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Lab for Systems Analysis and VErification (SAVE)

Assisting Students in Finding Their Own Bugs in Programming Exercises using Verification and Group Testing Techniques

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http://prove.somee.com/slide.pdf

Outline

1. **Student Program Correctness Problem**

2. **Our approach**

3. **Framework**

4. **How it works**

5. **Case study**

6. **Experiment**

7. **Issues & Future works**

1. Student Program Correctness Problem

- Traditional method: read all programs to verify

  ⇒ 999 999 999 LOC ?

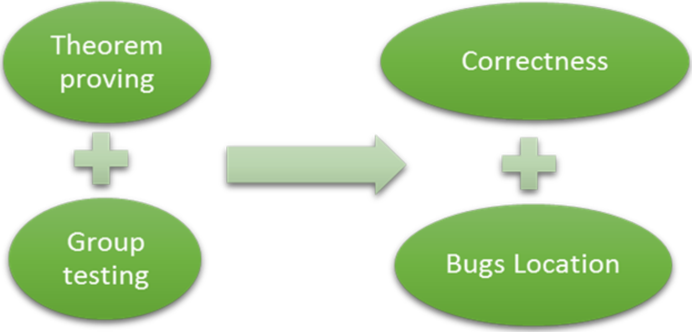
- Automated assessment system: execute, pass all test cases

  ⇒ test suite cover all possible errors ?

  ⇒ real execution is potentially dangerous for the system ?

