CSCI 1301 Book

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Contents

1 Introduction to Computers and Programming

1.1 Principles of Computer Programming

- Computer hardware changes frequently - from room-filling machines with punch cards and tapes to modern laptops and tablets
- Capabilities of computers have changed rapidly (storage, speed, graphics, etc.)
- Languages used to program computers have also changed over time
  - Older languages: Fortran, C, C++
  - Newer "compiled" languages: C#, Java, R
  - Newer "interpreted" languages: Python, JavaScript
- This class is about "principles" of computer programming
  - Common principles behind all languages won't change, even though hardware and languages do
  - How to organize and structure data
  - How to express logical conditions and relations
  - How to solve problems with programs

1.2 Programming Language Concepts

- Machine language
  - Computers are made of electronic circuits
  - Basic instructions are encoded by setting wires to "on" or "off"
    - Read data, write data, add, subtract, etc.
  - Binary digits represent on/off state of wires in a circuit
  - Machine language: which sequence of binary digits (circuit state) represents which computer instruction
    - Example instruction: 0010110010101101
  - Most CPUs use one of two languages: x86 or ARM
- Assembly language
  - Easier way for humans to write machine-language instructions
  - Use a sequence of letters/symbols to represent an instruction, instead of 1s and 0s.
    - Example x86 instruction: `movq %rdx, %rbx`
  - **Assembler**: Translates assembly language code to machine instructions
    - One assembly instruction = one machine-language instruction
    - x86 assembly produces x86 machine code
  - Computers can only execute the machine code
- High-level language
  - More human-readable than assembly language
  - Each statement does not need to correspond to a machine instruction
  - Statements represent more "high-level" concepts, such as storing a value in a variable, not "machine-level" concepts like "read these bits from this address"
  - Most languages we program in are high-level (C, C#, Python…)
  - **Compiler**: Translates high-level language to machine code
    - Small programs in high-level language might produce lots of machine code
    - Compiler is specific to both the source language and the target machine code
  - Compile then execute, since computers can only execute machine code
- Compiled vs. Interpreted languages
  - Not all high-level languages use a compiler - some use an interpreter
  - **Interpreter**: Lets a computer "execute" high-level code by translating one statement at a time to machine code
  - Advantage: Less waiting time before you can run the program (no separate "compile" step)
  - Disadvantage: Program runs slower, since you wait for each high-level statement to be translated before the program can continue
- Managed high-level languages (like C#)
  - Combine features of compiled and interpreted languages
  - Compiler translates high-level statements to **intermediate language** instructions, not machine code
    - Intermediate language: Looks like assembly language, but not specific to any CPU
  - **Runtime** executes compiled program by *interpreting* the intermediate language instructions - translates one at a time to machine code
  - Advantages of managed languages:
    - In a "non-managed" language, a compiled program only works on one OS + CPU combination (**platform**) because it is machine code

