraction" as a technique for generalization and for simplifying levels of complexity.

1.4.2 Explain why abstraction is an important computer science concept.

1.4.3 Provide an example illustrating how abstraction can help identify variables.

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1.4.4 Provide examples of technology applications that have abstracted or hidden details.

1.4.5 Provide an example illustrating the use of a class as an abstraction of a set of objects.

1.4.6 Explain how the black box concept is an implementation of abstraction.

1.4.7 Identify appropriate levels of abstraction.

1.1 ALGORITHMS

Algorithm Basics (1.1.1, 1.1.4)

A password might not be enough to protect your online accounts. Two-factor authentication adds an extra layer of protection. A common form of two-factor authentication sends a personal identification number (PIN) to your cell phone. To log in, you perform the series of steps shown in **Figure 1-1**.

Figure 1-1 Steps for two-factor authentication

The procedure for two-factor authentication is an example of an algorithm. In a general sense, an **algorithm** is a series of steps for solving a problem or carrying out a task.

Algorithms exist for everyday tasks and tasks that involve technology. Here are some examples:

- A recipe for baking brownies
- The steps for changing a tire
- The instructions for pairing a smart watch with your phone
- The payment process at an online store
- The procedure for posting a tweet

Programming Algorithms (1.1.2, 1.1.3, 1.1.5)

Algorithms are also an important tool for programmers. A **programming algorithm** is a set of steps that specifies the underlying logic and structure for the statements in a computer program. You can think of programming algorithms as the blueprints for computer programs.

A **computer program** is a set of instructions, written in a programming language such as C++, Python, or Java, that performs a specific task when executed by a digital device. A computer program is an implementation of an algorithm.

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Q Programming algorithms tell the computer what to do. Can you tell which of these algorithms is a programming algorithm?

Algorithm 1:

Connect to the website's login page.

Enter your user ID.

Enter your password.

Wait for a text message containing a PIN to arrive on your smartphone.

On the website's login page, enter the PIN.

Algorithm 2:

Prompt the user to enter a user ID.

Prompt the user to enter a password.

Make sure that the user ID and password match.

If the user ID and password match:

    Generate a random PIN.

    Send the PIN to user's phone.

    Prompt the user to enter the PIN.

    If the PIN is correct:

        Allow access.

A Algorithm 1 is not a programming algorithm because it outlines instructions for the user. Algorithm 2 is a programming algorithm because it specifies what the computer is supposed to do. When you formulate a programming algorithm, the instructions should be for the computer, not the user.

There can be more than one programming algorithm for solving a problem or performing a task, but some algorithms are more efficient than others.

Q Here are two algorithms for summing the numbers from 1 to 10. Which algorithm is more efficient?

Algorithm 1:

Add 1 + 2 to get a total.

Repeat these steps nine times:

    Get the next number.

    Add this number to the total.

Algorithm 2:

Get the last number in the series (10).

Divide 10 by 2 to get a result.

Add 10 + 1 to get a sum.

Multiply the result by the sum.

A Both algorithms contain four instructions, but Algorithm 2 is more efficient. You can use it to amaze your friends by quickly calculating the total in only four steps. Algorithm 1 is also four lines long, but two of the instructions are repeated nine times. Counting the first step, that's 19 steps to complete this task!

"Good" Algorithms (1.1.6, 1.1.7)

Computer scientists are interested in designing what they call "good" algorithms. A good algorithm tends to produce a computer program that operates efficiently, quickly, and reliably. Good algorithms have these characteristics:

Input: The algorithm applies to a set of specified inputs.
Output: The algorithm produces one or more outputs.
Finite: The algorithm terminates after a finite number of steps.
Precise: Each step of the algorithm is clear and unambiguous.
Effective: The algorithm successfully produces the correct output.

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When formulating an algorithm, you can easily check to make sure it satisfies all the criteria for a good algorithm. You can see how these criteria apply to an algorithm in **Figure 1-2**.

