How to THINK like a Programmer

Problem Solving for the Bewildered

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chapter 4

choices and repeated actions

Purpose

- This chapter is all about applying the problem solving strategy to problems that involve making choices and repeating things
  - High-level control abstractions: sequence, selection, iteration
  - Evaluating solutions

Making coffee

- Last chapter's coffee making problem:
  - Using an electric filter machine (also called a percolator) make a pot of coffee and pour a cup
- We need to apply the strategy (chapter 2) to work up a solution.
- First three steps of the strategy:
  - Understanding the problem
  - Devising a plan to solve the problem
  - Carrying out the plan
- Here is a worked through application of the strategy

A diagram

- First, a sketch of the problem and its parts

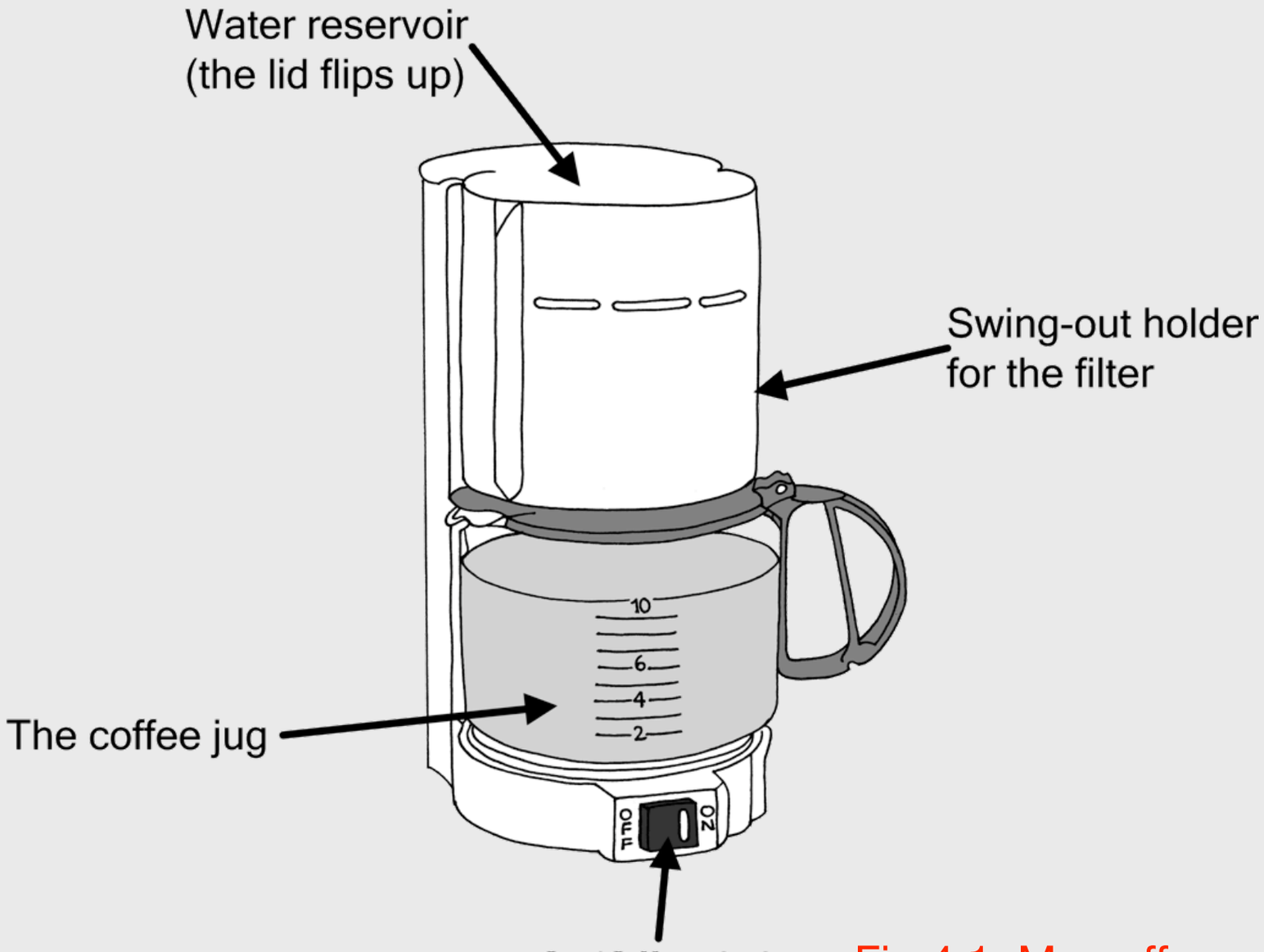


Fig 4.1: My coffee machine

Understanding the problem

Q. What are you being asked to do?

- I need to make a pot of coffee and pour a cup.

Q. What is required?

- A cup of coffee.

Q. Is that all that is required?

- I think that before I can get a cup of coffee I need the machine's jug to have enough coffee to pour into the cup.

Q. What is the unknown?

- How much coffee to make. I need to pour a cup, but I also have to make a pot. How much is a pot? Does it mean a whole pot, or just enough coffee to fill one cup?

Understanding the problem

Q. Can the problem be better expressed by drawing a diagram or a picture?

- I do not know. Looking at Figure 4.1 I can see the jug probably holds more coffee than the cup.

Q. What are the principal parts of the problem

- 1) Make a pot of coffee. 2) Pour a cup. Or, looking at it another way: 1) The filter machine, 2) the cup, 3) the coffee, 4) some water, 5) the cup of coffee — is there just coffee in it, or milk and sugar as well?

Q. Have you made any assumptions?

- Well, I have assumed that the jug holds more than one cupful of coffee. That is not always the case — you can buy single-cup filter machines.

Understanding the problem

Q. What can you do about the assumptions?

- I could ask the person who wants me to make the coffee what size coffee machine to use.

- Now we have a good understanding of the problem and the issues it raises.
