Software Debugging

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Debugging

- Once errors are identified:
  - it is necessary to identify the precise location of the errors and to fix them.
- Each debugging approach has its own advantages and disadvantages:
  - each is useful in appropriate circumstances.

Some Debugging Approaches

- Brute Force method
- Symbolic Debugger
- Backtracking
- Cause-Elimination Method
- Program Slicing

Brute-force method

- This is the most common method of debugging:
  - least efficient method.
  - program is loaded with print statements
  - print the intermediate values
  - hope that some of printed values will help identify the error.

Symbolic Debugger

- Brute force approach becomes more systematic:
  - with the use of a symbolic debugger,
  - symbolic debuggers get their name for historical reasons
  - early debuggers let you only see values from a program dump:
    - determine which variable it corresponds to.

Symbolic Debugger

- Using a symbolic debugger:
  - values of different variables can be easily checked and modified
  - single stepping to execute one instruction at a time
  - break points and watch points can be set to test the values of variables.

Backtracking

- This is a fairly common approach.
- Beginning at the statement where an error symptom has been observed:
  - source code is traced backwards until the error is discovered.

Example

```
int main( ){
 int i, j, s;
 i=1;
 while(i<=10){
        s=s+i;
        i++;
        j=j++;}
printf("%d",s);
}
```

Backtracking

- Unfortunately, as the number of source lines to be traced back increases,
  - the number of potential backward paths increases
  - becomes unmanageably large for complex programs.

Cause-elimination method

- In this method, once a failure is observed, the symptoms of the failure (e.g. certain variable is having a negative value though it should be positive) are noted.
- Determine a list of causes:
  - which could possibly have contributed to the error symptom.
  - tests are conducted to eliminate each.
- A related technique of identifying errors by examining error symptoms:
  - software fault tree analysis.

Program Slicing

- This technique is similar to back tracking.
- However, the search space is reduced by defining slices.
- A slice is defined for a particular variable at a particular statement:
  - set of source lines preceding this statement which can influence the value of the variable.

Program Slicing cont …

- Slice of a program w.r.t. program point **p** and variable **x**:

  - All statements and predicates that might affect the value of **x** at point **p**.

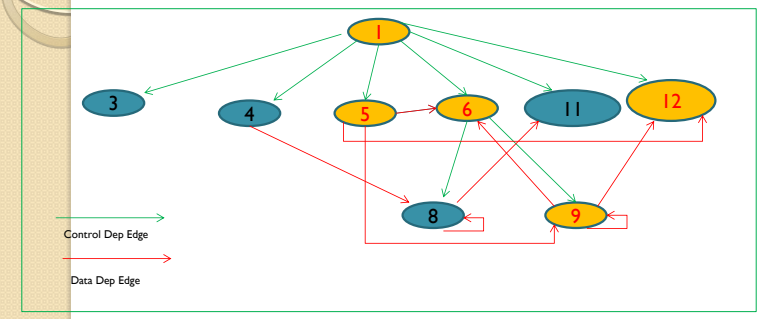
- <**p**, **x**> known as slicing criterion.

Example

```
1 main( )
2 {
3   int i, sum;
4   sum = 0;
5   i = 1;
6   while(i <= 10)
7         {
8       Sum = sum + 1;
9       ++ i;
10       }
11      printf("%d", sum);
12      printf("%d", i);
13      }
```

An Example Program & its backward slice w.r.t. <12, i>

Program Dependence Graph



Example

An Example Program

& its slice w.r.t. <9, i>

```
1.  int main( ){
2.  int  i, s;
3.   i=1;
4.  s=1;
5.   while(i<=10){
6.        s=s+i;
7.        i++;}
8.  printf("%d",s),
9.  printf("%d",i);
10. }
```

Types of Slices

Static Slice: Statements that may affect value of a variable at a program point for *all possible executions*.

Dynamic Slice: Statements that actually affect value of a variable at a program point for *that particular execution*.

Backward Slice: Statements that *might have* affected the variable at a program point.

Forward Slice: Statements that *might be* affected by the variable at a program point.

Example of Forward Slice

```
1 main( )
2 {
3   int i, sum;
4   sum = 0;
5   i = 1;
6   while(i <= 10)
7         {
8       sum = sum + 1;
9       ++ i;
10       }
11      printf("%d", sum);
12      printf("%d", i);
13      }
```

An Example Program & its forward slice w.r.t. <5, i>

Types of Slices cont …

- **Intra-Procedural Slice:** for programs having only one procedure
  - Not applicable for OOPs
- **Inter-Procedural Slice:** for programs having more than one procedure
  - Applicable for OOPs

Applications of Slicing

- Debugging
- Program understanding
- Testing
- Software maintenance
- Complexity measurement
- Program integration
- Reverse engineering
- Software reuse

Debugging Guidelines

- Debugging usually requires a thorough understanding of the program design.
- Debugging may sometimes require full redesign of the system.
- A common mistake novice programmers often make:
  - not fixing the error but the error symptoms.

Debugging Guidelines

- Be aware of the possibility:
  - an error correction may introduce new errors.
- After every round of error-fixing:
  - regression testing must be carried out.

Program Analysis Tools

- An automated tool:
  - takes program source code as input
  - produces reports regarding several important characteristics of the program,
  - such as size, complexity, adequacy of commenting, adherence to programming standards, etc.

Program Analysis Tools

- Some program analysis tools:
  - produce reports regarding the adequacy of the test cases.
- There are essentially two categories of program analysis tools:
  - Static analysis tools
  - Dynamic analysis tools

Static Analysis Tools

- Static analysis tools:
  - Assess properties of a program without executing it.
  - Analyze the source code
    - provide analytical conclusions.

Static Analysis Tools

- Whether coding standards have been adhered to?
  - Commenting is adequate?
- Programming errors such as:
  - uninitialized variables
  - mismatch between actual and formal parameters.
  - Variables declared but never used, etc.

Static Analysis Tools

- Code walk through and inspection can also be considered as static analysis methods:
  - however, the term static program analysis is generally used for automated analysis tools.

Dynamic Analysis Tools

- Dynamic program analysis tools require the program to be executed:
  - its behaviour recorded.
  - Produce reports such as, extent of coverage achieved, adequacy of test cases, etc.

Summary

- Discussed different debugging approaches.
  - Brute Force method
  - Symbolic Debugger
  - Backtracking
  - Cause-Elimination Method
  - Program Slicing
- Presented some debugging guidelines.
- Explained the Program Analysis Tools
  - Static analysis tools
  - Dynamic analysis tools

References

1. Rajib Mall, Fundamentals of Software Engineering, (Chapter – 10), Fifth Edition, PHI Learning Pvt. Ltd., 2018.

Thank You