COMP 102: Computers and Computing
Lecture 5: Solving problems by programming

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Motivation

- The advantage of a computer it its ability to solve almost any problem.

  BUT: You need to explain what you want!

- With the right programming, a computer can:
  - Create movie animations.
  - Compose music.
  - Play chess.
  - At a low-level, all are implemented with Boolean logic blocks and finite-state machines.

- Programming gives you a higher-level way of expressing problems.
  - It also means you can think about problems at a higher-level.

A programming language

- A programming language is a set of building blocks for constructing computer software.
- Like human language, there is a vocabulary and a grammar.
  - Sometimes called “semantic” and “syntactic” rules.
- Unlike human language, there is a very precise meaning for every word and sentence.
  - This is necessary so that the computer knows exactly how to interpret your instructions.

Languages

- Many different languages have been devised for people to communicate.
  - How many languages do you speak?
- Many different languages have been devised to communicate with computers.
  - How many can you name?
- Why do we need many languages?

Languages

- Each language provides a way of writing a kind of script along with rules for the computer to interpret the script as instructions.
- They can do very similar things, but some things are easier to say in some languages than in others.

Programming languages

- Thousands of different programming languages have been created.
  - E.g. Java, C, C++, Perl, Python, O'Caml, …
- Each has its own vocabulary.
  - Elements of the vocabulary can be combined to define new concepts.
- Each has its own syntax.
- Each language is good at describing different things.

A computer program

- Simplest definition of a program: "A sequence of instructions that a computer can interpret and execute".
- Is the following a computer program?
  "Predict the weather."
- No! As stated, it cannot be understood and therefore cannot be executed by the computer. It is an instruction written in English.
- With computers, it is important to be very precise!
  - What is the weather, for what location, during what time period, with what precision, ...

Recall 4 key steps of computing

- Input
- Output
- Calculate
- Memorize

Programming languages need to handle all these components.

A computer program

- In programming, need to deal with 2 kinds of things:

1. Data:
   - Input
   - Output
   - Intermediate

2. Procedures:
   - List of instructions.
   - Each instruction tells the computer to do something.
   - Instructions are ordered correctly.

A Recipe for Scrambled Eggs

- Ingredients:
  2 eggs, 1 tbsp oil
- Instructions:
  Step 1: Add oil to pan.
  Step 2: Heat pan on stove.
  Step 3: Crack 1st egg into pan.
  Step 4: Crack 2nd egg into pan.
  Step 5: Mix until light and cooked.
- Output:
  Scrambled eggs!

A recipe is a series of steps.
What if we did not follow the order? Would not get scrambled eggs!
Can we express this more generally?

Making Scrambled Eggs for 10

- Ingredients:
  20 eggs, 1 tbsp oil
- Instructions:
  Step 1: Add oil to pan.
  Step 2: Heat pan on stove.
  Step 3: Crack 1st egg into pan.
  Step 4: Crack 2nd egg into pan.
  …
  Step 22: Crack 20th egg into pan.
  Step 23: Mix until light and cooked.
- Output:
  Scrambled eggs for 10!

Another way of making eggs for 10

Repeat 10 times:

- Ingredients:
  2 eggs, 1 tbsp oil
- Instructions:
  Step 1: Add oil to pan.
  Step 2: Heat pan on stove.
  Step 3: Crack 1st egg into pan.
  Step 4: Crack 2nd egg into pan.
  Step 5: Mix until light and cooked.
- Output:
  Scrambled eggs!

Done repeating.

Making Scrambled Eggs for "N" people

- Ingredients:
  2*N eggs, 1 tbsp oil ← Introduce input **variable**, N
- Instructions:
  Step: Add oil to pan.
  Step: Heat pan on stove.
  Step: For i = 1 to 2*N ← Introduce a **loop**, with count **variable**, i
  Step: Crack i^{th} egg into pan. ← Repeat step, until count variable is done
  Step: End loop ← Terminate loop when counter reaches max
  Step: Mix until light and cooked.
- Output:
  Scrambled eggs for N !

Variables

- Variables are containers (in memory) for information that you want to store.
- The information you put in the variable is called its value.
- Putting a value in the container is called assigning a variable.
- When you write the variable name in a program, the variable name will be replaced by its value, whenever the computer gets to that point in the program. This is called accessing a variable.
- Variables can be reassigned values at different points in the program. (When that happens, the old value is lost.)