- Remember, you can always come back to step 1 later on

Devising a plan

Q. Have you solved this problem before/is it similar to one you have solved before?

- In the context of this book, the answer must be ‘no’.

Q. Are some parts of the problem more easily solved than others?

- Yes. Pouring the coffee is easy. Adding the water and the coffee grounds requires some thought as to how much to add. After pouring the coffee I do not know if anything else is needed (e.g. milk and sugar).

Q. Does restating the problem help? Try restating it in a different language.

- I do not think that applies here. It is not a weird logical problem, or one that requires a puzzle to be solved. Mind you, the picture of the coffee machine does clarify the main parts of the problem.

Devising a plan

Q. Did you make use of all the information in the problem statement?

- Yes, I think so. In fact, the statement seems to be incomplete as I do not know how much coffee to make or whether milk and sugar are needed.

Q. Can you satisfy all the conditions of the problem?

- If I make some assumptions, yes. Without any further information I have to define what is meant by ‘pot of coffee’ (how much is in a pot) and what constitutes pouring a cup — is it just pouring out the coffee, or is it also adding milk or sugar?

Q. Have you left anything out?

- No, I do not think so; I seem to have gleaned all the information I can from the statement.

Carrying out the plan

- Here we have to "write down the basic sequence of actions necessary to solve the general problem". We should do this using the pseudo-code notation introduced in the last chapter

1. Put water in coffee machine ;
2. Open the coffee holder ;
3. Put filter paper in machine ;
4. Measure coffee for one cup ;
5. Put coffee into filter paper ;
6. Shut the coffee holder ;
7. Turn on machine ;
8. Wait for coffee to filter through ;
9. Pour coffee into mug ;
10. Turn off machine ;

An underlined action is based on an assumption that needs resolving

Reflection

- Why 10 steps in the sequence?
- Is the assumption valid that only enough coffee for one cup should be made?
- What assumption underlies task #3?
- Task #1: how much water?
- Any other hidden assumptions?
- When should the machine be switched off? Try this:

```
10.  When jug empty turn off machine ;
```

