Ch01-Introduction

September 2, 2020

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, assembling components into systems and evaluating 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:

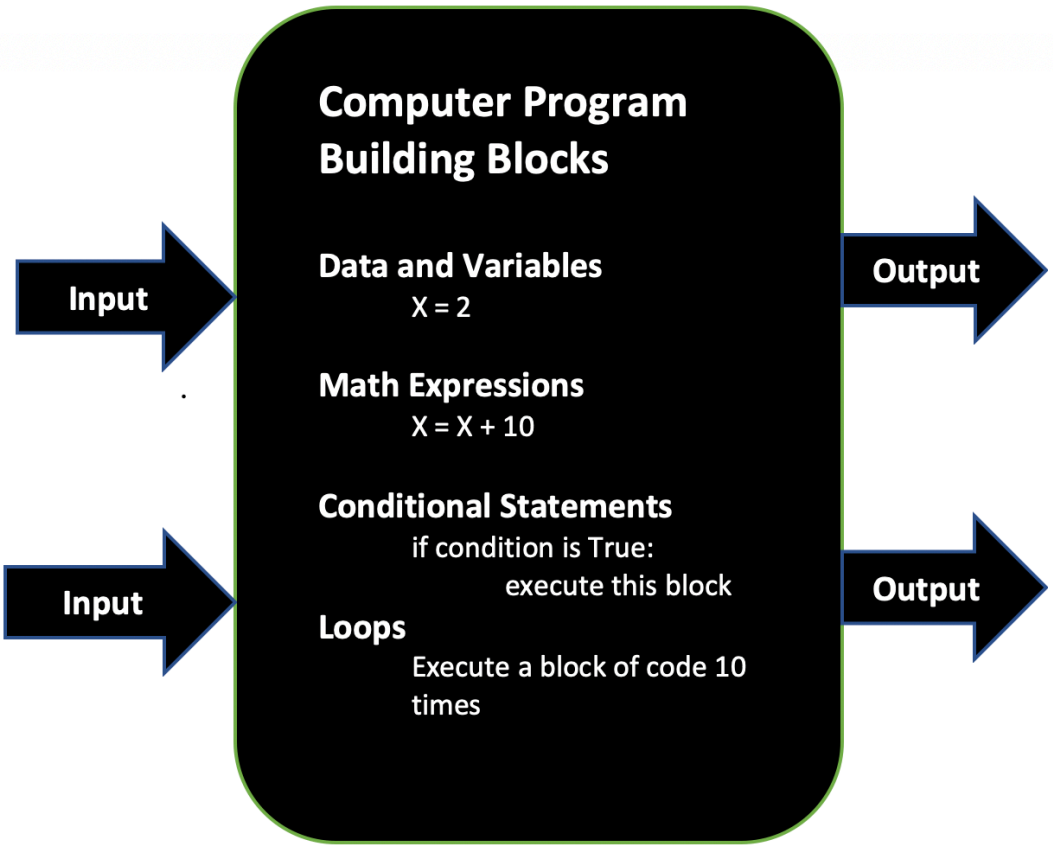
  - what is the sum of 9 and 999?
- or can be as complicated as:
  - what is the shortest path from San Francisco, California to New York City, New York?
- one must understand the problem, analyze the requirements, constrains and assumptions in order to correctly solve the problem

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
  - Drive to a grocery store
  - Park your car
  - Find items in the list
  - Checkout
  - Load grocery
  - 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 diffrent 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. input
  - output
  - math
  - conditional (logical) execution
  - repitition



