Introduction

August 20, 2021

1 Introduction

1.1 Topics

- computer science fundamentals
- problems, algorithms and programs
- programming languages
- C++ language and C++ program development steps
- setting up development and learning environments
- the first program and its anatomy
- errors and debugging

1.2 Computer science (CS) fundamentals

- the core is a disciplined ability to be logical and creative in a pragmatic way to solve problems in varieties of disciplines
- CS is a newer discipline that burrows from Mathematics, Engineering, and Natural Science
- like mathematicians, computer scientist use formal languages to denote ideas (esp. computation)
- like engineers, they design things, assemble components into systems and evaluate tradeoffs among alternatives
- like scientists, they observe the behavior of complex systems, form hypothesis, and test predictions
- **the single most important skill for a computer scientist is problem-solving mostly writing computer programs**
- the goal of this course is to teach you how to think like a computer scientist
- computer scientists primary job revolves around problems, algorithms and programs

1.3 Problems, Algorithms and Programs

1.3.1 Problem

- we deal with and solve a lot of problems in every walk of lives
- problem is a question raised for inquiry that someone needs to answer or find solution to
- computer scientists typically deal with computational problems
- can be as simple as:

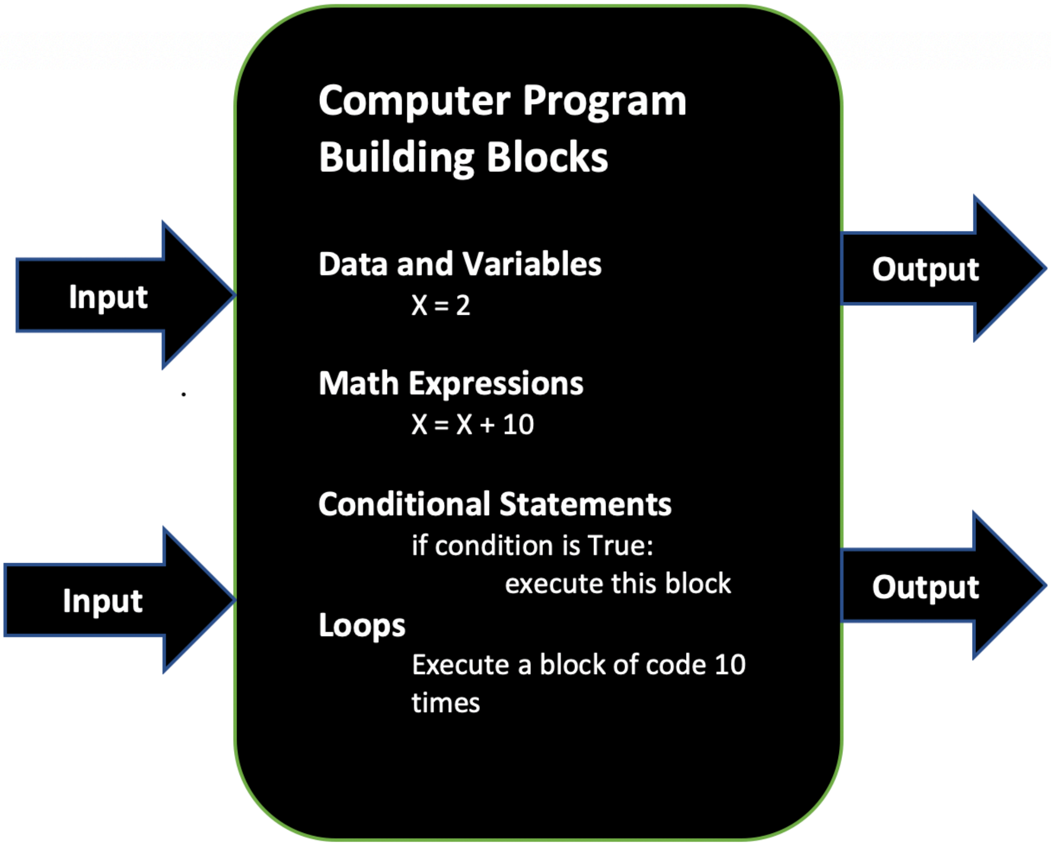
- what is the sum of 9 and 999?
- or can be as complicated as:
  - what is the shortest path from San Francisco, California to New York City, New York?
- one must understand the problem, analyze the requirements, constrains and assumptions in order to correctly solve the problem