Naming variables (and functions)

- What names can we choose for our variables?
- Lots of possibilities! But it depends on the programming language.
- Avoid key words/characters that are used by the programming language to mean something specific.
  - E.g. “for” is used to denote a loop type, so can’t use it to name a variable!
  - Same for mathematical operators and most punctuation signs.
  - Can’t have a space (“ “) as part of the name, because spaces denote a change of word.

  These are just examples - specific rules change from one programming language to another.
- Good names: Bob, C3P0, The_cat_in_the_hat
- Bad names: 1*2, a-b, for, print, if, while

Types of variables

- Boolean / binary: Value can be 0 or 1.
  E.g. Bob = 0
- Integer: Value can be any whole number.
  E.g. Bob = 5
- Float: Value can be any real number (up to some pre-set precision).
  E.g. Bob = 1.3333333333
- Characters: Value can be any ASCII character.
  E.g. Bob = “p”
- Strings: Value is a sequence of characters.
  E.g. Bob = “Happy birthday!”

Worrying about types of variables

- The types listed in the previous slide are available in most programming languages. Other types are possible in some languages.
- Most languages require that the variable type be declared before the variable is assigned or accessed.

  E.g. Integer bob
  bob = 5
  bob = bob + 2
- Why is it useful to know the types of variables?

Worrying about types of variables

- The variable's type determines:
  - How much space is needed to store its value.
  - What operations can be applied to the variable.
- Some languages do not handle variable types (e.g. Scratch).
  - The language assumes all variables are of the same type.
  - Each variable is stored in a memory container of a fixed size.
- Some languages do not require type to be declared (e.g. Matlab).
  - The language will assume something about variable type.
  - The language will reserve a memory block according to the type it assumed.

Arithmetic Operations

- The arithmetic operators (+, -, *, /) are reserved for mathematical operations.

  Integer *x* <- Variable is declared.

  x = 5 <- Initial variable assignment.

  x = x+2 <- Variable is re-assigned.

- What happens if you skip the initial assignment step, ***x = 5*** ?
  - It depends on the programming language.
  - Usually, when x is declared (or first used), a memory block is set aside for it. The initial value of x will depend on what was in the memory block before! (Memory gets recycled.)
  - Remember to be precise! Don't forget to assign, if necessary.
- Most languages also accommodate logical operators (AND, OR, NOT) for logical variables.

Comparison Operators

- The comparison operators compare two values (numbers or variables).
- There are several comparison operators:

  < *less than*

  <= *less than or equal to*

  > *greater than*

  >= *greater than or equal to*

  == *equal to*

  != *not equal to*

Loops

- Syntax for telling the computer to repeat the same instruction many times.
- Example: Write a program to sum the numbers from 1 to K.

```
SumUpTo ( K )                 Program name "SumUpTo" with input variable "K"
n = 1                         Add new variable "n" to count from 1 to K
sum = 0                       Add new variable "sum" to store the intermediate sum
While n <= K                  Loop command "While", with the termination defined by comparison "n<=K"
        sum = sum + n         First instruction in the loop.
        n = n+1               Second instruction in the loop.
End loop                      Syntax requires that you specify which instructions go inside the loop
Return sum                    Return the final output.
```

- What if you want to print the intermediate results? Easy to do!

Comparing Loops

- Different types of loop:

```
SumUpTo ( K )
n = 1
sum = 0
While n <= K
        sum = sum + n
        n = n+1
End loop
Return sum
```

```
SumUpTo ( K )

sum = 0
For n = 1 to K
        sum = sum + n
End loop
Return sum
```

- Similar syntax, slightly different functionality. In this case, it does not matter, but in other cases, it might.
  - E.g. when the termination condition depends on something that is calculated within the loop.

Loop that quits when it reaches its goal

- Consider summing integers, until the sum reaches 100.

```
SumUpTo ( )
n = 1
sum = 0
While sum <= 100
        sum = sum + n
        n = n+1
End loop
Return sum
```

- Can we do the same thing for any target max value? Yes!

```
SumUpTo ( max )
n = 1
sum = 0
While sum <= max
        sum = sum + n
        n = n+1
End loop
Return sum
```

- This is much easier to do with a While loop than with a For loop.