1.3.4 input

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

1.3.5 output

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

1.3.6 math

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

1.3.7 conditional (logical) execution

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

1.3.8 repitition

- 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

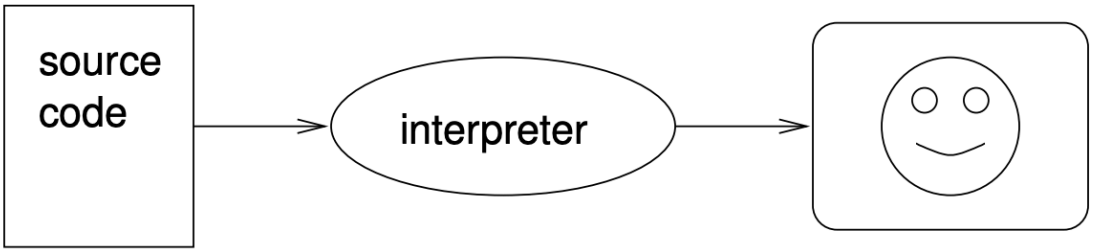
- machine language e.g., Assembly language
- loosely speaking: computers can only execute programs written in low-level languages
- programs written in a high-level languages must be translated before they can run
- advantage:
  - prgrams run faster
- disadvantages:
  - harder to learn and write code (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

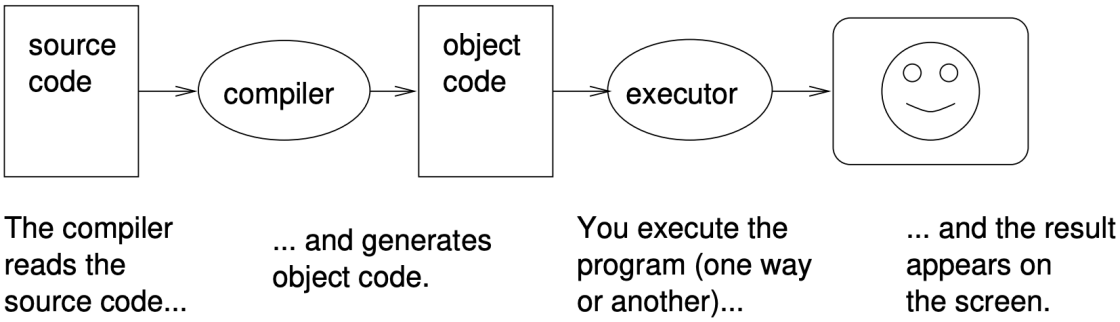


The interpreter reads the source code...

... and the result appears on the screen.

