Programming key concepts

1

Programming?

- It may be (almost) impossible to solve a problem by executing commands at the command prompt.
- What is needed? A **sequence** of **precise instructions** that, once performed, will complete a **specific task**.
- Computer programs can't do that many things, they can:
  - Assign values to variables (memory locations).
  - Make decisions based on comparisons.
  - Repeat a sequence of instructions over and over.
  - Call subprograms.

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2

Why programming?

- Programming is an integral part of research:
  - Write small scripts,
  - Write complete projects,
  - Or need a good understanding of what a software package does
- All programming languages offer to a certain extend the same building blocks
  - Understand the basic building blocks
  - Decompose your problem to fit those blocks

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Programming language

- There are many programming languages, with changing popularity
- Check the Tiobe Index: https://www.tiobe.com/tiobe-index/
- Consider:
  - it is suited to the problem?
  - is there an active community?
  - is it any good for the job market?

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Key concepts in programming

- Check Isaac Computer Science: https://isaaccomputerscience.org/topics/programming_concepts?examBoard=all&stage=all
- Instructions / Basic **Syntax**
- **Data Types**
  - Classification of the type of data being stored or manipulated within a program.
  - Data types are important because they determine the operations that can be performed on the data.
- **Variables**
  - Named container, held by the computer in a memory location.
  - Has a unique identifier (name) that refers to a value.

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Key concepts in programming

- **Operators**
  - Arithmetic
  - Comparison
  - Logical
- **Input / Output**

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Key concepts in programming

- **Sequence**
  statements are written one after another, will be executed one statement at a time in the order that the statements are written in.
- **Selection**
  execute lines of code only if a certain condition is met.
- **Iteration (loop)**
  repeat a group of statements .
- **Subprogram (function)**
  is a named sequence of statements, can be repeatedly "called" from different places in the program

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Top-down

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Some thoughts

- http://www.walkingrandomly.com/?p=3586
- https://blogs.mathworks.com/loren/2014/01/29/coding-best-practices-a-good-read/
- https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001745

- *Correct and consistent is always better than faster* (Yair Altman – Accelerating Matlab Performance)

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Program design?

- Turn a problem statement into a programmable solution
- Be as clear as possible about what your program should do, apply formal techniques to design an appropriate program that fulfills or answers the problem
- Work incrementally
- Write concise programs
- Write clear programs
- Many different styles of techniques of program design exist: we stick with Top-Down design (structured programming)

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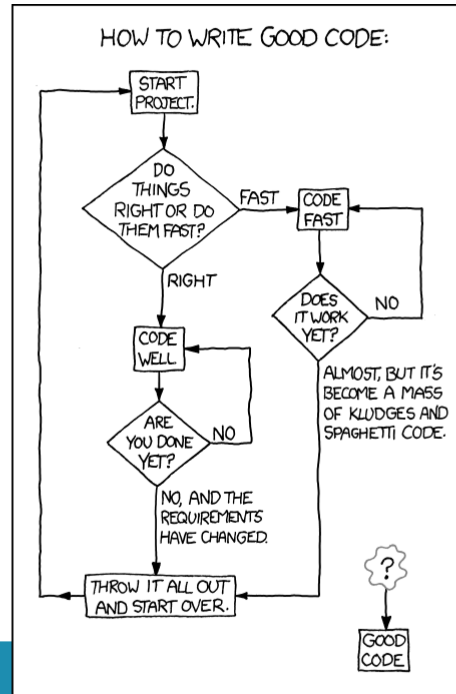
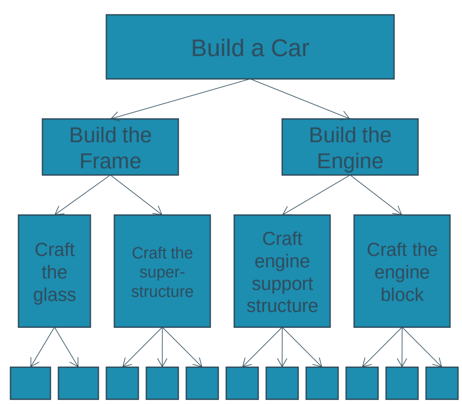
- http://www.explainxkcd.com/wiki/index.php?title=844#Explanation



What is Top-down design?

