Software Testing

Background

- Main objectives of a project: High Quality & High Productivity (Q&P)
- Quality has many dimensions
  - reliability, maintainability, interoperability etc.
- Reliability is perhaps the most important
- Reliability: The chances of software failing
- More defects => more chances of failure => lesser reliability
- Hence Q goal: Have as few defects as possible in the delivered software

Faults & Failure

- Failure: A software failure occurs if the behavior of the s/w is different from expected/specified.
- Fault: cause of software failure
- Fault = bug = defect
- Failure implies presence of defects
- A defect has the potential to cause failure.
- Definition of a defect is environment, project specific

Role of Testing

- Reviews are human processes - can not catch all defects
- Hence there will be requirement defects, design defects and coding defects in code
- These defects have to be identified by testing
- Therefore testing plays a critical role in ensuring quality.
- All defects remaining from before as well as new ones introduced have to be identified by testing.

Detecting defects in Testing

- During testing, a program is executed with a set of test cases
- Failure during testing => defects are present
- No failure => confidence grows, but can not say “defects are absent”
- Defects detected through failures
- To detect defects, must cause failures during testing

Test Oracle

- To check if a failure has occurred when executed with a test case, we need to know the correct behavior
- I.e. need a test oracle, which is often a human
- Human oracle makes each test case expensive as someone has to check the correctness of its output

Role of Test cases

- Ideally would like the following for test cases
  - No failure implies “no defects” or “high quality”
  - If defects present, then some test case causes a failure
- Psychology of testing is important
  - should be to ‘reveal’ defects(not to show that it works!)
  - test cases must be “destructive
- Role of test cases is clearly very critical
- Only if test cases are “good”, the confidence increases after testing

Test case design

- During test planning, have to design a set of test cases that will detect defects present
- Some criteria needed to guide test case selection
- Two approaches to design test cases
  - functional or black box
  - structural or white box
- Both are complimentary; we discuss a few approaches/criteria for both

Black Box testing

- Software tested to be treated as a block box
- Specification for the black box is given
- The expected behavior of the system is used to design test cases
- i.e test cases are determined solely from specification.
- Internal structure of code not used for test case design

Black box Testing…

- Premise: Expected behavior is specified.
- Hence just test for specified expected behavior
- How it is implemented is not an issue.
- For modules,specification produced in design specify expected behavior
- For system testing, SRS specifies expected behavior

Black Box Testing...

- Most thorough functional testing - exhaustive testing
  - Software is designed to work for an input space
  - Test the software with all elements in the input space
- Infeasible - too high a cost
- Need better method for selecting test cases
- Different approaches have been proposed

Equivalence Class partitioning

- Divide the input space into equivalent classes
- If the software works for a test case from a class the it is likely to work for all
- Can reduce the set of test cases if such equivalent classes can be identified
- Getting ideal equivalent classes is impossible
- Approximate it by identifying classes for which different behavior is specified

Equivalence class partitioning...

- Rationale: specification requires same behavior for elements in a class
- Software likely to be constructed such that it either fails for all or for none.
- E.g. if a function was not designed for negative numbers then it will fail for all the negative numbers
- For robustness, should form equivalent classes for invalid inputs also

Equivalent class partitioning..

- Every condition specified as input is an equivalent class
- Define invalid equivalent classes also
- E.g. range 0< value<Max specified
  - one range is the valid class
  - input < 0 is an invalid class
  - input > max is an invalid class
- Whenever that entire range may not be treated uniformly - split into classes

Equivalent class partitioning..

- Should consider eq. classes in outputs also and then give test cases for different classes
- E.g.: Compute rate of interest given loan amount, monthly installment, and number of months
  - Equivalent classes in output: + rate, rate = 0 ,-ve rate
  - Have test cases to get these outputs

Equivalence class…

- Once eq classes selected for each of the inputs, test cases have to be selected
  - Select each test case covering as many valid eq classes as possible
  - Or, have a test case that covers at most one valid class for each input
  - Plus a separate test case for each invalid class

Example

- Consider a program that takes 2 inputs – a string s and an integer n
- Program determines n most frequent characters
- Tester believes that programmer may deal with diff types of chars separately
- A set of valid and invalid equivalence classes is given

Example..