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

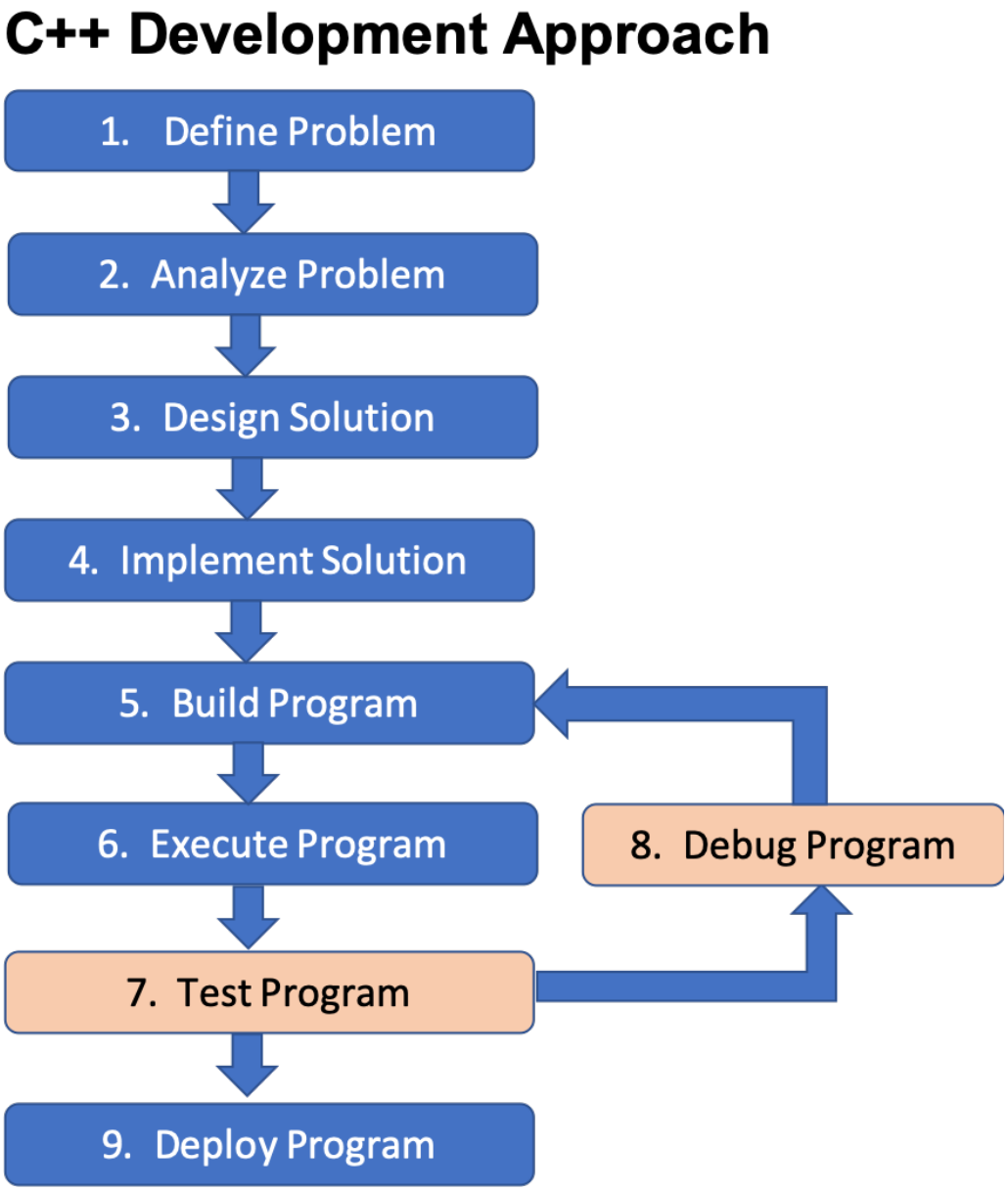
- C++ is one of the most popular general pupurpose programming languages - see tiobe index
- high level, compiled language
- extension of C programming language
  - same syntax; burrows all C libraries and supports class (object oriented programming, OOP)
- you can use all the C libraries and features 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 are you trying to solve
- may be be just an idea or 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 problems; look into tradeoffs e.g. efficieny, cost, etc.
  - often simple and straight forward solutions are better ones
- break the problem into smaller modules or sub problem
  - 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 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. linking 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++) do the both the steps
- **Makefile** is better way to build C/C++ programs
  - a bash like script that simplifies a lot of step for building programs over and again
  - a simple makefile tutorial: 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 makes sure 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
- couple 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, pases rigorous testing, etc.

1.8 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
- the following tools are recommended for this course
  1. Visual Studio (VS) Code editor
     - light weight cross-platform editor for many programming languages; has rich extensions
  2. git client for version control
     - Note: VS Code provides GUI-based git
  3. g++ compiler
- follow the instructions from https://github.com/rambasnet/DevEnvSetup to setup Jupyter Notebook on various platforms

1.8.1 Using g++ compiler on Windows WSL, Mac and Linux

- open a Terminal program
- change current working directory to where the right folder where the .cpp file is
- make sure the current working directory is where your .cpp file is
  - use pwd command on *nix terminal to know the current working directory
  - use ls commad to see all the contents of the directory
- compile using g++
- run the executable
- the following sequence of commands are worth remembering
  - can use these commands on repl.it cloud-based IDE as well

```
$ cd projectFolder # change working directory to the project folder
$ pwd # print current working directory
$ ls # list contents of current directory
$ g++ -std=c++17 -o outputProgram inputFile.cpp  # compile inputFile.cpp to outputPrgram
$ ./outputProgram  # run output program
```