2. Our approach

- Static methods & Automation


Theorem proving

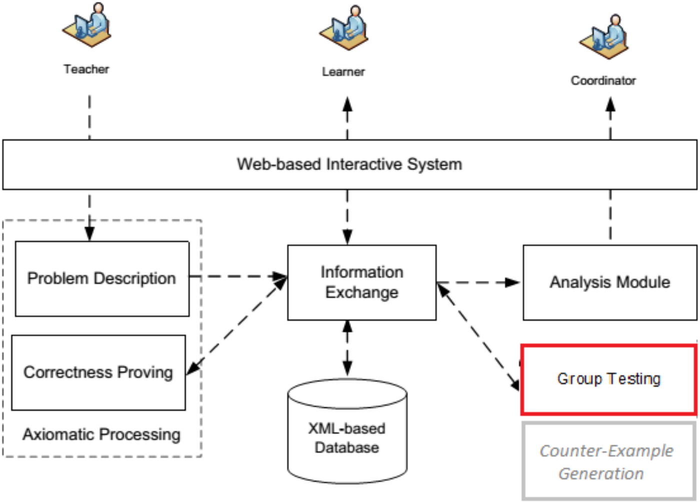
Group testing

Correctness

Bugs Location

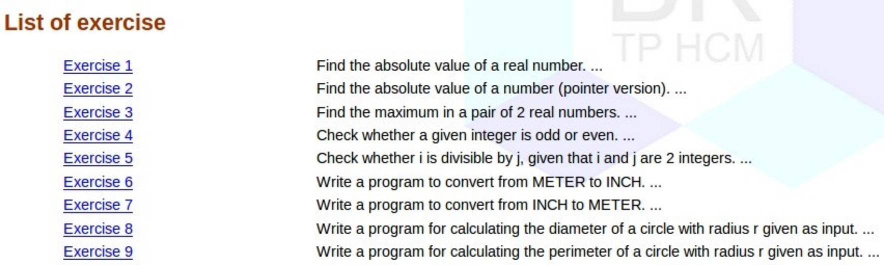
3. Framework

Verification and Group Testing Techniques



Verification and Group Testing Techniques

- Exercise list



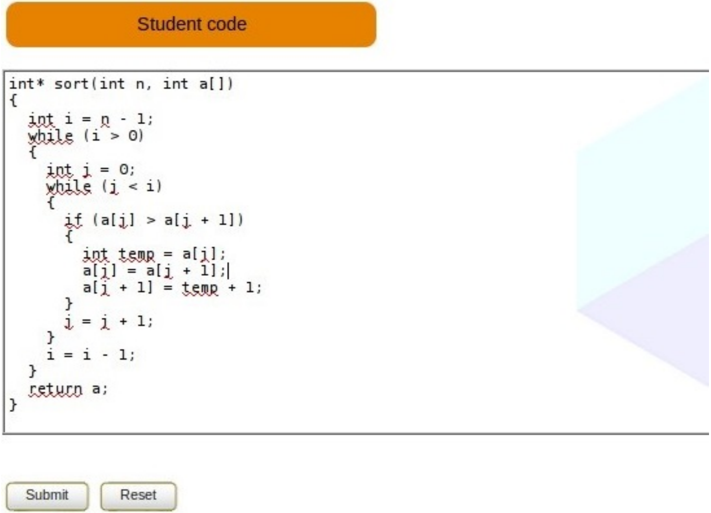
List of exercise

Exercise 1	Find the absolute value of a real number. ...
Exercise 2	Find the absolute value of a number (pointer version). ...
Exercise 3	Find the maximum in a pair of 2 real numbers. ...
Exercise 4	Check whether a given integer is odd or even. ...
Exercise 5	Check whether i is divisible by j, given that i and j are 2 integers. ...
Exercise 6	Write a program to convert from METER to INCH. ...
Exercise 7	Write a program to convert from INCH to METER. ...
Exercise 8	Write a program for calculating the diameter of a circle with radius r given as input. ...
Exercise 9	Write a program for calculating the perimeter of a circle with radius r given as input. ...

Verification and Group Testing Techniques

- Bubble sort problem

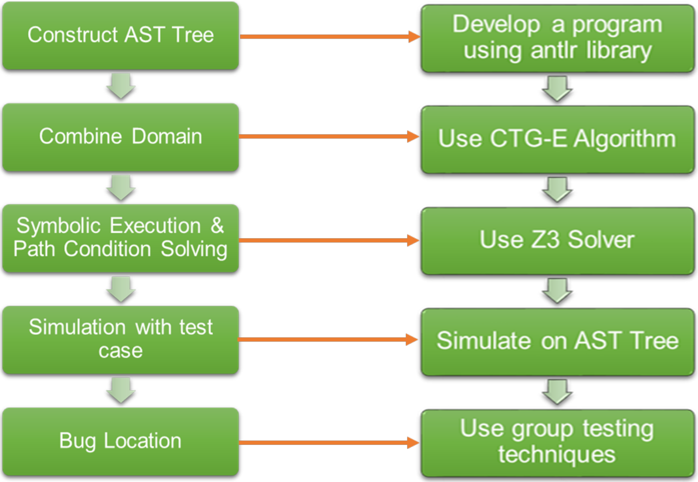
Verification and Group Testing Techniques



```
int* sort(int n, int a[])
{
  int i = n - 1;
  while (i > 0)
  {
    int j = 0;
    while (j < i)
    {
      if (a[j] > a[j + 1])
      {
        int temp = a[j];
        a[j] = a[j + 1];
        a[j + 1] = temp + 1;
      }
      j = j + 1;
    }
    i = i - 1;
  }
  return a;
}
```