Input	Valid Eq Class	Invalid Eq class
S	1: Contains numbers 2: Lower case letters 3: upper case letters 4: special chars 5: str len between 0-N(max)	1: non-ascii char 2: str len > N
N	6: Int in valid range	3: Int out of range

Example…

- Test cases (i.e. s , n) with first method
  - s : str of len < N with lower case, upper case, numbers, and special chars, and n=5
  - Plus test cases for each of the invalid eq classes
  - Total test cases: 1+3= 4
- With the second approach
  - A separate str for each type of char (i.e. a str of numbers, one of lower case, …) + invalid cases
  - Total test cases will be 5 + 2 = 7

Boundary value analysis

- Programs often fail on special values
- These values often lie on boundary of equivalence classes
- Test cases that have boundary values have *high yield*
- These are also called *extreme cases*
- A BV test case is a set of input data that lies on the edge of a eq class of input/output

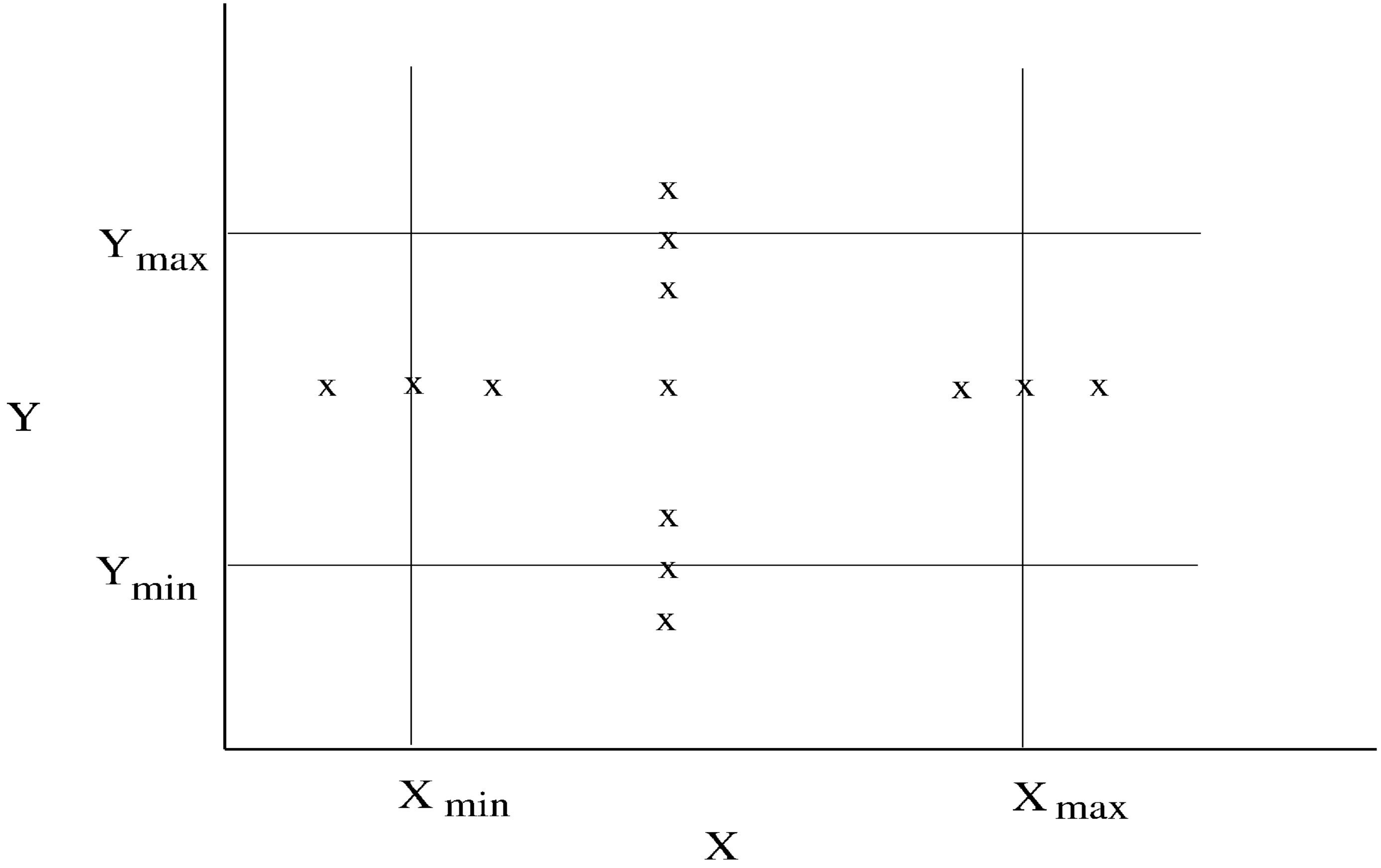
BVA...

- For each equivalence class
  - choose values on the edges of the class
  - choose values just outside the edges
- E.g. if 0 <= x <= 1.0
  - 0.0 , 1.0 are edges inside
  - -0.1,1.1 are just outside
- E.g. a bounded list - have a null list , a maximum value list
- Consider outputs also and have test cases generate outputs on the boundary

BVA…

- In BVA we determine the value of vars that should be used
- If input is a defined range, then there are 6 boundary values plus 1 normal value (tot: 7)
- If multiple inputs, how to combine them into test cases; two strategies possible
  - Try all possible combination of BV of diff variables, with n vars this will have 7^n test cases!
  - Select BV for one var; have other vars at normal values + 1 of all normal values

BVA.. (test cases for two vars – x and y)



Cause Effect graphing

- Equivalence classes and boundary value analysis consider each input separately
- To handle multiple inputs, different combinations of equivalent classes of inputs can be tried
- Number of combinations can be large – if n diff input conditions such that each condition is valid/invalid, total: 2^n
- Cause effect graphing helps in selecting combinations as input conditions

CE-graphing

- Identify causes and effects in the system
  - Cause: distinct input condition which can be true or false
  - Effect: distinct output condition (T/F)
- Identify which causes can produce which effects; can combine causes
- Causes/effects are nodes in the graph and arcs are drawn to capture dependency; and/or are allowed

CE-graphing

- From the CE graph, can make a decision table
  - Lists combination of conditions that set different effects
  - Together they check for various effects
- Decision table can be used for forming the test cases

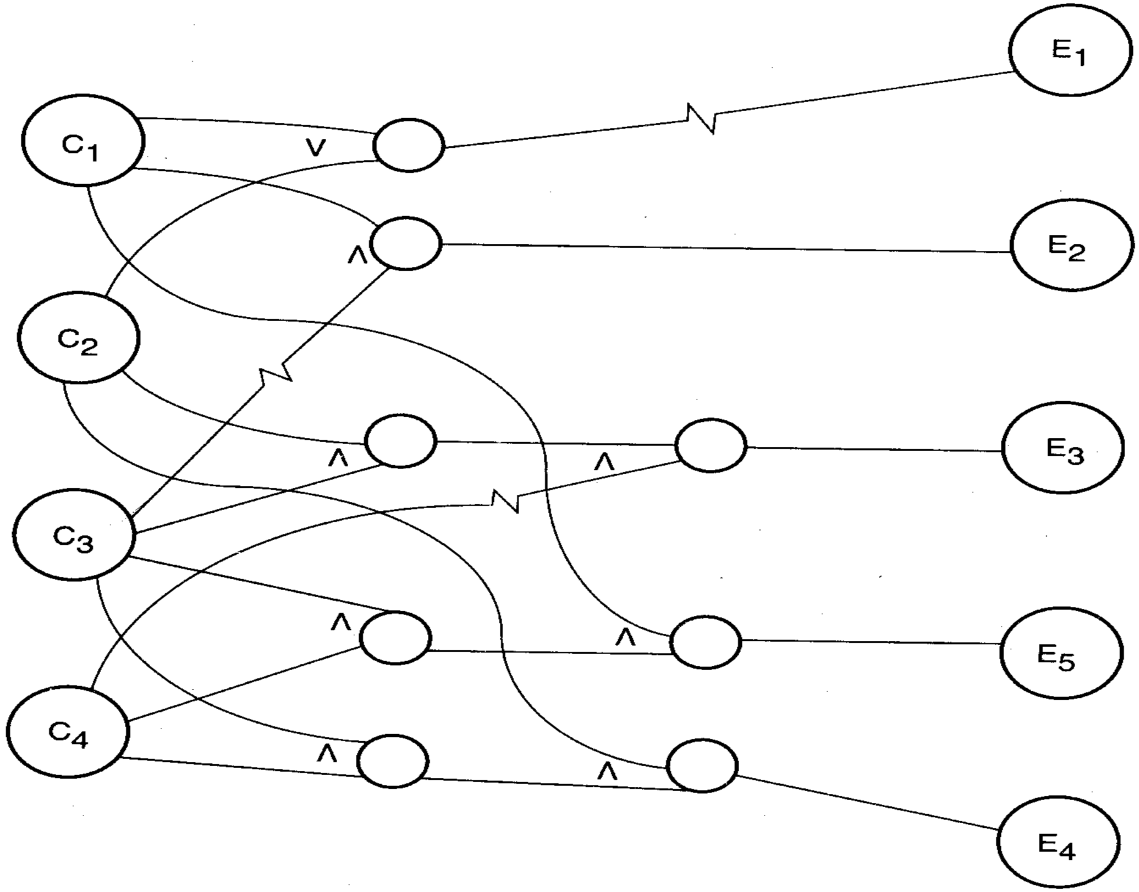
CE graphing: Example

- A bank database which allows two commands
  - Credit acc# amt
  - Debit acc# amt
- Requirements
  - If credit and acc# valid, then credit
  - If debit and acc# valid and amt less than balance, then debit
  - Invalid command - message

Example…

- Causes
  - C1: command is credit
  - C2: command is debit
  - C3: acc# is valid
  - C4: amt is valid
- Effects
  - Print “Invalid command”
  - Print “Invalid acct#”
  - Print “Debit amt not valid”
  - Debit account
  - Credit account

Example...



Example...

#	1	2	3	4	5
C1	0	1	x	x	x
C2	0	x	1	1	x
C3	x	0	1	1	1
C4	x	x	0	1	1
E1	1				
E2		1			
E3			1		
E4				1	
E5					1

Pair-wise testing

- Often many parmeters determine the behavior of a software system
- The parameters may be inputs or settings, and take diff values (or diff value ranges)
- Many defects involve one condition (single-mode fault), eg. sw not being able to print on some type of printer
  - Single mode faults can be detected by testing for different values of diff parms
  - If n parms and each can take m values, we can test for one diff value for each parm in each test case
  - Total test cases: m

Pair-wise testing…

- All faults are not single-mode and sw may fail at some combinations
  - Eg tel billing sw does not compute correct bill for night time calling (one parm) to a particular country (another parm)
  - Eg ticketing system fails to book a biz class ticket (a parm) for a child (a parm)
- Multi-modal faults can be revealed by testing diff combination of parm values
- This is called combinatorial testing

Pair-wise testing…

- Full combinatorial testing not feasible
  - For n parms each with m values, total combinations are n^m
  - For 5 parms, 5 values each (tot: 3125), if one test is 5 mts, tot time > 1 month!
- Research suggests that most such faults are revealed by interaction of a pair of values
- I.e. most faults tend to be double-mode
- For double mode, we need to exercise each pair – called pair-wise testing

Pair-wise testing…

- In pair-wise, all pairs of values have to be exercised in testing
- If n parms with m values each, between any 2 parms we have m*m pairs
  - 1^{st} parm will have m*m with n-1 others
  - 2^{nd} parm will have m*m pairs with n-2
  - 3^{rd} parm will have m*m pairs with n-3, etc.
  - Total no of pairs are m*m*n*(n-1)/2

Pair-wise testing…

- A test case consists of some setting of the n parameters
- Smallest set of test cases when each pair is covered once only
- A test case can cover a maximum of (n-1)+(n-2)+…=n(n-1)/2 pairs
- In the best case when each pair is covered exactly once, we will have m^2 different test cases providing the full pair-wise coverage

Pair-wise testing…

- Generating the smallest set of test cases that will provide pair-wise coverage is non-trivial
- Efficient algos exist; efficiently generating these test cases can reduce testing effort considerably
  - In an example with 13 parms each with 3 values pair-wise coverage can be done with 15 testcases
- Pair-wise testing is a practical approach that is widely used in industry

Pair-wise testing, Example

- A sw product for multiple platforms and uses browser as the interface, and is to work with diff OSs
- We have these parms and values
  - OS (parm A): Windows, Solaris, Linux
  - Mem size (B): 128M, 256M, 512M
  - Browser (C): IE, Netscape, Mozilla
- Total no of pair wise combinations: 27
- No of cases can be less

Pair-wise testing…

Test case	Pairs covered
a1, b1, c1	(a1,b1) (a1, c1) (b1,c1)
a1, b2, c2	(a1,b2) (a1,c2) (b2,c2)
a1, b3, c3	(a1,b3) (a1,c3) (b3,c3)
a2, b1, c2	(a2,b1) (a2,c2) (b1,c2)
a2, b2, c3	(a2,b2) (a2,c3) (b2,c3)
a2, b3, c1	(a2,b3) (a2,c1) (b3,c1)
a3, b1, c3	(a3,b1) (a3,c3) (b1,c3)
a3, b2, c1	(a3,b2) (a3,c1) (b2,c1)
a3, b3, c2	(a3,b3) (a3,c2) (b3,c2)