1.8.2 Using makefile

- create a make file inside the project folder
- use a simple template provided here demo_programs/Ch01/Makefile
- run the following commands from inside the project folder

```
$ cd projectFolder # change current working director - folder with c++ file(s)
$ make all # run all rule; build program
$ make clean # run clean rule; usually delete all object/exe files
```

1.9 The first program

- traditionally, 'hello world' is the first program one writes to learn coding in any given language
- type the following code in hello.cpp file
- compile and run the program on your system
- compile and run the helloworld program found in demo_programs/Ch01/helloworld.cpp or at https://repl.it/@rambasnet/CS1-HelloWorld

[1]:
```
/*=================================================
  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;
}
```

1.10 Setting up Jupyter notebook learning environment

- Jupyter notebook (popular tool in Data Science and Machine Learning) is merely a learning environment
  - not a professional development environment esp. for C++ programs
- see README for detail steps
- allows you to interactively execute code, take notes with text and HTML, and embed multimedia files (image, audio, video, etc.)
- most importantly, one can execute codes line by line and save the output result
  - can focus on the the line of code to really master all the details and basics
- you can also read and execute these notebooks from VS Code with right extensions

- pdfs of these notebooks are provided in pdfs folder in GitHub repository
  - pdfs are readonly; can't write and/or execute embedded code in PDF files
- GitHub (most of the time) renders these notebooks, so one can read the contents directly from GitHub repo
  - readonly; can't execute embedded code on GitHub
- follow the instructions from https://github.com/rambasnet/DevEnvSetup to setup Jupyter Notebook on various platforms

[2]:
```
// in Jupyter Notebook, main() is defined implicitly!
// simply, include libraries and write code to execute without main()
#include <iostream>

std::cout << "Hello World!" << std::endl;
```

```
Hello World!
```

[3]:
```
// include this line so you don't have to type std::
using namespace std;

cout << "Hello World!" << endl;
```

```
Hello World!
```

1.11 Structure of a C++ program

- C++ program may constitute one or many 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 file and folder names with spaces
- 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 compilers
    - 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*
    - // 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

1.12 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

1.12.1 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, solution, 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 plenty of testing

1.13 Exercises

1. Developement Environment
   - create your development environment
   - download and install tools that are typically used by programmers: C++ Editor, C++ Compiler, git client, etc.
2. Hello World
   - write a C++ program that prints "Hello World!" as an output to the console
3. Standard output
   - write a C++ program that produces the following output on console
   - obsever and note the special symbols such as single quote, double quotes and black slashes

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

   - see partial solution in demo_programs/Ch01/helloworld.cpp or at https://repl.it/@rambasnet/CS1-ASCIIArt.
4. 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%20S
5. 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!

1.14 Kattis (https://open.kattis.com)

- throughout these notebooks, you'll find Kattis problems listed under each chapter where appropriate
- Kattis is a free problem bank and online judge that is widely used in International Collegiate Programming Contest (ICPC) around the world
- Kattis is a great tool to learn various programming languages while solving intuitive problems and developing problem solving skills that are sought after by many potential employers
- research (https://rambasnet.github.io/pdfs/kattis.pdf) has shown that by introducing and assigning Kattis problems motivates students to continuously use Kattis and solve more problems there by becoming an effecting problem solver – a hallmark skill of computer scientist
- here's a repository of some sample solutions provided in various languages with automated test cases: https://github.com/rambasnet/KattisDemos
  - eventually (by Chapter 7), you'll be able to understand and use the all the programming concepts used in those demo solutions

- it provides help to get your started: https://open.kattis.com/help
- you must create a free acount here: https://open.kattis.com/login to be able to submit your solution be checked by Kattis

1.14.1 Kattis problems

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

1.15 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

[ ]: