# Chapter 15
# Static Analysis and Formal Development

# Objectives

- To explain static analysis as a verification technique
- To describe the Cleanroom software development process

# Topics covered

- 15.1 Automated static analysis
- 15.2 Cleanroom software development

# 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.
- They are very effective as an aid to inspections - they are a supplement to but not a replacement for inspections.

# Static analysis checks

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

# Stages of static analysis

- Control flow analysis. Checks for loops with multiple exit or entry points, finds unreachable code, etc.
- Data use analysis. Detects uninitialised 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

# 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. They 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
```

# 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.

# Verification and formal methods

- Formal methods can be used when a mathematical specification of the system is produced.
- They are the ultimate static verification technique.
- They involve detailed mathematical analysis of the specification and may develop formal arguments that a program conforms to its mathematical specification.

# Arguments for formal methods

- Producing a mathematical specification requires a detailed analysis of the requirements and this is likely to uncover errors.
- They can detect implementation errors before testing when the program is analysed alongside the specification.

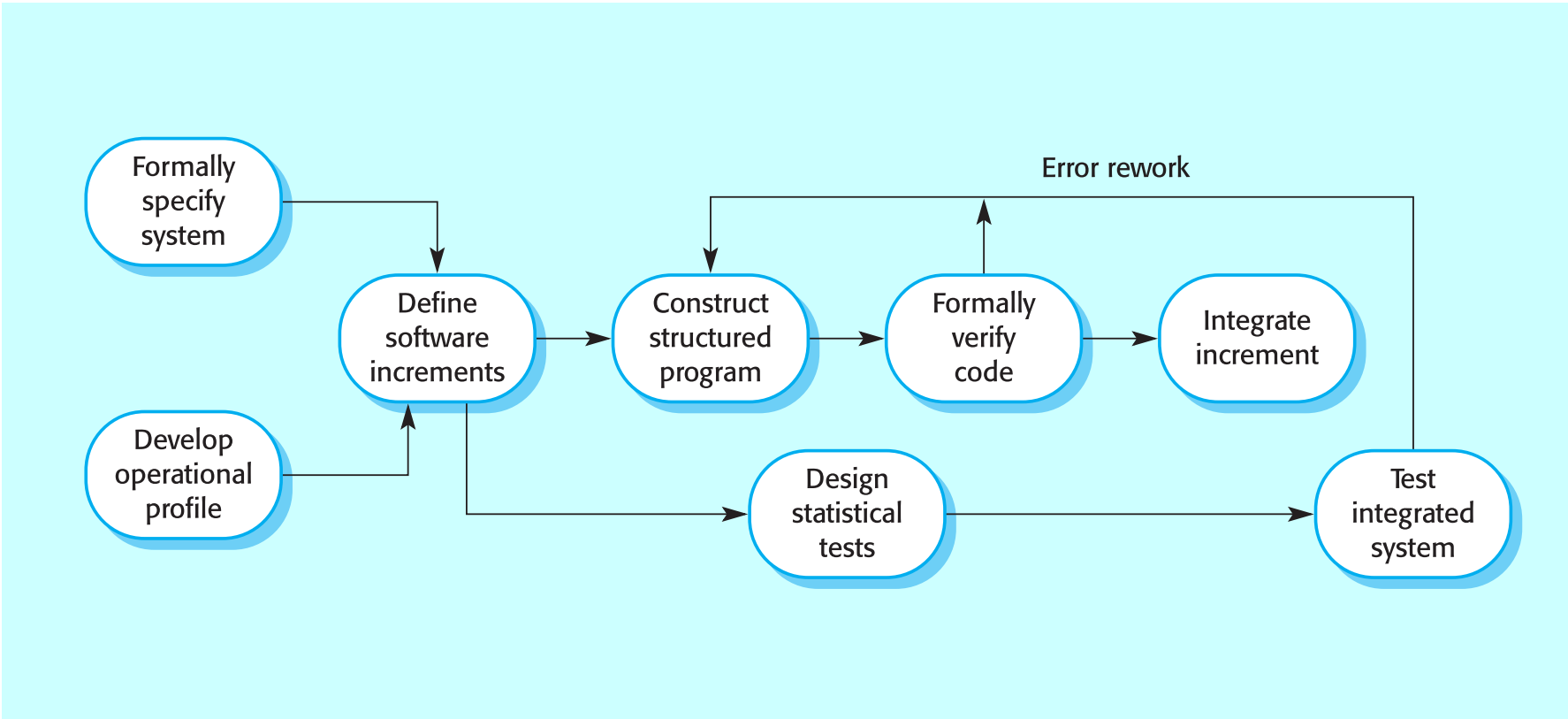
# Arguments against formal methods

- Require specialised notations that cannot be understood by domain experts.
- Very expensive to develop a specification and even more expensive to show that a program meets that specification.
- It may be possible to reach the same level of confidence in a program more cheaply using other V & V techniques.

# Cleanroom software development

- The name is derived from the 'Cleanroom' process in semiconductor fabrication. The philosophy is defect avoidance rather than defect removal.
- This software development process is based on:
  - Incremental development;
  - Formal specification;
  - Static verification using correctness arguments;
  - Statistical testing to determine program reliability.

# The Cleanroom process



# Cleanroom process characteristics

- Formal specification using a state transition model.
- Incremental development where the customer prioritises increments.
- Structured programming - limited control and abstraction constructs are used in the program.
- Static verification using rigorous inspections.
- Statistical testing of the system (covered in Ch. 24).

# Formal specification and inspections

- The state based model is a system specification and the inspection process checks the program against this model.
- The programming approach is defined so that the correspondence between the model and the system is clear.
- Mathematical arguments (not proofs) are used to increase confidence in the inspection process.

# Cleanroom process teams

- Specification team. Responsible for developing and maintaining the system specification.
- Development team. Responsible for developing and verifying the software. The software is NOT executed or even compiled during this process.
- Certification team. Responsible for developing a set of statistical tests to exercise the software after development. Reliability growth models used to determine when reliability is acceptable.

# Cleanroom process evaluation

- The results of using the Cleanroom process have been very impressive with few discovered faults in delivered systems.
- Independent assessment shows that the process is no more expensive than other approaches.
- There were fewer errors than in a 'traditional' development process.
- However, the process is not widely used. It is not clear how this approach can be transferred to an environment with less skilled or less motivated software engineers.

# Key points

- Verification and validation are not the same thing. Verification shows conformance with specification; validation shows that the program meets the customer’s needs.
- Test plans should be drawn up to guide the testing process.
- Static verification techniques involve examination and analysis of the program for error detection.

# Key points

- Program inspections are very effective in discovering errors.
- Program code in inspections is systematically checked by a small team to locate software faults.
- Static analysis tools can discover program anomalies which may be an indication of faults in the code.
- The Cleanroom development process depends on incremental development, static verification and statistical testing.