4. How it works

Verification and Group Testing Techniques


Construct AST Tree

Combine Domain

Symbolic Execution & Path Condition Solving

Simulation with test case

Bug Location

Develop a program using antlr library

Use CTG-E Algorithm

Use Z3 Solver

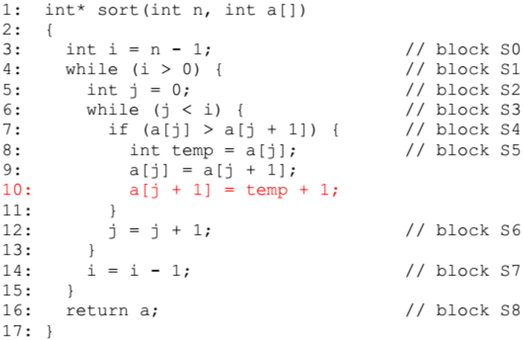
Simulate on AST Tree

Use group testing techniques

5. Case study

Verification and Group Testing Techniques

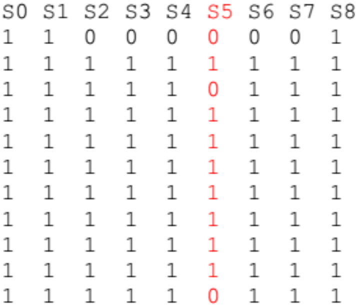
- Bubble sort algorithm with the 10th line is logically wrong
- The 10th line belongs to block S5 ⇒ S5 is expected as the error block.



```
1:  int* sort(int n, int a[])
2:  {
3:    int i = n - 1;                        // block S0
4:    while (i > 0) {                       // block S1
5:      int j = 0;                          // block S2
6:      while (j < i) {                     // block S3
7:        if (a[j] > a[j + 1]) {            // block S4
8:          int temp = a[j];                // block S5
9:          a[j] = a[j + 1];
10:         a[j + 1] = temp + 1;
11:       }
12:       j = j + 1;                        // block S6
13:     }
14:     i = i - 1;                          // block S7
15:   }
16:   return a;                             // block S8
17: }
```

Verification and Group Testing Techniques

- The testing matrix for above program has 1343 rows and 51 columns
- Loop structure ⇒ compact testing matrix to 11 rows and 9 columns
- The test outcome after running test cases is {0 1 0 1 1 1 1 1 1 1 0}



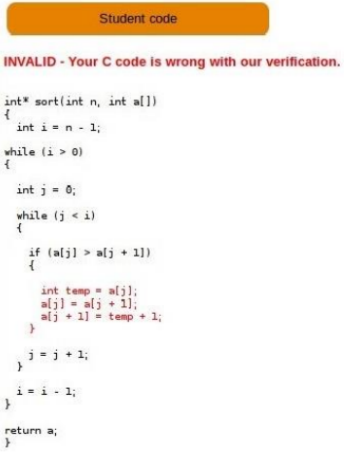
S0	S1	S2	S3	S4	S5	S6	S7	S8
1	1	0	0	0	0	0	0	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	1	1

Verification and Group Testing Techniques

- The error block is highlighted with red color

  ⇒ programmer can easily know where the problem is and fix it without too much effort.

Verification and Group Testing Techniques



INVALID - Your C code is wrong with our verification.

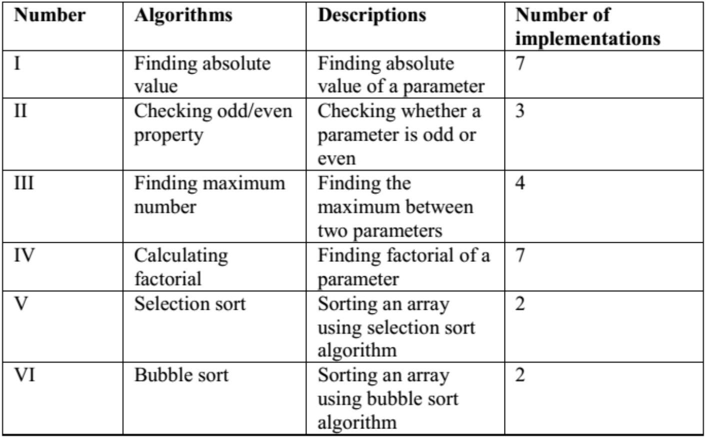
```
int* sort(int n, int a[])
{
  int i = n - 1;

while (i > 0)
{

  int j = 0;

  while (j < i)
  {

    if (a[j] > a[j + 1])
    {

      int temp = a[j];
      a[j] = a[j + 1];
      a[j + 1] = temp + 1;
    }

    j = j + 1;
  }

  i = i - 1;
}

return a;
}
```

6. Experiment

- 6 well-known algorithms, with some different implementations
- Each implementation has exactly one bug