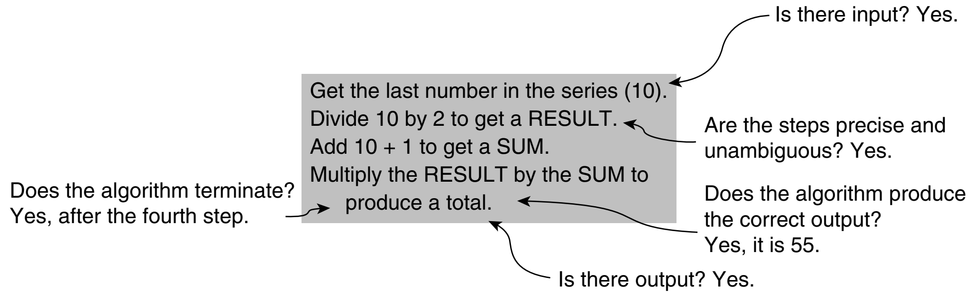

Figure 1-2 Is this a good algorithm?

Selecting and Creating Algorithms (1.1.8, 1.1.9, 1.1.10)

Before coding, programmers consider various algorithms that might apply to a problem. You can come up with an algorithm in three ways:

Use a standard algorithm. Programmers have created effective algorithms for many computing tasks, such as sorting, searching, manipulating text, encrypting data, and finding the shortest path. When you are familiar with these standard algorithms, you can easily incorporate them in programs.

Perform the task manually. When you can't find a standard algorithm, you can formulate an algorithm by stepping through a process manually, recording those steps, and then analyzing their effectiveness.

Apply computational thinking techniques. **Computational thinking** is a set of techniques designed to formulate problems and their solutions. You can use computational thinking techniques such as decomposition, pattern identification, and abstraction to devise efficient algorithms. Let's take a look at these techniques in more detail.

1.2 DECOMPOSITION

Decomposition Basics (1.2.1)

A mobile banking app contains many components. It has to provide a secure login procedure, allow users to manage preferences, display account balances, push out alerts, read checks for deposit, and perform other tasks shown in **Figure 1-3**.

The algorithm for such an extensive app would be difficult to formulate without dividing it into smaller parts, a process called **decomposition**. When devising an algorithm for a complex problem or task, decomposition can help you deal with smaller, more manageable pieces of the puzzle.

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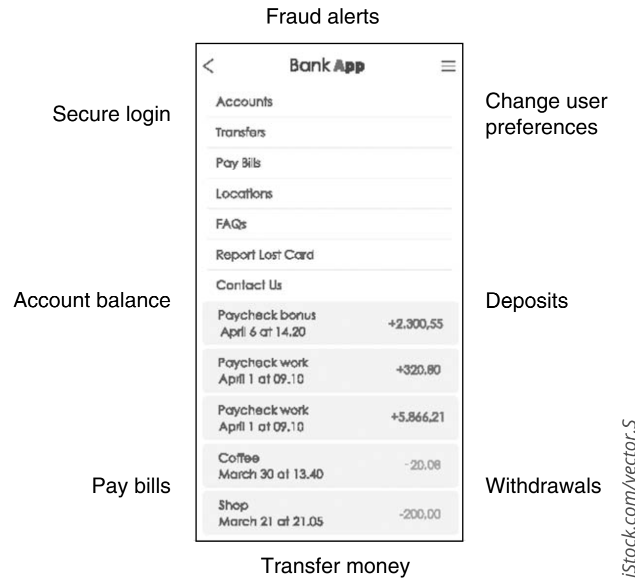

Figure 1-3 A mobile banking app handles many interacting tasks

Structural Decomposition (1.2.2, 1.2.3, 1.2.4, 1.2.7)

The first step in decomposition is to identify structural units that perform distinct tasks. **Figure 1-4** illustrates how you might divide a mobile banking app into structural units, called **modules**.