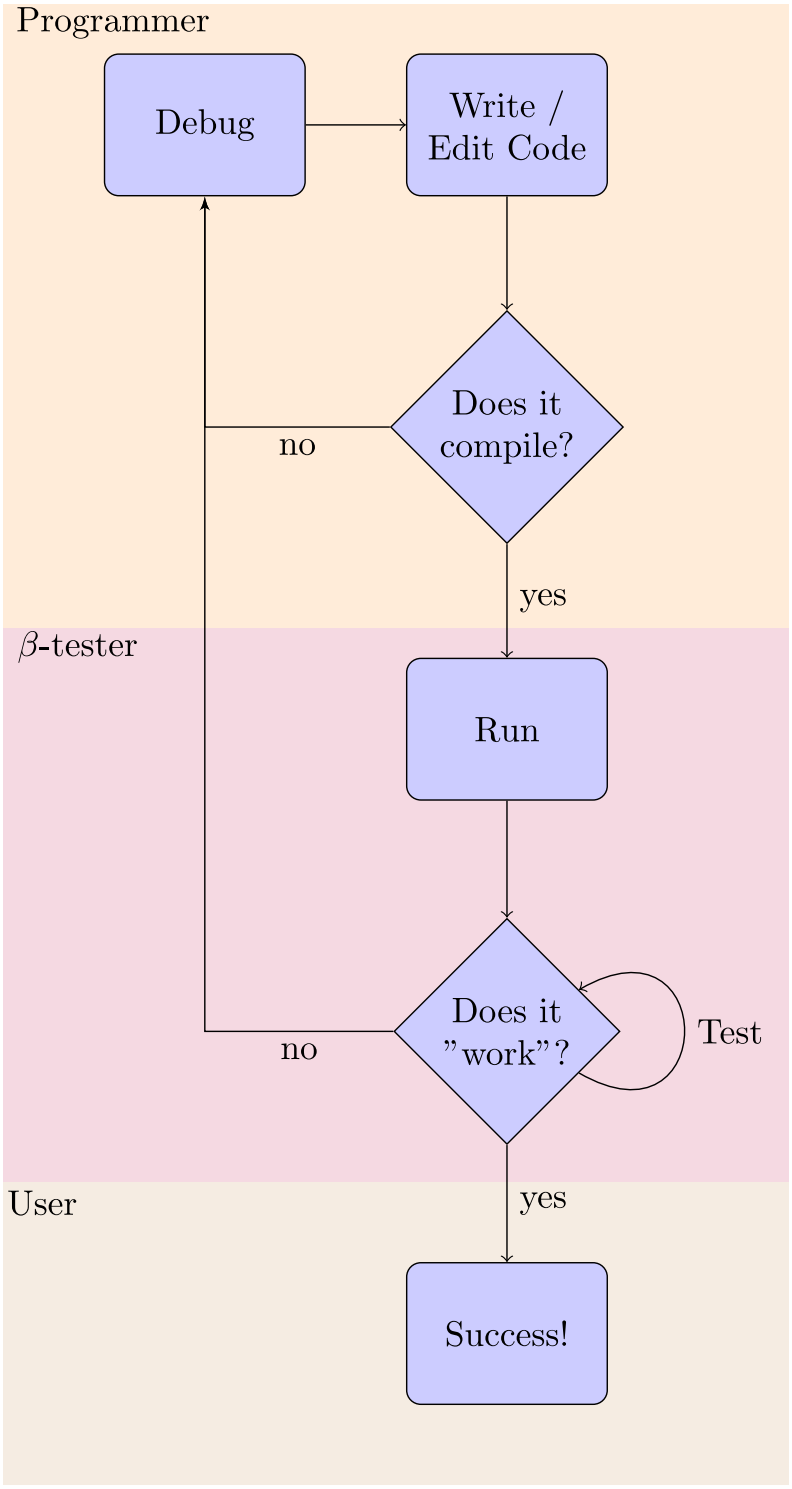
    * Managed-language programs can be reused on a different platform without recompiling - intermediate language is not machine code and not CPU-specific
    * Still need to write an intermediate language intepreter for each platform (so it produces the right machine code), but in a non-managed language you must write a compiler for each platform
    * Intermediate-language interpreter is much faster than a high-level language interpreter, so programs run faster than an "interpreted language" like Python
  - This still runs slower than a non-managed language (due to the interpreter), so performance-minded programmers use non-managed compiled languages (e.g. for video games)

1.3 Software Concepts

- Flow of execution in a program
  - Program receives input from some source, e.g. keyboard, mouse, data in files
  - Program uses input to make decisions
  - Program produces output for the outside world to see, e.g. by displaying images on screen, writing text to console, or saving data in files
- Program interfaces
  - **GUI** or Graphical User Interface: Input is from clicking mouse in visual elements on screen (buttons, menus, etc.), output is by drawing onto the screen
  - **CLI** or Command Line Interface: Input is from text typed into "command prompt" or "terminal window," output is text printed at same terminal window
  - This class will use CLI because it's simple, portable, easy to work with – no need to learn how to draw images, just read and write text