Special cases

- Programs often fail on special cases
- These depend on nature of inputs, types of data structures,etc.
- No good rules to identify them
- One way is to guess when the software might fail and create those test cases
- Also called error guessing
- Play the sadist & hit where it might hurt

Error Guessing

- Use experience and judgement to guess situations where a programmer might make mistakes
- Special cases can arise due to assumptions about inputs, user, operating environment, business, etc.
- E.g. A program to count frequency of words
  - file empty, file non existent, file only has blanks, contains only one word, all words are same, multiple consecutive blank lines, multiple blanks between words, blanks at the start, words in sorted order, blanks at end of file, etc.
- Perhaps the most widely used in practice

State-based Testing

- Some systems are state-less: for same inputs, same behavior is exhibited
- Many systems’ behavior depends on the state of the system i.e. for the same input the behavior could be different
- I.e. behavior and output depend on the input as well as the system state
- System state – represents the cumulative impact of all past inputs
- State-based testing is for such systems

State-based Testing…

- A system can be modeled as a state machine
- The state space may be too large (is a cross product of all domains of vars)
- The state space can be partitioned in a few states, each representing a logical state of interest of the system
- State model is generally built from such states

State-based Testing…

- A state model has four components
  - States: Logical states representing cumulative impact of past inputs to system
  - Transitions: How state changes in response to some events
  - Events: Inputs to the system
  - Actions: The outputs for the events

State-based Testing…

- State model shows what transitions occur and what actions are performed
- Often state model is built from the specifications or requirements
- The key challenge is to identify states from the specs/requirements which capture the key properties but is small enough for modeling