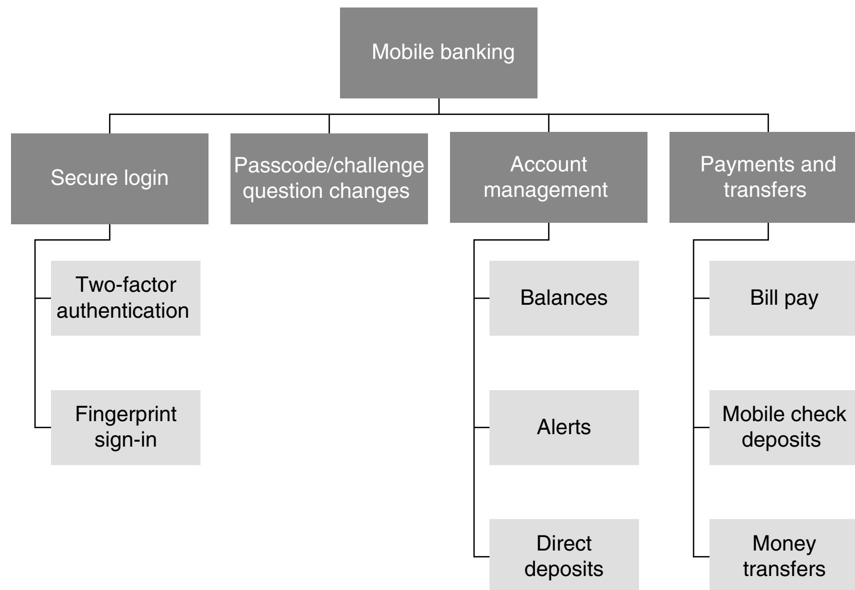

Figure 1-4 Structural decomposition diagram

Structural decomposition is a process that identifies a hierarchy of structural units. At the lowest levels of the hierarchy are modules, indicated in yellow in Figure 1-4, that have a manageable scope for creating algorithms.

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Q Which module of the hierarchy chart is not fully decomposed?

A The module for modifying passwords and challenge questions could be further decomposed into two modules: one module that allows users to change their passwords and one for changing their challenge questions.

Here are some tips for creating a structural decomposition diagram:

- Use a top-down approach. The nodes at the top break down into component parts in the nodes below them.
- Label nodes with nouns and adjectives, rather than verbs. For example, "Account management" is the correct noun phrase, rather than a verb phrase, such as "Manage accounts."
- Don't worry about sequencing. Except for the actual login process, the components in a mobile banking system could be accessed in any order. This is a key difference between an algorithm and decomposition. An algorithm specifies an order of activities, whereas decomposition specifies the parts of a task.

Functional Decomposition (1.2.5)

Functional decomposition breaks down modules into smaller actions, processes, or steps. **Figure 1-5** illustrates a functional decomposition of the two-factor authentication module.