1.4 Programming Concepts

- Programming workflow (see flowchart)
  - Writing down specifications
  - Creating the source code
  - Running the compiler
  - Reading the compiler's output, warning and error messages
  - Fixing compile errors, if necessary
  - Running and testing the program
  - Debugging the program, if necessary
- Intepreted language workflow (see flowchart)
  - Writing down specifications
  - Creating the source code
  - Running the program in the interpreter
  - Reading the interpreter's output, determining if there is a syntax (language) error or the program finished executing
  - Editing the program to fix syntax errors
  - Testing the program (once it can run with no errors)
  - Debugging the program, if necessary
  - **Advantages**: Fewer steps between writing and executing, can be a faster cycle
  - **Disadvantages**: All errors happen when you run the program, no distinction between syntax errors (compile errors) and logic errors (bugs in running program)



- Integrated Development Environment (IDE)
  - Combines a text editor, compiler, file browser, debugger, and other tools
  - Helps you organize a programming project
  - Helps you write, compile, and test code in one place

  - Visual Studio terms:
    * Solution: An entire software project, including source code, metadata, input data files, etc.
    * "Build solution": Compile all of your code
    * "Start without debugging": Run the compiled code
    * Solution location: The folder (on your computer's file system) that contains the solution, meaning all your code and the information needed to compile and run it

2 C# Fundamentals

2.1 Introduction to the C# Language

- C# is a managed language (as introduced in previous lecture)
  - Write in a high-level language, compile to intermediate language, run intermediate language in interpreter
  - Intermediate language is called CIL (Common Intermediate Language)
  - Interpreter is called .NET Runtime
  - Standard library is called .NET Framework, comes with the compiler and runtime
- It's widespread and popular
  - 7th most used language on StackOverflow, 5th-most if you discount JavaScript and HTML (which are used for websites, not programs)
  - .NET is the 2nd most used library/framework

2.2 The Object-Oriented Paradigm

- C# is called an "object-oriented" language
  - Programming languages have different *paradigms*: philosophies for organizing code, expressing ideas
  - Object-oriented is one such paradigm, C# uses it
  - Meaning of object-oriented: Program mostly consists of *objects*, which are reusable modules of code
  - Each object contains some data (*attributes*) and some functions related to that data (*methods*)
- Object-oriented terms
  - **Class**: A blueprint or template for an object. Code that defines what kind of data the object will contain and what operations (functions) you will be able to do with that data
  - **Object**: A single instance of a class, containing running code with specific values for the data. Each object is a separate "copy" based on the template given by the class.
  - **Method**: A function that modifies an object. This is code that is defined (written) in the class, but when it runs, it only runs on/for a specific object and modifies that object.
  - **Attribute**: A piece of data stored in an object
- Example objects:
  - "Car" object, represents a car
    * Attributes: Color, wheel size, engine status (on/off/idle), gear position
    * Methods: Press gas or brake pedal, turn key on/off, shift transmission
  - "Audio" object, represents a song being played in a music player
    * Attributes: Sound wave data, current playback position, target speaker device
    * Methods: Play, pause, stop, fast-forward, rewind

3 First Program

Here's a simple "hello world" program in the C# language:

```
/* I'm a multi-line comment,
 * I can span over multiple lines!
 */
using System;

class Program
{
    static void Main()
    {
        Console.WriteLine("Hello, world!"); // I'm an in-line comment.
    }
}
```