- New task #10 implies a decision to be made about when to turn off the machine

Making choices

- Step #3 of the strategy asks whether all actions should be carried out in every circumstance, or should some actions/groups of actions be carried out only when certain conditions are met?
- It is very common for solutions to problems to include some decision-making. Consider the extended coffee-making problem:
  - Using an electric filter machine (also called a percolator) make a pot of coffee and pour a cup for a guest. Add sugar and cream/ milk as required.
- Problem now contains some explicit decisions to be made
  - Add sugar? Add cream?

ACTIVITY

Write out a new solution to include this extra milk/ sugar requirement

Solution as a sequence

1. Put water in coffee machine ;
2. Open the coffee holder ;
3. Put filter paper in machine ;
4. Measure coffee for one cup ;
5. Put coffee into filter paper ;
6. Shut the coffee holder ;
7. Turn on machine ;
8. Wait for coffee to filter through ;
9. **Add sugar ;**
10. **Add milk/cream ;**
11. Pour coffee into mug ;
12. Stir coffee ;
13. Turn off machine ;

- Now we need to put in the decision making (tasks #9, #10)

Solution with decisions


```
1.  Put water in coffee machine ;
2.  Open the coffee holder ;
3.  Put filter paper in machine ;
4.  Measure coffee for one cup ;
5.  Put coffee into filter paper ;
6.  Shut the coffee holder ;
7.  Turn on machine ;
8.  Wait for coffee to filter through ;
9.  IF (sugar required)
        9.1.  Add sugar ;
    ENDIF
10. IF (white coffee required)
        10.1. Add milk/cream ;
    ENDIF
11. Pour coffee into mug ;
12. Stir coffee ;
13. Turn off machine ;
```

The IF construct

- We show decisions with the IF selection construct

Case 1

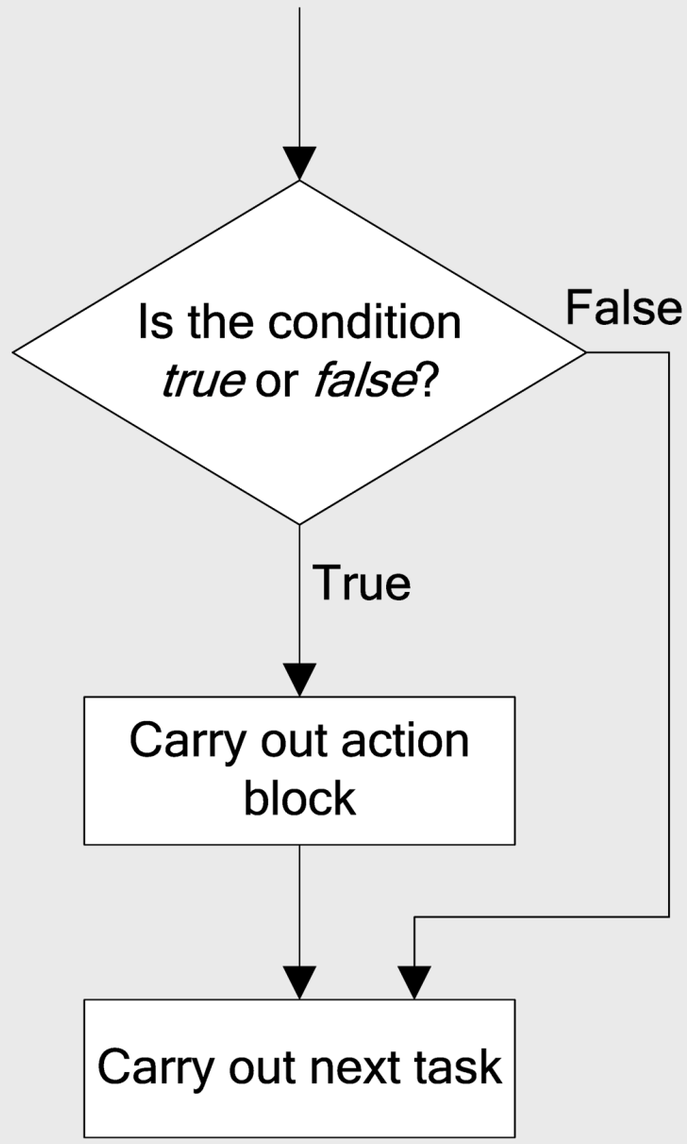
```
IF (condition)
   Action 1 ;
   Action 2 ;
ENDIF
```