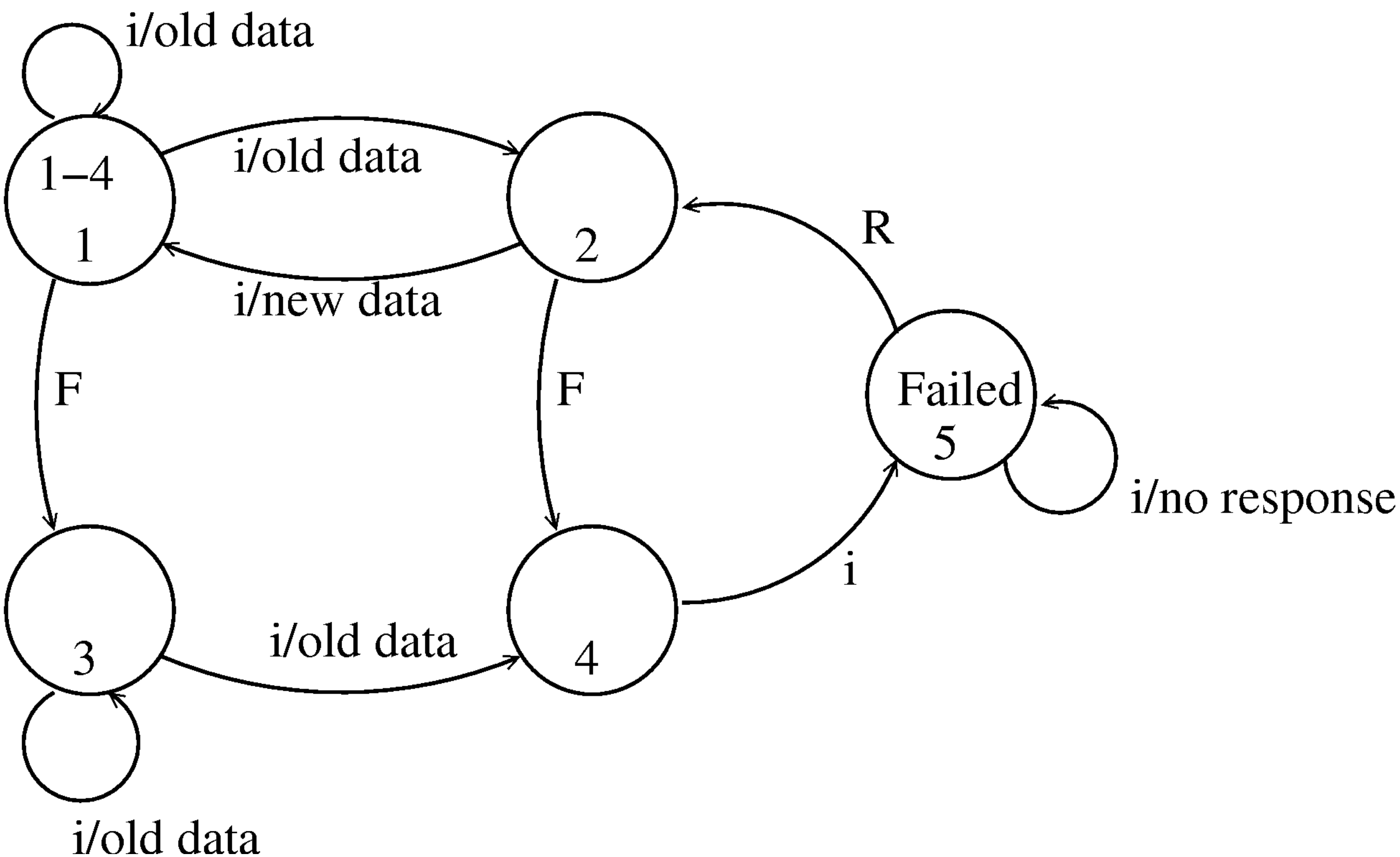
State-based Testing, example…

- Consider the student survey example (discussed in Chap 4)
  - A system to take survey of students
  - Student submits survey and is returned results of the survey so far
  - The result may be from the cache (if the database is down) and can be up to 5 surveys old

State-based Testing, example…

- In a series of requests, first 5 may be treated differently
- Hence, we have two states: one for req no 1-4 (state 1), and other for 5 (2)
- The db can be up or down, and it can go down in any of the two states (3-4)
- Once db is down, the system may get into failed state (5), from where it may recover

State-based Testing, example...



State-based Testing…

- State model can be created from the specs or the design
- For objects, state models are often built during the design process
- Test cases can be selected from the state model and later used to test an implementation
- Many criteria possible for test cases

State-based Testing criteria

- All transaction coverage (AT): test case set T must ensure that every transition is exercised
- All transitions pair coverage (ATP). T must execute all pairs of adjacent transitions (incoming and outgoing transition in a state)
- Transition tree coverage (TT). T must execute all simple paths (i.e. a path from start to end or a state it has visited)

Example, test cases for AT criteria

SNo	Transition	Test case
1	1 -> 2	Req()
2	1 -> 2	Req(); req(); req(); req();req(); req()
3	2 -> 1	Seq for 2; req()
4	1 -> 3	Req(); fail()
5	3 -> 3	Req(); fail(); req()
6	3 -> 4	Req(); fail(); req(); req(); req();req(); req()
7	4 -> 5	Seq for 6; req()
8	5 -> 2	Seq for 6; req(); recover()

State-based testing…

- SB testing focuses on testing the states and transitions to/from them
- Different system scenarios get tested; some easy to overlook otherwise
- State model is often done after design information is available
- Hence it is sometimes called *grey box testing* (as it not pure black box)

White box testing

- Black box testing focuses only on functionality
  - What the program does; not how it is implemented
- White box testing focuses on implementation
  - Aim is to exercise different program structures with the intent of uncovering errors
- Is also called *structural testing*
- Various criteria exist for test case design
- Test cases have to be selected to satisfy coverage criteria

Types of structural testing

- Control flow based criteria
  - looks at the coverage of the control flow graph
- Data flow based testing
  - looks at the coverage in the definition-use graph
- Mutation testing
  - looks at various mutants of the program
- We will discuss control flow based and data flow based criteria

Control flow based criteria

- Considers the program as control flow graph
  - Nodes represent code blocks – i.e. set of statements always executed together
  - An edge (i,j) represents a possible transfer of control from i to j
- Assume a start node and an end node
- A path is a sequence of nodes from start to end

Statement Coverage Criterion

- Criterion: Each statement is executed at least once during testing
- I.e. set of paths executed during testing should include all nodes
- Limitation: does not require a decision to evaluate to false if no else clause
- E.g. : abs (x) : if (x>=0) x = -x; return(x)
  - The set of test cases {x = 0} achieves 100% statement coverage, but error not detected
- Guaranteeing 100% coverage not always possible due to possibility of unreachable nodes

Branch coverage

- Criterion: Each edge should be traversed at least once during testing
- i.e. each decision must evaluate to both true and false during testing
- Branch coverage implies stmt coverage
- If multiple conditions in a decision, then all conditions need not be evaluated to T and F

Control flow based…

- There are other criteria too - path coverage, predicate coverage, cyclomatic complexity based, ...
- None is sufficient to detect all types of defects (e.g. a program missing some paths cannot be detected)
- They provide some quantitative handle on the breadth of testing
- More used to evaluate the level of testing rather than selecting test cases

