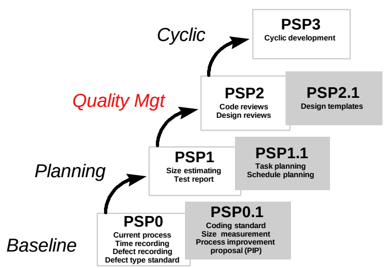
Design Verification

Outline

- Review of PSP Levels
- Overview
- Selecting Verification Methods
- Design Standards
- Verification Methods
  - Approaches
  - State Machines
  - Program Tracing
  - Program Correctness
- Etc.

Review of PSP Levels (Humphrey, 1995, p. 11)



Overview (cf. Humphrey, 1995, p. 373-374)

- To build high-quality software you must ensure that your designs are correct.
- Thus, the question is not <u>whether</u>, but <u>how</u>, to verify your programs.
  - These approaches are not foolproof.
  - They are prone to human error.
  - However, their structure facilitates accuracy and reliability.
- This chapter discusses a number of methods for doing this.
  - Formal methods can sometimes be used.
  - However, this book presents "semi-formal" methods.

Selecting Verification Methods

(cf. Humphrey, 1995, p. 374-376)

Verification Methods
Humphrey (1995, p. 375)

Method	Application	Comments
Loop Verification	Program Loops	Use on loop logic whenever practical.
Proper State Machines	State Machines Only	Use during design and in reviews and inspections on every state machine.
Symbolic Execution	Algorithmic Logic	Use whenever it applies.
Proof by Induction	Loops & Recursion	Use in conjunction with trace tables.
Trace Tables	Complex Logic	Use for small program elements and with proof by induction and/or symbolic execution whenever possible. Use if other verification methods do not apply.
Execution Tables	Complex Logic	Use for small program elements and, as a last resort, when no other methods apply.
Formal Verification	Entire Program	Use whenever you know how to apply the verification methods, they appear feasible, and they are cost effective.

- Select appropriate methods based on:
  - Your defect profile: Use verification where you have problems.
  - Effectiveness of your current methods: Use methods you know and are effective with.
  - Economics of your methods: Use the most cost-effective methods.

Verification Methods: Design Standards (cf. Humphrey, 1995, p. 376-378)

- Design standards do not seem like a verification method.
- However, they provide criteria against which to evaluate a design.
- Some standards you should use are:
  - Product conventions
    - "Conceptual integrity"
  - Product design standards
    - Calling & naming conventions
    - Header, test, and documentation standards & formats, …
    - May be arbitrary, but you need a standard.
  - Reuse standards
    - Components must be well-documented, available, meet needs, and be reliable
    - IBM's German lab's "OS components catalog" parts have never received a user defect report
    - Toshiba's control system, which achieved 90% reuse, had the "lowest defect content of any software [that users] had ever seen."

Verification Methods: Symbolic Execution

(cf. Humphrey, 1995, p. 378-379, & lecture slides)

- *In symbolic execution, the approach is to:*
  - *assign algebraic symbols to the program variables*
  - *restate the program as one or more equations in these symbols*
  - *analyze the behavior of these equations*
- *Some questions to ask are:*
  - *does the program converge on a result?*
  - *how does the program behave for both normal and abnormal input values?*
  - *does the program always produce the desired results?*
- *cf. Example, p. 379, and Lect13.Ppt, p. 9+*

Verification Methods: Proof by Induction

(cf. Humphrey, 1995, p. 379-380, and lecture notes)

- *Proof by induction states that:*

  1. *if f(n) is true for n = k*
  2. *and if*
     - *when n = z where z > k*
     - *and f(z) is true*
     - *you can show that f(z+1) is true*
  3. *then*
     - *f(n) is true for all values of n larger than k*

- *Look for places where there would be problems at z+1 (logical or hardware limits, memory, etc.)*
- *cf. Example, p. 380 (Function call)*
- *cf. Example, Lect12.Ppt, p. 39 (Factorial)*