1.3.2 Algorithm

- once the problem is formulated and well analyzed, computer scientists work on algorithm
- step by step process/task to solve a given problem
  - like a recipe for a food menu
- typically written in human language or pseduo-code (in between)
- e.g. problem: How can your martian friend buy grocery on earth?
- you should be able to help solve this problem given you live on earth and shopped groceries many times
  - in other words, you're the domain expert
- algorithm steps:
  1. Make a shopping list
  2. Drive to a grocery store
  3. Park your car
  4. Find items in the list
  5. Checkout
  6. Load grocery
  7. Drive home
- there's a lot of details missing from these steps
  - it's a good start and can be refined by drilling each step further down

1.3.3 Program

- once the algorithm steps are finalized, programmers can convert them into computer instructions
- sequence of instructions that specifies how to perform a computation using computers
  - computation can be mathematical (solving system of equations), symbolic computation (searching and replacing text in a document, scientific simulations), etc.
- the instructions (or commands or statements) look different in differnt programming languages, but the basic fundamental concepts are the same
- some fundamental concepts that make up a computer program regardless of the language are:
  1. data/values and variables
  2. input
  3. output
  4. math
  5. conditional (logical) execution
  6. repitition



1.3.4 data and variables

- program works with data (called values) which must be stored in computer memory; variables are names given to memory locations to store values

1.3.5 input

- get data from keyboard, a file, or some device

1.3.6 output

- display data/answer on screen, or save it to file or to a device

1.3.7 math

- basic mathematical operations such as addition, subtraction, multiplication, etc.

1.3.8 conditionals

- test for certain conditions or logics and execute appropriate sequence of statements

1.3.9 loops

- perform some action repeatedly, usually with some variation every time

1.4 Programming languages

- programming langugage is a formal language used to create computer program
- there are dozens of programming languages

1.4.1 Types of programming languages

1.4.2 High-level languages

- languages that are disigned to be programmer friendly hiding all the details
  - C++, Java, C, FORTRAN, Python, PhP, JavaScript, Rust, etc.
- advantages:
  - simpler; easier to learn and write
  - shorter and easier to read
  - programs are portable; can run in differnet machines with a few or no modifications
- disadvantages:
  - translation to machine code can take some time
  - slower to run if the translation is not optimal

1.4.3 Low-level languages

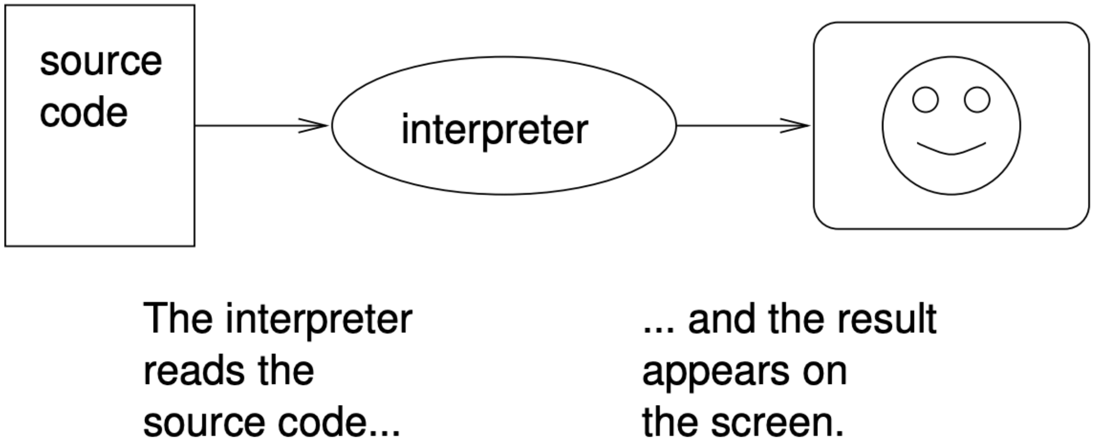
- machine language e.g., Assembly language
- loosely speaking: computers can only execute programs written in low-level languages
- programs written in a high-level languages must be translated before they can run
- advantage:
  - prgrams run faster
- disadvantages:
  - harder to learn and write code (need to know very low level details about computers)
  - programs are not portable; usually need to rewrite for each kind of machine architecture

