ETH zürich

Exercise Session W06

Computer Science (CSE) – AS 23

Overview

Today's Agenda

Follow-up
Feedback on **code** expert
Objectives
PRE and POST
Functions
Exam Question
Stepwise Refinement
Outro

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1. Follow-up

Follow-up

- What is *Binary Expansion*?
  - This[1]
- When you ask me questions during the session, please make sure to also send me a follow-up e-mail so I know your name and can answer before the next session

[1] https://lec.inf.ethz.ch/math/informatik_cse/2023/slides/lecture5.en.handout.pdf

2. Feedback on **code** expert

General things regarding **code** expert

- Please don't write past the gray line
  - Just use multi-line comments
- There's almost always a better approach; don't feel bad if you didn't get it the first time
- `n = n+1` and `n += 1` are not very idiomatic for C++, use `n++` instead
- *Magic Numbers*[2] must be explained
- Feel free to delete the `<Insert your answer here, within the comment block>` when answering questions

[2] `https://en.wikipedia.org/wiki/Magic_number_(programming)`

General things regarding **code** expert

- Almost all the submissions were way wordier than needed
- What $\neq$ How
  - When asked *what* a code snippet does, don't explain *how* it does it
  - Hint: If you're mentioning variable names, you're probably not describing *what* something does but *how*
- If there were multiple similar exercises, extensive feedback was given to only one of them
- No feedback $\Longrightarrow$ Well done
- I can make changes/suggestions to your code and you're able to see it

Questions?

3. Objectives

Objectives

- ☐ Be able to write good PRE and POST conditions
- ☐ Be able to solve tasks using *Stepwise Refinement*

4. PRE and POST

PRE and POST Conditions

```
// PRE:  describes accepted input
// POST: describes expected output
int yourfunction(int a, int b){
    ...
}
```

PRE and POST Conditions

Questions

What would be sensible conditions here?

```
// PRE:
// POST:
double area(double height, double lenght){
    return height*lenght;
}
```

They don't have to be very detailed but they have to describe what the function expects and what will be returned *if* the provided input matches the expectations

Questions?

5. Functions

PRE and POST Conditions I

Find sensible PRE and POST conditions for this function

```
// PRE:  ???
// POST: ???
double f(double i, double j, double k){
    if(i > j){
        if(i > k){return i;}
        else {return k;}
    } else {
        if(j > k){return j;}
        else {return k;}
    }
}
```

PRE and POST Conditions I (Solution)

Possible Solution

```
// PRE:  (not needed)
// POST: return value is maximum of {i, j, k}
double f(double i, double j, double k){
    if(i > j){
        if(i > k){return i;}
        else {return k;}
    } else {
        if(j > k){return j;}
        else {return k;}
    }
}
```

PRE and POST Conditions II

Find sensible PRE and POST conditions for this function

```
// PRE:  ???
// POST: ???
double g(int i, int j){
    double r = 0.0;
    for(int k = i; k <= j; k++){
        r += 1.0 / k;
    }
    return r;
}
```

PRE and POST Conditions II (Solution)

Possible Solution

```
// PRE:  0 not in [i, j] and i <= j <= INT_MAX
// POST: return value is the sum 1/i + 1/(i+1) + ... + 1/j
double g(int i, int j){
    double r = 0.0;
    for(int k = i; k <= j; k++){
        r += 1.0 / k;
    }
    return r;
}
```

Output?

```
int f(int i){
    return i * i;
}

int g(int i){
    return i * f(i) * f(f(i));
}

int h(int i){
    std::cout << g(i) << "\n";
}
// ...
```

```
// ...
int main(){
    int i;
    std::cin >> i;
    h(i);
    return 0;
}
```

What is the output going to be (ignoring possible over- and underflows)? **Solution**: i^7

Bug hunt

```
double f(double x){
    return g(2.0 * x);
}

double g(double x){
    return x % 2.0 == 0;
}

double h(double x){
    std::cout << result;
}
// ...
```

```
// ...
int main(){
    double result = f(3.0);
    h();

    return 0;
}
```

Find 3 mistakes in this program.