Functions

```
SumUpTo ( K )
n = 1
sum = 0
While n <= K
        sum = Add (sum, n)
        n = n+1
End loop
Return sum
```

```
Add ( n1, n2)
 sum = n1 + n2
Return sum
```

- Here both SumUpTo(K) and Add(n1, n2) are examples of functions.
- Functions allow you to write re-usable code.
- When a function is called, the computer "jumps" to the body of the function to execute that block of code, then comes to where it left off.
- Functions can call other functions. E.g. SumUpTo() calls Add()

Functions

```
SumUpTo ( K )
n = 1
sum = 0
While n <= K
        sum = Add (sum, n)
        n = n+1
End loop
Return sum
```

```
Add ( n1, n2)
 sum = n1 + n2
Return sum
```

- Functions can take inputs (variables or constants). E.g. **K**, **n1**, **n2, 100.**
- Functions only know variables which are given as input, or defined inside the function.

  E.g. Add() does not know about variable n, only knows n1, n2, sum.
- Functions can return outputs.

Functions that call themselves

- A more compact way of summing up the first K integers:

```
SumUpTo ( K,  n, sum)
If  n < K
        sum = n + SumUpTo ( K, n+1, sum)
End if condition
Return sum
```

```
SumUpTo ( K,  sum)
If  K > 0
        sum = K + SumUpTo ( K-1, sum)
End if condition
Return sum
```

- New element here: **conditional statement**

Conditional statement

- Execute a block of code only **if** a certain statement is true.

General form:

```
If  some expression is true
        Do this.
Else
        Do that.
```


Generalizing some of these ideas

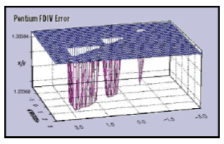
- You can have conditionals within loops, conditionals within functions, conditionals within conditionals, functions within loops, functions within conditionals, functions within functions, loops within loops, loops within functions, loops within conditionals ...
- Most examples we saw today deal with numbers. Many programs deal with other types of data, e.g. Strings, logical variables, etc.
  - Easy to declare variables of those types.
  - But: Need to be careful about how we use mathematical operators and comparison operators when dealing with these types of variables.

Is your program correct?

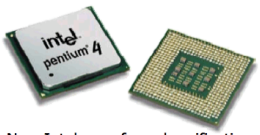
- Very important to have the correct program!
- Can you "check" for correctness of the program?
  - Need to check it works for all possible inputs (or types of inputs).
  - E.g. Check it won't loop forever. Check it won't set variables to wrong values.
- Substantial work in this area in software engineering.

Software verification

Correctness: Avoiding Bugs to Save Money and Lives

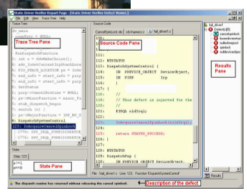


Intel Pentium FPU error



Now Intel uses formal verification.

Ariane 5 failure



Now Microsoft uses formal verification.

Throughout the software industry, roughly 90% of efforts goes to testing/ debugging and only 10% of efforts for programming.

Exercises

- What does this program do? What are the variables?

```
Input Number
Set Total = 0
Set Counter = 1
While Counter <= Number
        Input the next Grade
        Total = Total + Grade
        Counter = Counter + 1
Average = Total / Number
Output Average
```

- What about these two programs?

```
Input Hours                          Input Hours
Input Rate                           Input Rate
Input Type                           If Hours > 40
If Type = "Taxable"                          Pay = Rate * 40 + 1.5 * Rate * (Hours – 40)
    Tax = Price * Rate               Else
    Price = Price + Tax                      Pay = Rate * Hours
Output Price                         Output Pay
```

- Can you write a program that returns the maximum grade?

Take-home message

- Know the difference between **a programming language** and a **program**.
- Understand the need to be very precise when writing instructions for a computer.
- Realize that there are **different ways of instructing the computer to do the same thing**.
- Understand the basic concepts of programming: **variables, mathematical operators, comparison operators, loops, conditionals, functions.**

Reminder: Homework 3 posted today!