Data flow-based testing

- A def-use graph is constructed from the control flow graph
- A stmt in the control flow graph (in which each stmt is a node) can be of these types
  - Def: represents definition of a var (i.e. when var is on the lhs)
  - C-use: computational use of a var
  - P-use: var used in a predicate for control transfer

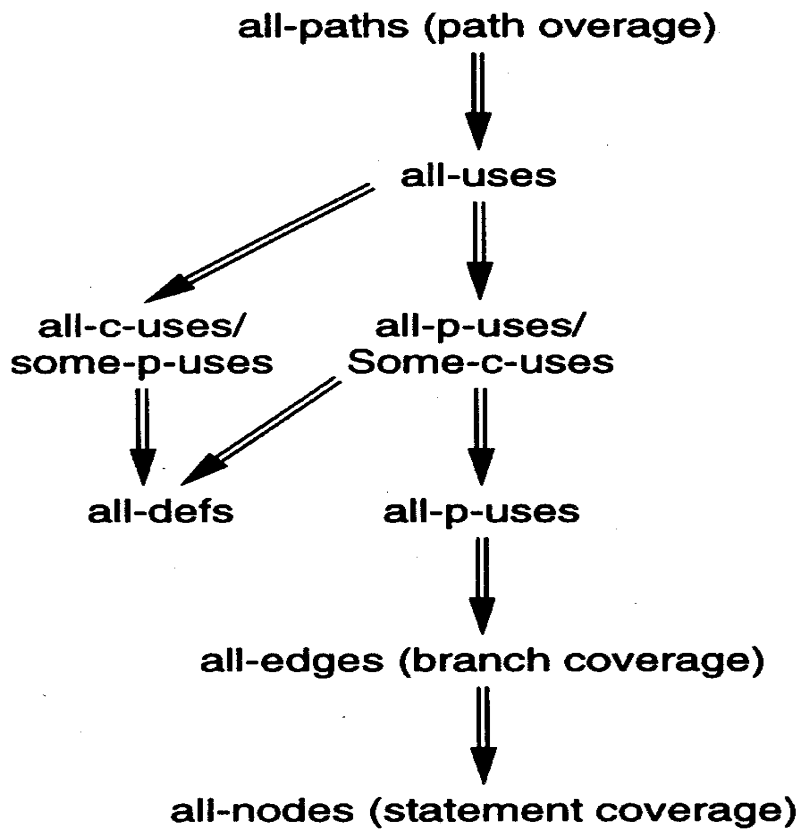
Data flow based...

- A def-use graph is constructed by associating vars with nodes and edges in the control flow graph
  - For a node I, def(i) is the set of vars for which there is a global def in I
  - For a node I, C-use(i) is the set of vars for which there is a global c-use in I
  - For an edge, p-use(I,j) is set of vars whor which there is a p-use for the edge (I,j)
- Def clear path from I to j wrt x: if no def of x in the nodes in the path

Data flow based criteria

- all-defs: for every node I, and every x in def(i) there is a def-clear path
  - For def of every var, one of its uses (p-use or c-use) must be tested
- all-p-uses: all p-uses of all the definitions should be tested
  - All p-uses of all the defs must be tested
- Some-c-uses, all-c-uses, some-p-uses are some other criteria

Relationship between diff criteria



Tool support and test case selection

- Two major issues for using these criteria
  - How to determine the coverage
  - How to select test cases to ensure coverage
- For determining coverage - tools are essential
- Tools also tell which branches and statements are not executed
- Test case selection is mostly manual - test plan is to be augmented based on coverage data

In a Project

- Both functional and structural should be used
- Test plans are usually determined using functional methods; during testing, for further rounds, based on the coverage, more test cases can be added
- Structural testing is useful at lower levels only; at higher levels ensuring coverage is difficult
- Hence, a combination of functional and structural at unit testing
- Functional testing (but monitoring of coverage) at higher levels

Comparison

	Code Review	Structural Testing	Functional Testing
Computational	M	H	M
Logic	M	H	M
I/O	H	M	H
Data handling	H	L	H
Interface	H	H	M
Data defn.	M	L	M
Database	H	M	M

Testing Process

Testing

- Testing only reveals the presence of defects
- Does not identify nature and location of defects
- Identifying & removing the defect => role of debugging and rework
- Preparing test cases, performing testing, defects identification & removal all consume effort
- Overall testing becomes very expensive : 30-50% development cost