1.5 Ways to translate high level programs

- there are two ways to translate high level programs: **intrepreting** and **compiling**

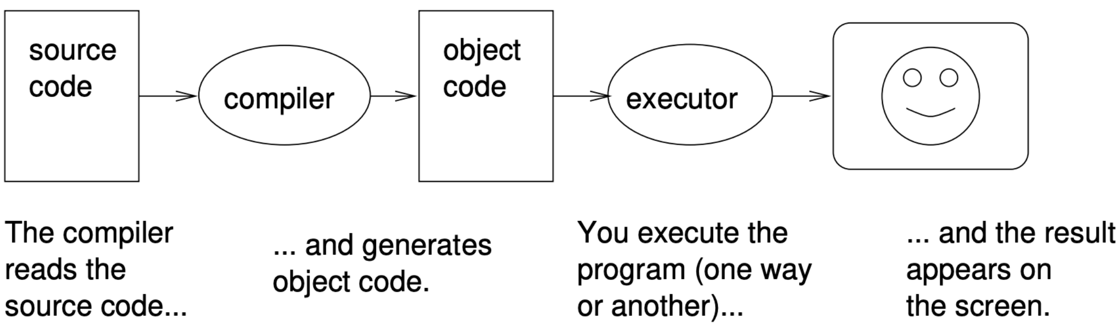
1.5.1 intrepreting

- an interpreter reads a high-level program and does what it says
- it translates the program line-by-line alternately reading lines and carriying out commands
- Python, PhP, JavaScript are intrepreted languages



1.5.2 compiling

- a compiler reads a high-level program and translates it all at once into byte code before executing any of the commands
- compilers check for syntax/grammers of languages
- the byte code or binary program must be then loaded into memory to execute
- C++, C, Rust, Java, FORTRAN are compiled programming languages



1.6 C++ Programming language

- C++ is one of the most popular general pupurpose programming languages - see tiobe index
- high level, compiled language
- extension of C programming language
  - same syntax; burrows all C libraries and supports class (object oriented programming, OOP)
- you can use all the C libraries and features in C++
- designed for system programming and embedded, resource-constrained software and large systems with performance, efficiency, and flexibility
- see Wikipedia entry for history and other details: - https://en.wikipedia.org/wiki/C%2B%2B
- official C++ reference site https://en.cppreference.com/w/