Action #2 carried out only when the condition is true

Case 2

```
IF (condition)
   Action 1 ;
ENDIF
Action 2 ;
```

Action #2 always carried out



ACTIVITY

Before you leave home in the morning you check to see whether it is raining; if it is you take an umbrella with you. Write an `IF…ENDIF` construct that shows this decision-making process

Write an `IF…ENDIF` construct that adds a 10% tip to a restaurant bill and compliments the chef if the service was of a high standard. After the `ENDIF` add a statement to pay the bill. Convince yourself that the tip is only added when good service is received

Get a friend/person sitting next to you to evaluate your solutions

Repeated actions

- What if more than 1 spoon of sugar is required? We need to repeat the task of adding sugar
- If two sugars required we *could* do this:

```
IF (sugar required)
   Add spoonful of sugar ;
ENDIF
IF (more sugar required)
   Add spoonful of sugar ;
ENDIF
```

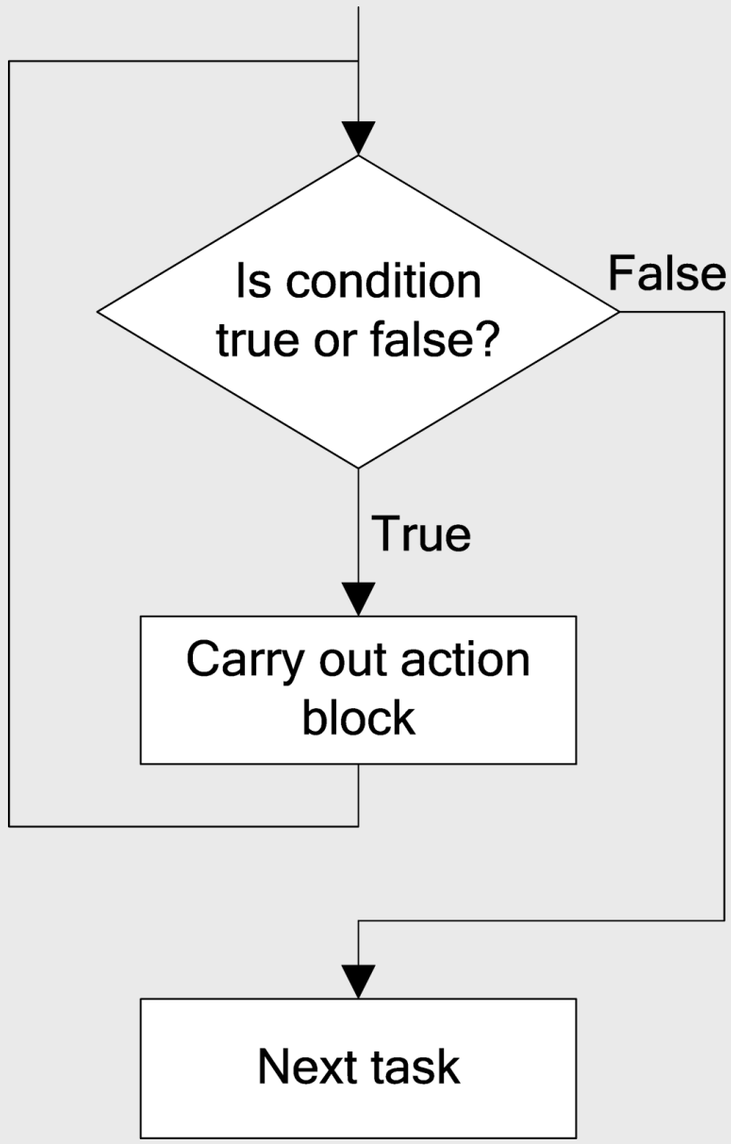
- But what is wrong with this approach?
  - We need to find out once how much sugar is required then repeatedly add a spoon of sugar until the required amount has been added