Bug hunt (Solution)

1. `g()` is not yet known to `f()`, since scope of `g()` starts later
2. There's no `%`-operator for `double`
3. `h()` does not "see" the variable `result`, since it is not in its scope

Number of Divisors

Write a function `number_of_divisors` which takes an `int n` as argument and returns the number of divisors of n (including 1 and n)

```
// PRE:  0 < n < MAX_INT
// POST: returns number of divisors of n (incl. 1 and n)
unsigned int number_of_divisors(int n){
    // ...
}
```

Example
6 has 4 divisors, namely $1, 2, 3, 6$

Number of Divisors (Solution)

```
// PRE:  0 < n < MAX_INT
// POST: returns number of divisors of n (incl. 1 and n)
unsigned int number_of_divisors(int n){
    assert(n > 0);
    unsigned int counter = 0;

    for (int i = 1; i <= n; ++i){
        if(n % 1 == 0){
            counter++;
        }
    }

    return counter;
}
```

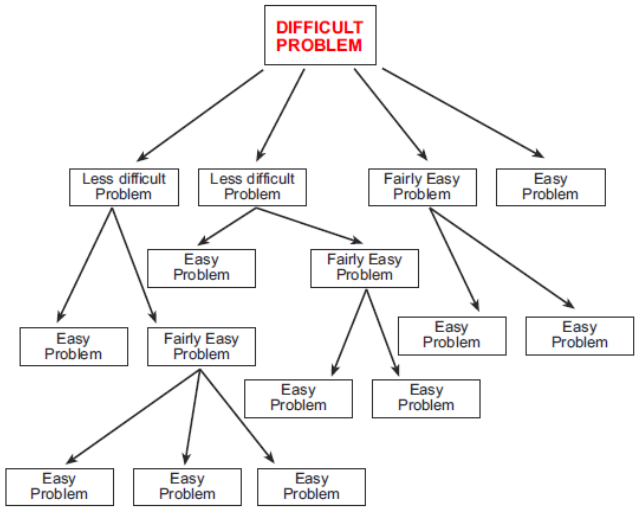
Questions?

6. Exam Question

Very Exam Relevant!

- This is a real exam exercise from 2022
- Open the exercise “[Exam 2022.02 (MAVT + ITET)] Decimal to arbitrary base” on **code** expert
- Discuss your approach with your neighbours
- Solve the exercise

7. Stepwise Refinement


DIFFICULT PROBLEM
Less difficult Problem
Less difficult Problem
Fairly Easy Problem
Easy Problem
Easy Problem
Fairly Easy Problem
Easy Problem
Fairly Easy Problem
Easy Problem
Easy Problem
Easy Problem
Easy Problem
Easy Problem
Easy Problem
Easy Problem

Stepwise Refinement

Code Example “Perfect Numbers” on **code** expert

Write a program that counts how many perfect numbers exist in the range $[a, b]$. Please use stepwise refinement to develop a solution to this task that is divided into meaningful functions. We provide a function `is_perfect` in `perfect.h` that checks if a given number is perfect.

A number $n \in \mathbb{N}$ is called perfect if and only if it is equal to the sum of its proper divisors. For example:

- $28 = 1 + 2 + 4 + 7 + 14$ is perfect
- $12 \neq 1 + 2 + 3 + 4 + 6$ is not perfect

Stepwise Refinement

- *Don’t start right away*
- Identify the easier subproblems
- What subproblems were you able to identify?

“Problem Tree”

How many perfect numbers are there?

Solution “Perfect Numbers”

```
// PRE:
// POST:
bool is_perfect(unsigned int number) {
  unsigned int sum = 0;
  for (unsigned int d = 1; d < number; ++d) {
    if (number % d == 0) {
      sum += d;
    }
  }
  return sum == number;
}
```

Solution “Perfect Numbers”

```
#include <iostream>
#include "perfect.h"

// PRE:
// POST:
unsigned int count_perfect_numbers(unsigned int a, unsigned int b) {
  unsigned int count = 0;
  for (unsigned int i = a; i <= b; ++i) {
    if (is_perfect(i)) {
      count++;
    }
  }
  return count;
}

...
```

Solution “Perfect Numbers”

```
...

int main () {
  // input
  unsigned int a;
  unsigned int b;
  std::cin >> a >> b;

  // computation and output
  unsigned int count = count_perfect_numbers(a, b);

  // output
  std::cout << count << std::endl;

  return 0;
}
```

Questions?

8. Outro

General Questions?

Till next time!

Cheers!