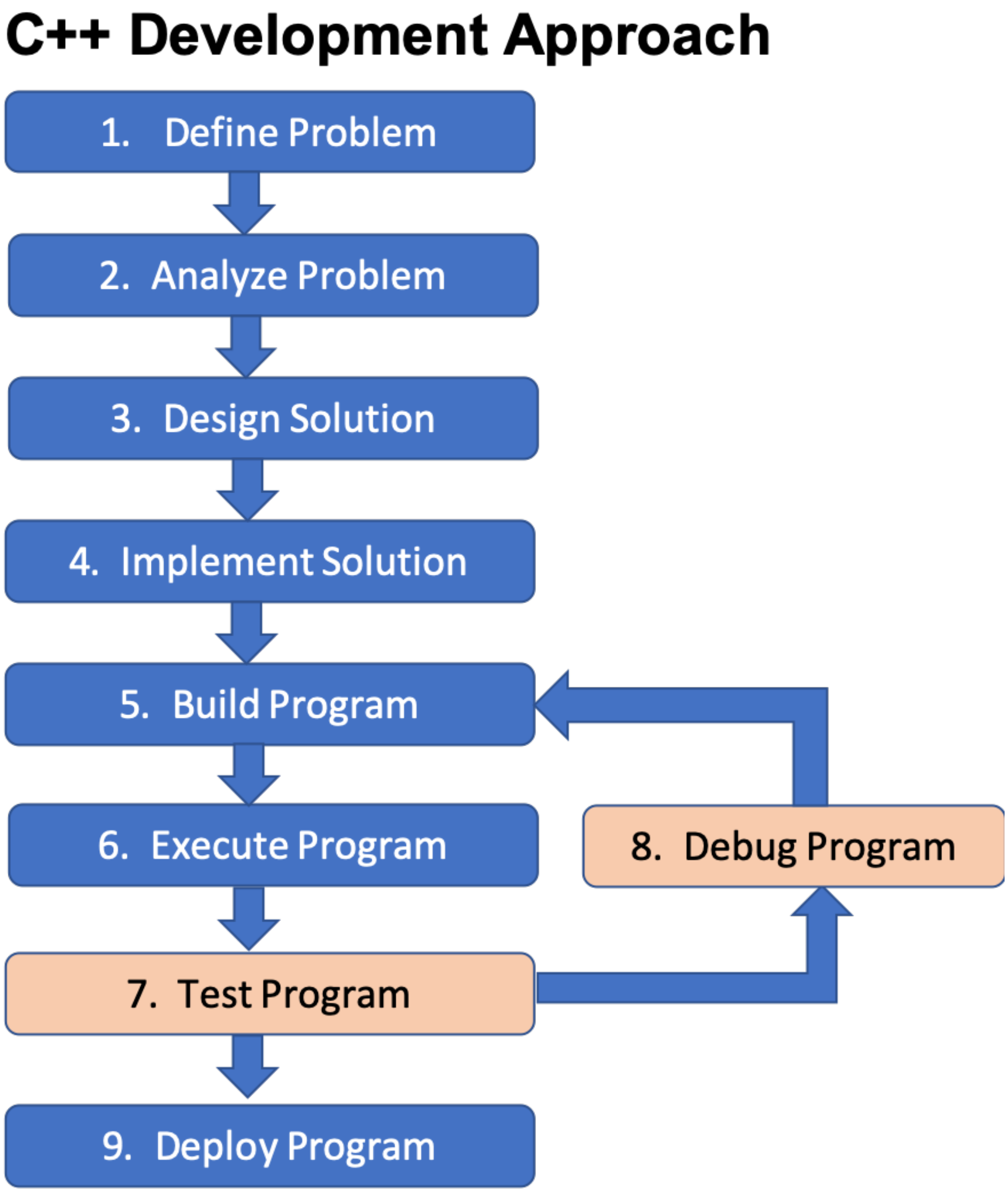
1.7 Problem solving using C++

- C++ is one of many tools computer scientists use to solve problems
- learning and being proficient using your tools are important

- ultimate goal is to learn problem solving like comupter scientists
  - writing code, though important, is a small part of problem solving
  - programmers spend about 20% of their time developing code
- program design and development requires many steps
  - a major part of software engineering process

1.7.1 C++ development steps

- a simple high-level approach to developing C++ programs is depicted in the following figure



Step 1: Define problem

- figure out what problem you are trying to solve
- it may be be just an idea or a fully researched problem statement

1. write a program to find the average temperatures in the USA over the last decade
   - write a program that checks if a given string is a palindrome
   - write a program that finds the shortest path from New York City to San Francisco
   - design and develop a system for Mars rover

Step 2: Analyze problem

- really understand the scope and all the parameters of the problem
- gather all the requirements, outline any assumptions, input and output constraints, etc.
  - let's say you want to solve the temperature problem #1 defined in step 1
  - how'd you get the temperatures data? would you include all 50 states?
  - what if there's no temperature data for some states? are you going to average out the states and then find the average of the average?
  - are there any outliers, how'd you handle those?

Step 3: Design solution

- determine "how" you'd actually solve the problem
- many ways to solve a problem; look into tradeoffs e.g. efficiency vs cost, etc.
  - often simple and straight forward solutions are better ones
- break the problem into smaller modules or sub problems
  - write algorithm steps for each sub problem
  - modular solution is easier to update, expand, and reuse without affecting other parts
- design mockups; draw system design
  - explain how various modules and components interact with each other
  - helps address any assumptions made or limitations

Step 4: Implement solution

- write the program using a programming language
  - use C++ in this course
- programmers spend only about 20% of their time writing code
- need a computer with a text editor or an Integrated Development Environment (IDE)
  - depends on the system: Windows, Linux, Mac, etc.
- a good code editor or IDE typically provides
  - way to organize project with multiple files and resources
  - syntax highlighting, color coding, line numbers, easy way to compile, run and debug code