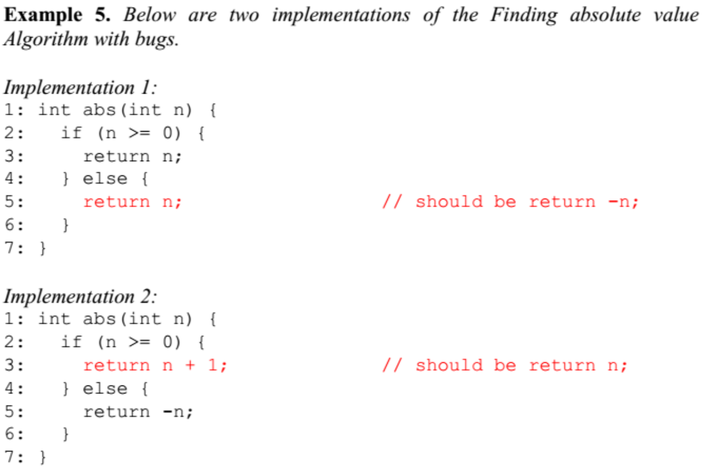
  ⇒ test whether the system can localize these bugs or not

Verification and Group Testing Techniques



Number	Algorithms	Descriptions	Number of implementations
I	Finding absolute value	Finding absolute value of a parameter	7
II	Checking odd/even property	Checking whether a parameter is odd or even	3
III	Finding maximum number	Finding the maximum between two parameters	4
IV	Calculating factorial	Finding factorial of a parameter	7
V	Selection sort	Sorting an array using selection sort algorithm	2
VI	Bubble sort	Sorting an array using bubble sort algorithm	2

Verification and Group Testing Techniques



Example 5. *Below are two implementations of the Finding absolute value Algorithm with bugs.*

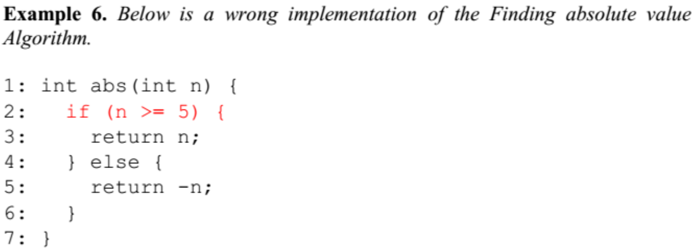
Implementation 1:

```
int abs(int n) {
  if (n >= 0) {
    return n;
  } else {
    return n;                    // should be return -n;
  }
}
```

Implementation 2:

```
int abs(int n) {
  if (n >= 0) {
    return n + 1;                // should be return n;
  } else {
    return -n;
  }
}
```

Verification and Group Testing Techniques



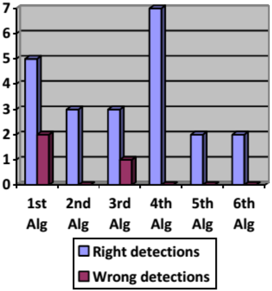
Example 6. *Below is a wrong implementation of the Finding absolute value Algorithm.*

```
int abs(int n) {
  if (n >= 5) {
    return n;
  } else {
    return -n;
  }
}
```

- The result of our experiment is shown in the table and figure below
- The figure shows the chart comparing right localizations with wrong localizations in each algorithm.
- The detailed numbers of right/wrong localizations are in the table.

Verification and Group Testing Techniques

- Successfully 19 times in total 22 implementations
- 3 remained implementations are not localized successfully because the generated test suite is not good enough



Algorithms	Number of implementations	Number of right localizations	Number of wrong localizations
Finding absolute value	7	5	2
Checking odd/even property	3	3	0
Finding maximum number	4	3	1
Calculating factorial	7	7	0
Selection sort	2	2	0
Bubble sort	2	2	0
Total	**22**	**19 (88%)**	**3 (12%)**

7. Issues & Future works

- Path explosion
- Missing code

Thanks for your listenning.

Question?