A simple problem-solving approach

How to go from problem description to code

Terence Parr
MSDS program
University of San Francisco

BTW, This is an abbreviated version of what we normally talk about in data structures

UNIVERSITY OF SAN FRANCISCO

Overall process

1. Understand
2. Solve
3. Code (notice this is a separate step from #2)
4. Verify/test

1. Understand

- Read the description (3x) then restate the problem, either on paper or out loud (yes, I talk to myself in my office)
- Describe and write out a minimal but *representative* example of
  - the intended input data or data structure *and*
  - the expected output *and*
  - ask if the example is correct
- Identify any edge cases you can think of by example, but don't focus on those cases initially

act → *cat*
its → *sit*

UNIVERSITY OF SAN FRANCISCO

Reading problem descriptions

- Details matter, pay careful attention to the description
  - Pretend that someone is trying to trick you with the problem description!
  - Are the input data elements strings, ints, floats?
  - If data is numeric, are they always between 0 and 1? Can they be negative?
  - Is the input sorted?
  - Can you see all of the data at once or must you worry about streaming data?
  - Can you bound the maximum size of the input (e.g., to fit in memory)?
- When reading description, identify who is doing what to whom?
  - What are the nouns and verbs used in the description?
  - The nouns are usually data sources or data elements
  - The verbs are often operations you need to perform
  - Look for keywords like min, max, average, median, sort, argmax, sum, find, search, collect, filter out, select, compute, etc...

2. Solve

Key ideas for solving problems

- Solving the problem has nothing to do with the computer
- You might not even be asked to code the solution
- If you can't walk through a correct sequence of operations **by hand** on paper, no amount of coding skill will help you!
- All the good programmers I know keep a notepad next to their computers, and it is full of boxes, bubbles, arrows, and notes
- It helps to use established **patterns**, templates, strategies, and common data transformation operations as a crutch

Strategies for solving problems

1. *Start with the end result and work your way backwards*
   - Ask what the prerequisites are for each step
   - The processing step or steps preceding step *i* compute the data or values needed by step *i*
   - E.g., median: to pick middle value, previous step must sort data
2. *Reduce or simplify a new problem to a variation of an existing problem with a known solution*
   - Ask what the difference is between the problem you're trying to solve and other problems for which you have a solution
   - E.g., Engineers building a new suspension bridge do not proceed as if such a thing has never been built before

Requisite mathematician joke

“*A physicist and a mathematician are sitting in a faculty lounge. Suddenly, the coffee machine catches on fire. The physicist grabs a bucket and leaps towards the sink, fills the bucket with water, and puts out the fire.*

Second day, the same two sit in the same lounge. Again, the coffee machine catches on fire. This time, the mathematician stands up, gets a bucket, hands the bucket to the physicist, thus, reducing the problem to one with a known solution.”

Steps in “solve” phase

A. Explore

- Look at the input-output example and imagine how you can manually operate on the input to get the output (using fingers on paper)
- Attempt any manual sequence of operations that appears to be in the right direction, even if you know it's not quite right
- Exploration helps you understand the problem and will trigger more questions, so ask questions
- Write down what you know; e.g., in a geometry problem, you might know which angles or arcs are the same length or that you can make two triangles out of the given rectangle by drawing a line

Steps in “solve” phase continued

B. **Reduce**
   - Can you reduce the problem to known solution by preprocessing the input a bit?

C. **Reuse**
   - Look for and reuse familiar programming patterns like vector sum, min, sort, map, filter, and find
   - E.g., to sort a list of numbers (slowly), repeatedly pull then delete the minimum value out of one array and add it to the end of another.

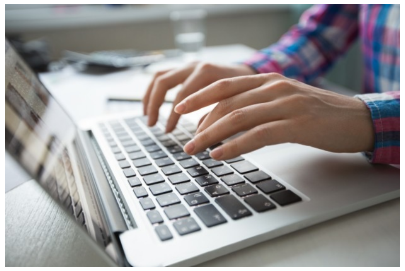
D. **Systematize**
   - Simplify and organize the steps in your process as pseudo-code
   - This is your algorithm

Steps in “solve” phase

E. Verify algorithm / process

- Check that your algorithm solves the main problem and the edge cases.
- Later, when you have more experience, you will need to check your algorithm's complexity (performance as function of input size)

3. Translate your algorithm to code



A. Write a function that takes your input as parameter(s)
   - Return value of function will typically be the expected problem result

B. Write a main script that:
   - acquires the data
   - passes it to your function
   - sends the results to the appropriate file or standard output

C. Translate the algorithm steps into statements in your function (It's okay if you create helper functions)

4. Verify/test

- Test your code on the representative examples you identified early on in this process
- Now, try some edge cases, which will likely break your code
- Go back to the algorithm and process design phase and alter it to handle the edge cases
- Translate the changes to code
- Verify that you did not break the representative examples and then test on the edge cases

Unit tests

- In a job situation, you'd encode these tests as "unit tests"
- These tests are reproducible and should check edge cases, representative examples, and examples that should fail or cause exceptions
- All code changes over time, which can introduce bugs
- These tests are your primary line of defense against the introduction of bugs in working code (so-called "regressions")
- This is the difference between an amateur and a professional programmer; you cannot safely change code without tests that check the sanity of your system
- For machine learning scripts that just develop models, this might be less true, but it is very true for large or complex systems