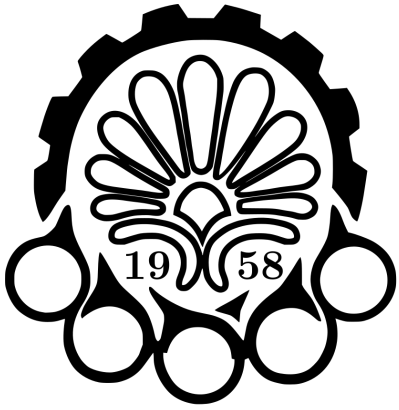
Embedded Systems

Prof. Sedighi



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Homework 11

Chapter 16 - Quantitative Analysis

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Question 2

Consider the program given below:

```
1  void testFn(int *x, int flag)
2  {
3      while (flag != 1)
4      {
5          flag = 1;
6          *x = flag;
7      }
8      if (*x > 0)
9          *x += 2;
10 }
```

In answering the questions below, assume that `x` is not `NULL`.

(a) Draw the control-flow graph of this program. Identify the basic blocks with unique IDs starting with 1.

Soloution

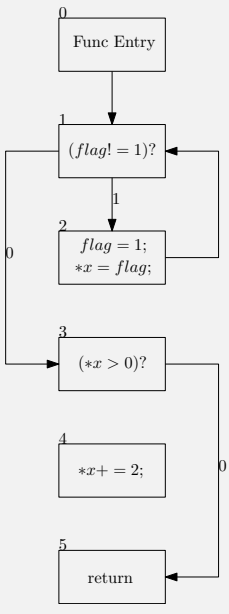

Figure 1: Control-flow graph of Q3

Note that we have added a dummy source node, numbered 0, to represent the entry to the function. For convenience, we have also introduced a dummy sink node, although this is not strictly required.

(b) Is there a bound on the number of iterations of the while loop? Justify your answer.

Soloution

Yes, given that if the condition is true, `flag` will be set to 1, the `while` loop will therefore iterate at most once.

(c) How many total paths does this program have? How many of them are feasi ble, and why?

Soloution

"The program has 4 paths (two for the while loop and two for the if statement). If the program enters the while loop, the value of `*x` will be set to 1, thus one of the if conditions after the while loop will not be reachable. Therefore, it can be concluded that there are 3 reachable states."

(d) Write down the system of flow constraints, including any logical flow con straints, for the control-flow graph of this program.

Soloution

$$x_0 = 1$$
$$x_1 = 2$$
$$x_1 = d_{12} + d_{13}$$
$$x_2 = 1$$
$$x_2 = d_{12} = d_{21}$$
$$x_3 = d_{13} = d_{34} + d_{35}$$
$$x_4 = d_{34} = d_{45}$$
$$x_5 = d_{35} + d_{45}$$

(e) Consider running this program uninterrupted on a platform with a data cache. Assume that the data pointed to by `x` is not present in the cache at the start of this function.

For each read/write access to `*x`, argue whether it will be a cache hit or miss. Now, assume that `*x` is present in the cache at the start of this function. Iden tify the basic blocks whose execution time will be impacted by this modified assumption.

Soloution

The topic of write-allocate versus no-write-allocate is not mentioned, so the more common write-allocate is considered. In this case, if the while loop executes, the first miss will occur at `ID=2`, and after that, it will be a hit. If the while loop does not execute, the first miss will occur at `ID=3`, and after that, it will be a hit. If a block containing `*x` is in memory, the two mentioned `IDs` will execute faster.

Question 3

Consider the function `check_password` given below that takes two arguments: a user ID uid and candidate password `pwd` (both modeled as `ints` for simplicity). This function checks that password against a list of user IDs and passwords stored in an array, returning 1 if the password matches and 0 otherwise.

(a) Draw the control-flow graph of the function `check_password`. State the num ber of nodes (basic blocks) in the CFG. (Remember that each conditional statement is considered a single basic block by itself.)

Also state the number of paths from entry point to exit point (ignore path feasibility).

Soloution

(b) Suppose the array `all_pwds` is sorted based on passwords (either increasing or decreasing order). In this question, we explore if an external client that calls `check_password` can *infer anything about the passwords* stored in `all_pwds` by repeatedly calling it and *recording the execution time* of `check_ password`. Figuring out secret data from "physical" information, such as running time, is known as a *side-channel attack*. In each of the following two cases, what, if anything, can the client infer about the passwords in `all_pwds`?

- The client has exactly one (uid, password) pair present in `all_pwds`
- The client has NO (uid, password) pairs present in in `all_pwds`

Assume that the client knows the program but not the contents of the array `all_pwds`

Soloution

End of Homework 11