Verification Methods: State Machines

(cf. Humphrey, 1995, p. 380-397)

- *A program is likely a state machine if, with identical inputs, it behaves differently at different times.*
- *Example: LOC counter*
  - *comments*
  - *non-comments (program, executable)*
- *In a proper state machine:*
  - *it is possible to reach a program return state from every other state*
  - *all state conditions are complete and orthogonal*
  - *all transitions from each state are complete and orthogonal*

Rules for Checking for a Proper State Machine

(cf. Humphrey, 1995, p. 381)

- *Check for hidden traps or loops.*
  - *It cannot get stuck in an endless loop and never reach a return state.*
- *See if all possible states have been identified.*
  - *A state is defined for every possible combinations of attributes.*
- *Check for state orthogonality.*
  - *For every set of conditions there is one and only one possible state.*
- *Check for transition completeness and orthogonality.*
  - *From every state, a unique next state is defined for every possible combination of state machine input values.*

Two Examples of Checking State Machines (cf. Humphrey, 1995, p. 381-397)

- *BSet*
  - *cf. Fig 12.1 (state machine) and Table 12.3 (state specification), p. 382, 383*
  - *Do checks*
- *CData*
  - *cf. Fig 12.2 (state machine) and Table 12.5 (state specification), p. 385, 387-389*
  - *Do checks*

Verification Methods: Program Tracing

(cf. Humphrey, 1995, p. 397)

- *Program tracing is performed with two general methods:*
  - *Execution Tables*
  - *Trace Tables*

Verification Methods: Execution Tables

(cf. Humphrey, 1995, p. 397-405, and lecture notes)

- An execution table is an orderly way to trace program execution.
  - it is a manual check of the program flow
  - it starts with initial conditions
  - a set of variable values is selected
  - each execution step is examined
  - every change in variable values is entered
  - program behavior is checked against the specification
- The advantages of execution tables are
  - they are simple
  - they give reliable proofs
- The disadvantages of execution tables are
  - they only check one case at a time
  - they are time consuming
  - they are subject to human error

An Execution Table Example

(cf. Humphrey, 1995, p. 397-405, and lecture notes)

- To use an execution table
  - identify the key program variables and enter them at the top of the trace table
  - enter the principal program steps
  - determine and enter the initial conditions
  - trace the variable values through each program step
  - for repeating loops, add additional execution table steps for each additional loop cycle
  - for long loops, group intermediate steps if their results are obvious
- cf. ClearSpaces Example, Table 12.9, Fig 12.3, etc., p. 396-405

Verification Methods: Trace Tables

(cf. Humphrey, 1995, p. 400-418, and lecture notes)

- Trace tables are similar to execution tables, but more general.
- Trace tables examine general program behavior rather than verifying individual cases.
- Trace tables use
  - symbolic execution
  - case checking

Example Trace Tables

(cf. Humphrey, 1995, p. 400-418, and lecture notes)

- Walk through examples from book and from lecture notes

Verification Methods: Program Correctness

(cf. Humphrey, 1995, p. 418-435, and lecture notes)

- Formal mathematical proof techniques exist and are good to use when possible.
- However, we cover less formal approaches, but borrow some ideas from the formal methods.
- We apply these approaches to the testing of loops:
  - For-loop verification
  - While-loop verification
  - Repeat-until (do-while) verification
- Check:
  - Preconditions
  - Appropriate test cases
  - Loop termination conditions
  - FirstPart, SecondPart, ...

Comments on Verification Methods

(cf. Humphrey, 1995, p. 436-437)

- If you have any question about the validity of the design, perform verification.
- Test at least a single case, even when confident of the design.
- Design down, verify up.
- Verify all cases.
- Track time spent in verification and assess cost-effectiveness of approaches after you become familiar with the techniques.
- "When you verify your designs as you produce them, your design verification data can greatly accelerate your design reviews."