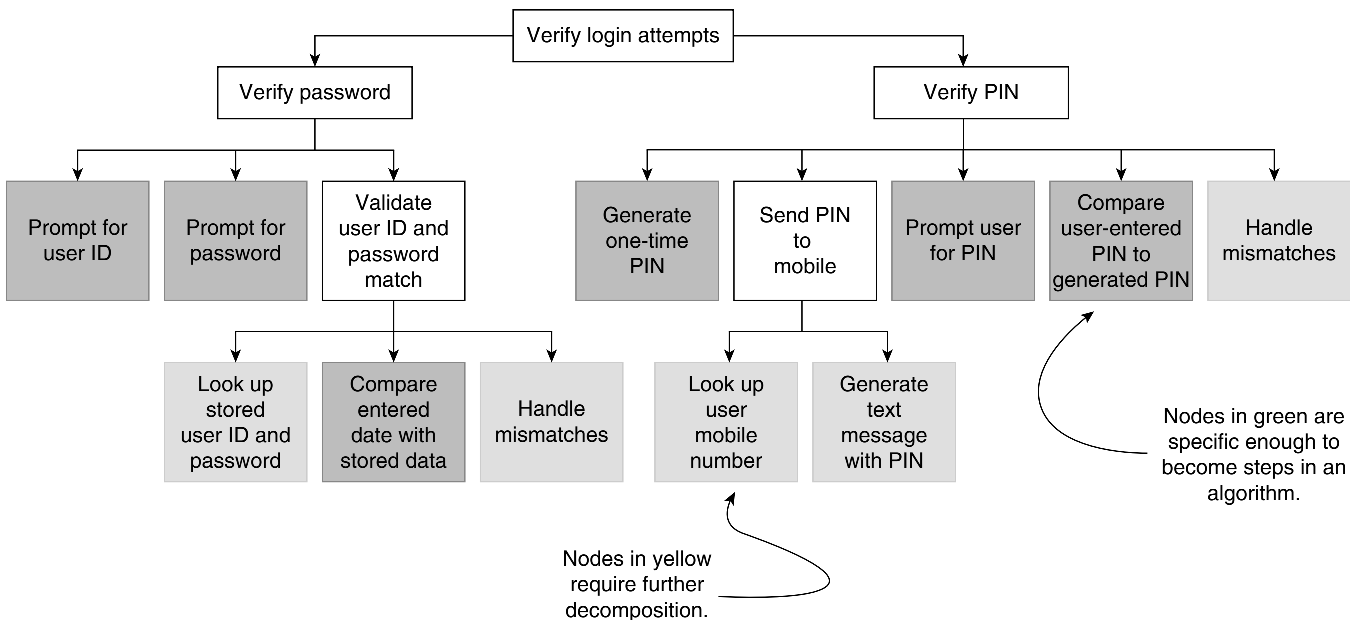

Figure 1-5 Functional decomposition diagram

Notice how the levels of the functional decomposition diagram get more specific until the nodes in the lowest levels begin to reveal instructions that should be incorporated in an algorithm.

Here are some tips for constructing functional decomposition diagrams and deriving algorithms from them:

- Label nodes with verb phrases. In contrast to the nodes of a structural decomposition diagram, the nodes of a functional decomposition are labeled with verb phrases that indicate "what" is to be done.
- Sequence from left to right. Reading left to right on the diagram should correspond to the sequence in which steps in the algorithm are performed.

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Object-Oriented Decomposition (1.2.6)

Another way to apply decomposition to a module is to look for logical and physical objects that a computer program will manipulate. **Figure 1-6** illustrates an **object-oriented decomposition** of the two-factor authentication module.

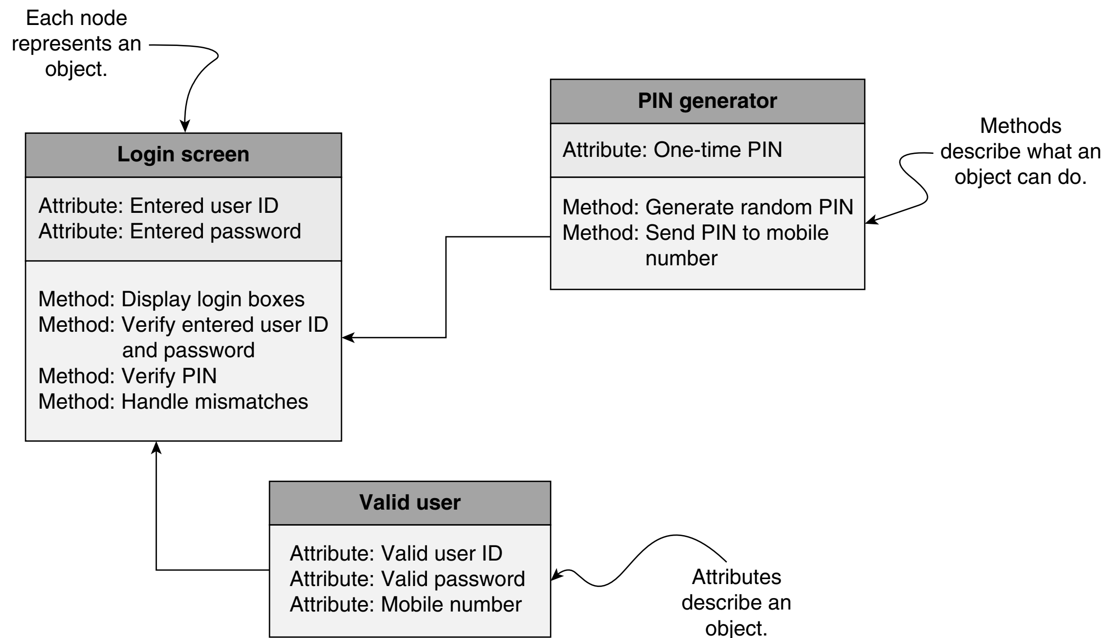

Figure 1-6 Object-oriented decomposition diagram

An object-oriented decomposition does not produce a hierarchy. Instead it produces a collection of **objects** that can represent people, places, or things.

Tips for object-oriented decomposition:

- Node titles are nouns. Each node in the object-oriented decomposition diagram is labeled with a noun.
- Attributes are nouns. A node can contain a list of **attributes**, which relate to the characteristics of an object.
- Methods are verb phrases. An object can also contain **methods**, which are actions that an object can perform. You may need to devise an algorithm for each method.
- Sketch in connection arrows. Connection arrows help you visualize how objects share data.