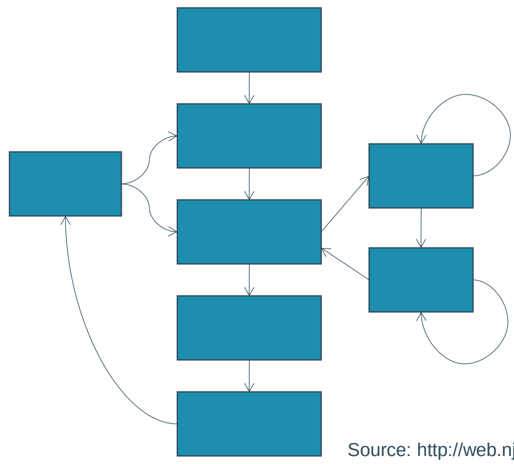
- Process of starting with a large task and breaking it into smaller tasks
- Smaller tasks can be divided into yet smaller pieces if useful
- Continue in this manner until each small task is clearly understood and achievable
- Note
  - Many different ways to divide each problem
  - Some divisions are better than others
  - Experience and practice can lead to better designs



Source: http://web.njit.edu/~djb38/cs101/

Steps in Top-down design

1. Problem Statement
2. Input and output definition
3. Algorithm design
   1. Decomposition
   2. Stepwise refinement
4. Conversion of algorithm to programming language statements
5. Test final solution



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Steps in Top-down design

1. Problem statement: understand the purpose of the problem.
2. Determine input/output you require.
   - What do you need to know?
   - Collect known data.
   - Some might later be found unnecessary
3. Develop conceptual model and draw a sketch.
   - Decomposition: simplify problem (enough) to enable it to be solved.
   - State any assumptions made.
   - Determine fundamental principles applicable. Set up mathematical model (logical plan if no mathematics).
   - Think generally about proposed solution approach and consider other approaches.

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Before coding

4. Put it in a programming language
   - What are the subprograms?
   - Which variables are needed in which subprogram?
   - In which order and under which conditions are subprograms called? …

- Advice:
  - Don’t write subprograms of more than one page
  - First part of a subprogram should check the input arguments
  - Functions are black boxes: their behavior should be clear to a user:
    Clearly specify inputs and outputs using "Pre-conditions" and "Post-conditions".
  - Make a sketch before writing to save time
  - Wait 2 days before writing

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Steps in Top-down design

5. Test!
   - Check dimensions and units.
   - Check solutions for a simple problem.
   - Perform a “reality check” on your answer.
     - Does it make sense?
     - Is the precision justified?
     - What does the mathematics tell you?
     - …

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Test and test

- Unit testing is key
  - Test each subdivided task to ensure it works correctly
  - Each small task is tested individually
- Combine subtasks into their larger composition
  - Repeat unit testing on this new subtask
- Continue until all subtasks are combined into a single “task” or program
- Find and fix bugs
  - Bugs are unexpected or inconsistent program behavior
  - Also includes logic errors or outputs that do not match based on inputs received.

Source: http://web.njit.edu/~djb38/cs101/

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When coding

- Functions specification (comments)
  - Pre-conditions specify:
    - the meaning of each of the input parameters
    - what kinds of data the input parameters are allowed to contain
    - constraints regarding when the function can be called
  - Post-conditions specify:
    - what values are guaranteed to be in the output parameters
    - the format (what kinds of data) of the output parameters
    - constraints that are guaranteed to be true of the output parameters
  - any side-effects that the function might have, e.g. input/output interaction with the user, plotting data etc.

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