Step 5: Build program

- this is tpically a two-step process:
  1. compile C++ code in object or byte code
     - a project/program may contain many c++ files and header files (.cpp, .cc, .h file extensions)
     - each C++ source file gets converted into object file (typically have .o extension)
  2. link object files and libraries
     - program called linker combines or links together all the object files and C++ standard library and any other libraries used into one single executable program

- modern compilers (e.g. g++) can do both the steps at once
- **Makefile** is a better way to build C/C++ programs
  - a bash like script that simplifies a lot of step for building programs over and again
  - learn about makefile from these tutorials:
    * https://makefiletutorial.com/
    * https://www.cs.bu.edu/teaching/cpp/writing-makefiles/

Step 6, 7, and 8: Execute, Test, and Debug Program

- you must execute or run the program to test it
- a program called loader loads the executable into main memory RAM (Random Access Memory)
  - CPU (Central Processing Unit) does the actual computation
- testing ensures you're getting right results under all the assumptions
- programmers may spend a lot of time testing their own programs or others'
  - counter intuitively, you try to break your own program!
- if bug or error exists, you need to pin point it and correct it
  - build the program again repeating from step 5 as many times as required
- two common ways to test your program for correctness; learn both in this course!
  1. manually run and feed input data and compare the results with the expected answers
  - write test cases and test your program automatically using code

Step 9: Deploy program

- deliver or deploy your program in production environment
  - given your program meets all the requirements, passes rigorous testing, etc.

1.8 The first program

- traditionally, "hello world" is the first program one writes to learn coding in any given language

[1]:
```cpp
/*================================================
  Hello World program
  Author: Ram Basnet
  Date: June 24, 2020
  Copyright: MIT License

  The program prints "Hello World!" on the console
==================================================*/

// include required libraries/header files
#include <iostream>

// one main function is always required in a C++ program
int main() // main entry to the program
{
    // output Hello World!
    std::cout << "Hello World!" << std::endl;
    return 0;
```

```
}
```

1.9 Structure of a C++ program

- C++ program may constitute one or many plain-text files
  - typically header and source files
- each C++ file contains various C++ statements, instructions and codes
- C++ source file typically has these extensions: `filename.cpp` or `filename.cc`
  - avoid spaces in file and folder names
- C++ program must have one file with the **main( )** function
  - **int main()** is the main entry of the program
  - computer starts executing instructions top to bottom starting from **main()**
- C++ file typically contains:
  - **program description**
    - brief information about the program and prorammer, copyright info
    - these are comments meant for programmers/readers
  - **libraries**
    - include the librabires (header files) that are only required
    - libraries provide built-in codes that programmers can use
    - programmers don't have to write all the basic, details and common tasks
      - so, they can focus on solving problems
    - libraries are mandatory for many common tasks such as input and output
  - **comments**
    - comments are ingnored by the C++ compiler
    - comments are for programmers to explain the thought process, subtle code blocks
    - it's best practice to write adequate notes as comments, esp. when learning
    - makes it easy to read and understand code without actually having to run and decode the code
    - *write code for others to read*
    - `//` - double forward slashes is used for single line comment
    - `/*` everything within are comments; used for multi-line comments `*/`
  - **instruction codes**
    - tells computer what to do!
    - code composed of keywords, identifiers, symbols, literal values, etc.
      - when put together following the language's grammer solves the problem
    - block of codes appear within squiggly-braces `{ }`
    - statements end with a semi-colon (`;`)
  - **white spaces**
    - indentations, extra spaces and blank lines are typically ignored by the compiler unless necessary
    - adequate white spaces are required as a best practice for readability of code

1.10 Setting up C++ development environment

- setting up a good development environment and getting familiar with it can make you an efficient learner and problem solver
- dev environment may depend on various factors: personal preference, available resources, project, etc.