Dependencies and Cohesion (1.2.8)

You might wonder if there is a correct way to decompose a problem or task. In practice, there may be several viable ways to apply decomposition, but an effective breakdown minimizes dependencies and maximizes cohesion among the various parts.

The principles of decomposition are:

- Minimize dependencies. Although input and output may flow between nodes, changing the instructions in one module or object should not require changes to others.
- Maximize cohesion. Each object or module contains attributes, methods, or instructions that perform a single logical task or represent a single entity.

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1.3 PATTERN IDENTIFICATION

Pattern Identification Basics (1.3.1, 1.3.2)

The Amaze-Your-Friends math trick for quickly adding numbers from 1 to 10 is very simple:

Get the last number in the series (10).
Divide 10 by 2 to get a result.
Add 10 + 1 to get a sum.
Multiply the result by the sum.

Q Try the algorithm yourself. What is your answer?

A If your math is correct, your answer should be 55.

Now, what if the challenge is to add the numbers from 1 to 200? That algorithm looks like this:

Get the last number in the series (200).
Divide 200 by 2 to get a result.
Add 200 + 1 to get a sum.
Multiply the result by the sum.

Notice a pattern? This fill-in-the-blank algorithm works for any number:
Get the last number in the series (____________________).
Divide ____________________ by 2 to get a result.
Add ____________________ + 1 to get a sum.
Multiply the result by the sum.

The process of finding similarities in procedures and tasks is called **pattern identification**. It is a useful computational thinking technique for creating algorithms that can be used and reused on different data sets. By recognizing the pattern in the Amaze-Your-Friends math trick, you can use the algorithm to find the total of any series of numbers.

Repetitive Patterns (1.3.3)

In addition to fill-in-the-blank patterns, you might also find repetitive patterns as you analyze tasks and problems. Think about this algorithm, which handles logins to a social media site:

Get a user ID.
Get a password.
If the password is correct, allow access.
If the password is not correct, get the password again.
If the password is correct, allow access.
If the password is not correct, get the password again.
If the password is correct, allow access.
If the password is not correct, get the password again.
If the password is correct, allow access.
If the password is not correct, lock the account.

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Q How many repetition patterns do you recognize?

A Two lines are repeated three times:
If the password is not correct, get the password again.
If the password is correct, allow access.

Recognizing this repetition, you can streamline the algorithm like this:
Get a password.
Repeat three times:
    If the password is correct, allow access.
    If the password is not correct, get the password again.
If the password is correct, allow access.
If the password is not correct, lock the account.

Classification Patterns (1.3.4, 1.3.5)

Everyone who subscribes to a social media site has a set of login credentials. Here are Lee's and Priya's:

Lee's login credentials:
Lee's user ID: LeezyBranson@gmail.com
Lee's password: MyCat411
Lee's mobile number: 415-999-1234

Priya's login credentials:
Priya's user ID: PriyaMontell@gmail.com
Priya's password: ouY52311v
Priya's mobile number: 906-222-0987

The series of attributes that define each user's login credentials have a pattern of similarities. Each user has three attributes: a user ID, a password, and a mobile number. By recognizing this pattern, you can create a template for any user's login credentials like this:

User ID: ____________________
Password: ____________________
Mobile number: ____________________

You can often discover **classification patterns** in the attributes that describe any person or object. Identifying classification patterns can help you design programs that involve databases because the template identifies fields, such as User ID, that contain data.

Classification patterns also come in handy if you want to design programs based on the interactions among a variety of objects, rather than a step-by-step algorithm. In some programming circles, templates are called **classes** because they specify the attributes for a classification of objects. For example, people classified as social media subscribers have attributes for login credentials. Vehicles classified as cars have attributes such as color, make, model, and VIN number. Businesses classified as restaurants have a name, hours of operation, and a menu.

1.4 ABSTRACTION

Abstraction Basics (1.4.1, 1.4.2, 1.4.3)

Think back to the Amaze-Your-Friends math trick. By identifying a pattern, you formulated a general algorithm that works for a sequence of any length, whether it is a sequence of 1 to 10 or 1 to 200.

Get the last number in the series (____________________).
Divide ____________________ by 2 to get a result.

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