The WHILE construct


```
WHILE (condition is true)
   Action 1 ;
ENDWHILE
Next task ;
```

Or, with multiple actions:

```
WHILE (condition is true)
   Action 1 ;
   Action 2 ;
   ...
   Action n ;
ENDWHILE
Next task ;
```



ACTIVITY

Write a `WHILE` loop to handle adding sugar to the coffee. Remember to close the action block with an `ENDWHILE`

Solution


```
8.  Wait for coffee to filter through ;
9.  WHILE (sugar required)
        9.1   Add spoonful of sugar ;
    ENDWHILE
10. IF (white coffee required)
        10.1   Add milk/cream ;
    ENDIF
11. Pour coffee into mug ;
```

- Need to found out how many sugars required...

Adding sugar


```
Find out how many sugars required ;
WHILE (sugars added not equal to number
required)
    Add spoonful of sugar ;
    Add 1 to number of sugars added ;
ENDWHILE
```

- In the above `WHILE` loop, why is there a statement to add 1 to the number of sugars added?

Updated solution


```
1.  Put water in coffee machine ;
2.  Open coffee holder ;
3.  Put filter paper in machine ;
4.  Measure coffee for one cup ;
5.  Put coffee into filter paper ;
6.  Shut the coffee holder ;
7.  Turn on machine ;
8.  Wait for coffee to filter through ;
9.  Find out how many sugars required ;
10. WHILE (sugars added not equal to number required)
        10.1  Add spoonful of sugar ;
        10.2  Add 1 to number of sugars added ;
    ENDWHILE
11. IF (white coffee required)
        11.1 Add milk/cream ;
    ENDIF
12. Pour coffee into mug ;
13. Stir coffee ;
14. Turn off machine ;
```

Reflection

- Should all actions be carried out in every circumstance? Should some actions (or groups/blocks of actions) only be carried out when certain conditions are met?
- Is carrying out each action once only sufficient to give the desired outcome? If not, do you have actions (or groups/blocks of actions) that must therefore be repeated?
- Do any actions/blocks of actions belong inside others? For example, do you have a block of actions that must be repeated, but only when some condition is met?

Assess the result

- To make sure the solution produces the correct results.
- To make sure that it produced the results in a sensible and efficient manner.

ACTIVITY

Write down a few different orderings of the first eight actions of the solution. Are any tasks dependent on other tasks happening first? When do we ask the guest if he/she wants sugar? When do we ask him/her if milk/cream is wanted?

Is there a more efficient way to interact with the guest?

Final coffee solution

1. Put water in coffee machine ;
2. Open coffee holder ;
3. Put filter paper in machine ;
4. Measure coffee for one cup ;
5. Put coffee into filter paper ;
6. Shut the coffee holder ;
7. Turn on machine ;
8. Wait for coffee to filter through ;
9. **Find out how many sugars required ;**
10. **Find out whether milk required ;**
11. WHILE (sugars added not equal to number required)
    11.1 Add spoonful of sugar ;
    11.2 Add 1 to number of sugars added ;
    ENDWHILE
12. IF (white coffee required)
    12.1 Add milk/cream ;
    ENDIF
13. Pour coffee into mug ;
14. Stir coffee ;
15. Turn off machine ;

ACTIVITY

Compare the first solution with the last one. Can you explain the differences?

end of chapter 4