- see this note for recommended C++ Dev Environment

1.10.1 Compiling C++ programs using g++ and Makefile

- modern integrated development environemt (IDE) makes it very easy to compile, build and deploy C++ programs
- however, the abstraction and easyness they provide may hide some of the important steps beginner programmer should know
- the compilation process using Makefile is highly recommended for both beginners and the professionals in the field
- see the basic tutorial and examples on how to create and use Makefile here

1.10.2 Compile and run hello world program

- write a program that prints "Hello World!"
- compile and run the program on your system
- see the example `helloworld.cpp` program found in `demos/intro/`
- run the provided Makefile using a terminal assuming you're using g++ and Makefile
  - must `cd` into the folder that contains the Makefile

```
make
make run
make clean
```

1.10.3 Using Jupyter Notebook as Teaching and Learning Environment

- setting up Jupyter Notebook program is only required if you're teaching/learning C++ interactively
- all these notes and corresponding pdfs are created using Jupyter Notebook program
- see this page for setting up and using Jupyter Notebook

1.10.4 Kattis Online Problem Bank and Judge

- throughout the chapters provided in these notebooks, you'll find Kattis Problems section
- you can use the knowledge and skills learned to challenge and solve myriad of problems as exercises
- see this notebook for more on Kattis

1.11 Testing and debugging

- programs often contains many types of errors called bugs
- programmers spend majority of their time in testing their programs, finding bugs and getting rid of them
- the process of finding and correting bugs is called debugging
- many IDEs provide a way to step through the code and examine memory as the program executes
- the key to finding and fixing bugs is testing
  - exhaustive testing makes sure program provides correct output for all sets of input

1.11.1 Types of errors

- there are three major types of bugs: syntax, run-time and semantic

Compile-time errors

- also called syntax errors or grammatical errors
- computer languages are formal languages with strict grammer to a semicolon
  - Natural languages (English, e.g.) are full of ambiguity, redundancy and literalness (idioms and metaphors)
- compiler parses the C++ code; provides a list of errors if any
- fails to compile a program to byte code if program has compiler error

Run-time errors

- also called run-time exceptions
- these errors appear while program is running
- can be handled to certain extent

Semantic errors

- also called logical errors
  - errors in thought process, may arise due to misunderstanding of problem, wrong solution/answer, language quirks
- program runs fine but gives wrong answer
  - e.g., adding instead of multiplying to solve an equation (e.g., $2+2$ is same as 2×2)
- can be identified and removed by doing adequate testing

1.12 Labs

1. Standard Output Lab
   - write a C++ program that produces the following output on console
   - use the partial solution provided in `labs/intro/main.cpp`
   - observe and note how the special symbols such as single quote, double quotes and black slashes
   - run the program as it is using the provided make file in the stdio folder
   - complete the rest of the ASCII Art by fixing all the FIXMEs
   - write #FIXED next to each fixme

```
  |\_/|        ******************************     (\_/)
 / @ @ \       *      ASCII Art              *    (='.'=)
( > 0 < )      *      Author: <Your Name>    *   ( " )_( " )
  >>x<<        *      CS Foundation Course   *
  / O \        ******************************
```

1.13 Exercises

1. Setup Developement Environment
   - setup your personal development environment
   - download and install tools that are typically used by programmers: C++ Editor, C++ Compiler, git client, etc.

- you can follow the steps provided here

2. Hello World
    - write a C++ program that prints "Hello World!" as an output to the console
    - see complete solution in `exercises/intro/helloworld/main.cpp`
    - write Makefile and use make to build the program
    - see Makefile solution here: exercises/intro/helloworld/Makefile
3. ASCII Art
    - google images made using ASCII arts
    - print some ASCII arts, texts and pictures of your choice
    - can use ASCII Art generator: `http://patorjk.com/software/taag/#p=display&f=Graffiti&t=Type%20Something%20`
4. The Game of Hangman
    - write a C++ program that prints various stages of the hangman game
    - game description: `https://en.wikipedia.org/wiki/Hangman_(game)`
    - produce the output seen in Example game section of the Wikipedia page
    - game will not have any logic to actually play, unless you know how to implement it!

1.13.1 Kattis problems

1. Hello World!
    - login and solve the Hello World! problem: https://open.kattis.com/problems/hello

1.14 Summary

- this chapter covered:
- the basics of Compter Science and programming
- different types of programming languages
- C++ basics, the first program and the basic structure of a C++ program
    - how to print data to standard output
- C++ editor and compiler
- exercises and sample solutions

[ ]:

```
```