Features of this program: - A multi-line comment: everything between the `/*` and `/*` is considered a *comment*, i.e. text for humans to read. It will be ignored by the C# compiler and has no effect on the program. - A `using` statement: This imports code definitions from the System *namespace*, which is part of the .NET Framework (the standard library). - In C#, code is organized into **namespaces**, which group related classes together - If you want to use code from a different namespace, you need a `using` statement to "import" that namespace - All the standard library code is in different namespaces from the code you will be writing, so you'll need `using` statements to access it - A class declaration - Syntax: `class [name of class]`, then `{` to begin the body of the class, then `}` to end the body of the class - All code between opening `{` and closing `}` is part of the class named by the `class [name]` statement - A method declaration - The name of the method is `Main`, and is followed by empty parentheses (we'll get to those later, but they're required) - Just like with the class declaration, after the name, `{` begins the body of the method, `}` ends it - A statement inside the body of the method - This is the part of the program that actually "does something": It prints a line of text to the console - A statement *must* end in a semicolon (the class header and method header aren't statements) - This statement contains a class name (`Console`), followed by a method name (`WriteLine`). It calls the `WriteLine` method in the `Console` class. - The **argument** to the `WriteLine` method is the text "Hello, world!", which is in parentheses after the name of the method. This is the text that gets printed in the console: The `WriteLine` method (which is in the standard library) takes an argument and prints it to the console. - Note that the argument to `WriteLine` is inside double-quotes. This means it is a **string**, i.e. textual data, not a piece of C# code. The quotes are required in order to distinguish between text and code. - An in-line comment: All the text from the `//` to the end of the line is considered a comment, and is ignored by teh C# compiler.

3.1 Rules of C# Syntax

- Each statement must end in a semicolon
  - Class and method declarations are not statements
  - A method *contains* some statements, but it is not a statement
- All words are case-sensitive
  - A class named `Program` is not the same as one named `program`
  - A method named `writeline` is not the same as one named `WriteLine`
- Braces and parentheses must always be matched
  - Once you start a class or method definition with `{`, you must end it with `}`
- Whitespace – spaces, tabs, and newlines – has almost no meaning

  - There must be at least 1 space between words
  - Spaces are counted exactly if they are inside string data, e.g. `"Hello      world!"`
  - Otherwise, entire program could be written on one line; it would have the same meaning
  - Spaces and new lines are just to help humans read the code
- All C# applications must have a `Main` method
  - Name must match exactly, otherwise .NET runtime will get confused
  - This is the first code to run when the application starts – any other code (in methods) will only run when its method is called

3.2 Conventions of C# Programs

- Conventions: Not enforced by the compiler/language, but expected by humans
  - Program will still work if you break them, but other programmers will be confused
- Indentation
  - After a class or method declaration (header), put the opening `{` on a new line underneath it
  - Then indent the next line by 4 spaces, and all other lines "inside" the class or method body
  - De-indent by 4 spaces at end of method body, so ending `}` aligns vertically with opening `{`
  - Method definition inside class definition: Indent body of method by another 4 spaces
  - In general, any code between `{` and `}` should be indented by 4 spaces relative to the `{` and `}`
- Code files
  - C# code is stored in files that end with the extension ".cs"
  - Each ".cs" file contains exactly one class
  - The name of the file is the same as the name of the class (Program.cs contains `class Program`)

3.3 Reserved Words and Identifiers

- Reserved words: Keywords in the C# language
  - Note they have a distinct color in the code sample and in Visual Studio
  - Built-in commands/features of the language
  - Can only be used for one specific purpose; meaning cannot be changed
  - Examples:
    - using
    - class
    - public
    - private
    - namespace
    - this
    - if
    - else
    - for
    - while
    - do
    - return
- Identifiers: Human-chosen names
  - Names for classes, variables, methods, namespaces, etc.
  - Some have already been chosen for the standard library (e.g. Console, WriteLine), but they're still identifiers, not keywords

- Rules for identifiers:
  - Must not be a reserved word
  - Must contain only letters, numbers, and underscore – no spaces
  - Must not begin with a number
  - Are case sensitive
- Conventions for identifiers
  - Should be descriptive, e.g. “AudioFile” or “userInput” not “a” or “x”
  - Should be easy for humans to read and type
  - If name is multiple words, use CamelCase to distinguish words
  - Class and method names should start with capitals, e.g. `class AudioFile`
  - Variable names should start with lowercase letters, then capitalize subsequent words, e.g. `myFavoriteNumber`