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Static and dynamic verification

- Software inspections
  - Concerned with analysis of the static system representation to discover problems (static verification)
  - May be supplement by tool-based document and code analysis
- Software testing
  - Concerned with exercising and observing product behaviour (dynamic verification)
  - The system is executed with test data and its operational behaviour is observed

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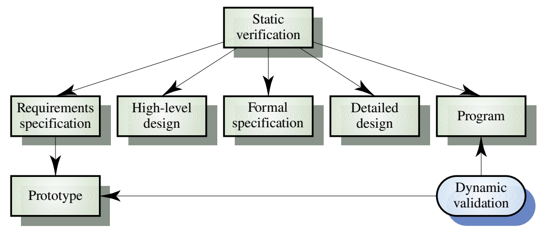
Static and dynamic V&V



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V& V goals

- Verification and validation should establish confidence that the software is fit for purpose
- This does NOT mean completely free of defects
- Rather, it must be good enough for its intended use and the type of use will determine the degree of confidence that is needed

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V & V confidence

- Depends on system's purpose, user expectations and marketing environment
  - Software function
    - The level of confidence depends on how critical the software is to an organization
  - User expectations
    - Users may have low expectations of certain kinds of software
  - Marketing environment
    - Getting a product to market early may be more important than finding defects in the program

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V & V planning

- Careful planning is required to get the most out of testing and inspection processes
- Planning should start early in the development process
- The plan should identify the balance between static verification and testing
- Test planning is about defining standards for the testing process rather than describing product tests

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Software inspections

- Involve people examining the source representation with the aim of discovering anomalies and defects
- Do not require execution of a system so may be used before implementation
- May be applied to any representation of the system (requirements, design, test data, etc.)
- Very effective technique for discovering errors

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Inspection success

- Many different defects may be discovered in a single inspection
  - In testing, one defect may mask another so several executions are required
- The reuse domain and programming knowledge
  - reviewers are likely to have seen the types of error that commonly arise

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Inspections and testing

- Inspections and testing are complementary and not opposing verification techniques
- Both should be used during the V & V process
- Inspections can check conformance with a specification but not conformance with the customer's real requirements
- Inspections cannot check characteristics such as performance, usability, etc.

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Program inspections

- Formalized approach to document reviews
- Intended explicitly for defect DETECTION (not correction)
- Defects may be logical errors, anomalies in the code that might indicate an erroneous condition (e.g. an uninitialized variable) or non-compliance with standards

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Inspection pre-conditions

- A precise specification must be available
- Team members must be familiar with the organization standards
- Syntactically correct code must be available
- An error checklist should be prepared
- Management must accept that inspection will increase costs early in the software process
- Management must not use inspections for staff appraisal

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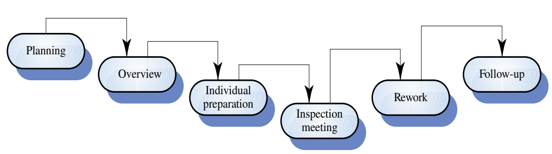
The inspection process



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Inspection procedure

- System overview presented to inspection team
- Code and associated documents are distributed to inspection team in advance
- Inspection takes place and discovered errors are noted
- Modifications are made to repair discovered errors
- Re-inspection may or may not be required

Inspection teams

- Made up of at least 4 members
- Author of the code being inspected
- Inspector who finds errors, omissions and inconsistencies
- Reader who reads the code to the team
- Moderator who chairs the meeting and notes discovered errors

Inspection checklists

- Checklist of common errors should be used to drive the inspection
- Error checklist is programming language dependent
- The 'weaker' the type checking, the larger the checklist
- Examples: Initialization, loop termination, array bounds, etc.

Inspection checks

Fault class	**Inspection check**
Data faults	Are all program variables initialised before their values are used? Have all constants been named? Should the lower bound of arrays be 0, 1, or something else? Should the upper bound of arrays be equal to the size of the array or Size -1? If character strings are used, is a delimiter explicitly assigned?
Control faults	For each conditional statement, is the condition correct? Is each loop certain to terminate? Are compound statements correctly bracketed? In case statements, are all possible cases accounted for?
Input/output faults	Are all input variables used? Are all output variables assigned a value before they are output?

Inspection checks

Interface faults	Do all function and procedure calls have the correct number of parameters? Do formal and actual parameter types match? Are the parameters in the right order? If components access shared memory, do they have the same model of the shared memory structure?
Storage management faults	If a linked structure is modified, have all links been correctly reassigned? If dynamic storage is used, has space been allocated correctly? Is space explicitly de-allocated after it is no longer required?
Exception management faults	Have all possible error conditions been taken into account?

Inspection rate

- 500 statements/hour during overview
- 125 source statement/hour during individual preparation
- 90-125 statements/hour can be inspected
- Inspection is therefore an expensive process
- Inspecting 500 lines costs about 40 man/hours effort = $$

Automated static analysis

- Static analysers are software tools for source text processing
- They parse the program text and try to discover potentially erroneous conditions and bring these to the attention of the V & V team
- Very effective as an aid to inspections. A supplement to but not a replacement for inspections

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Static analysis checks

Fault class	Static analysis check
Data faults	Variables used before initialisation Variables declared but never used Variables assigned twice but never used between assignments Possible array bound violations Undeclared variables
Control faults	Unreachable code Unconditional branches into loops
Input/output faults	Variables output twice with no intervening assignment
Interface faults	Parameter type mismatches Parameter number mismatches Non-usage of the results of functions Uncalled functions and procedures
Storage management faults	Unassigned pointers Pointer arithmetic

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Stages of static analysis

- *Control flow analysis.* Checks for loops with multiple exit or entry points, finds unreachable code, etc.
- *Data use analysis.* Detects uninitialized variables, variables written twice without an intervening assignment, variables which are declared but never used, etc.
- *Interface analysis.* Checks the consistency of routine and procedure declarations and their use

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Stages of static analysis

- *Information flow analysis.* Identifies the dependencies of output variables. Does not detect anomalies itself but highlights information for code inspection or review
- *Path analysis.* Identifies paths through the program and sets out the statements executed in that path. Again, potentially useful in the review process
- Both these stages generate vast amounts of information. Must be used with care.

LINT static analysis

```
138% more lint_ex.c

#include <stdio.h>
printarray (Anarray)
  int Anarray;
{
  printf("%d",Anarray);
}
main ()
{
  int Anarray[5]; int i; char c;
  printarray (Anarray, i, c);
  printarray (Anarray) ;
}

139% cc lint_ex.c
140% lint lint_ex.c

lint_ex.c(10): warning: c may be used before set
lint_ex.c(10): warning: i may be used before set
printarray: variable # of args. lint_ex.c(4) :: lint_ex.c(10)
printarray, arg. 1 used inconsistently lint_ex.c(4) ::
lint_ex.c(10)
printarray, arg. 1 used inconsistently lint_ex.c(4) ::
lint_ex.c(11)
printf returns value which is always ignored
```

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Use of static analysis

- Particularly valuable when a language such as C is used which has weak typing and hence many errors are undetected by the compiler
- Less cost-effective for languages like Java that have strong type checking and can therefore detect many errors during compilation