Incremental Testing

- Goals of testing: detect as many defects as possible, and keep the cost low
- Both frequently conflict - increasing testing can catch more defects, but cost also goes up
- Incremental testing - add untested parts incrementally to tested portion
- For achieving goals, incremental testing essential
  - helps catch more defects
  - helps in identification and removal
- Testing of large systems is always incremental

Integration and Testing

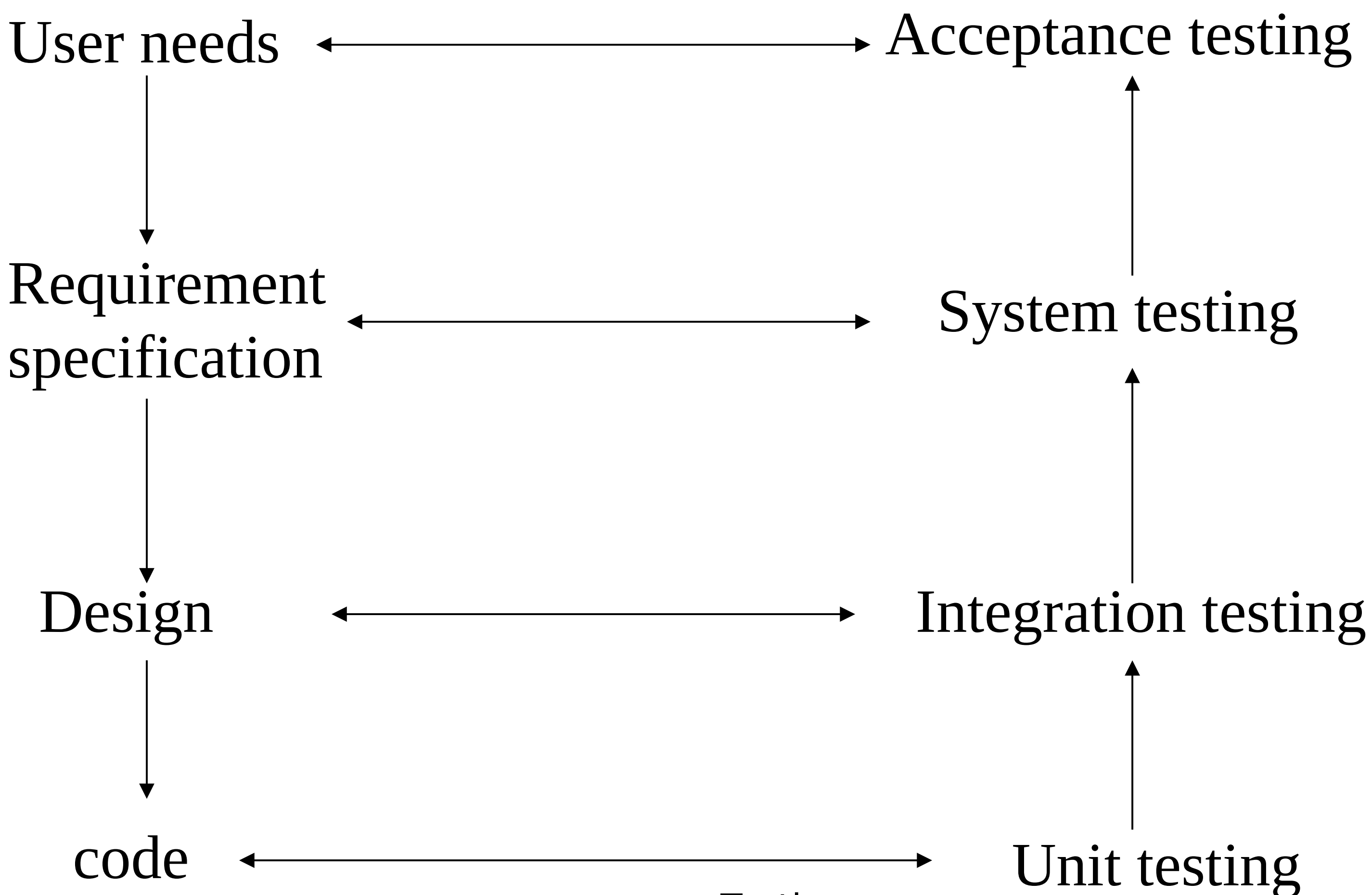
- Incremental testing requires incremental ‘building’ I.e. incrementally integrate parts to form system
- Integration & testing are related
- During coding, different modules are coded separately
- Integration - the order in which they should be tested and combined
- Integration is driven mostly by testing needs

Top-down and Bottom-up

- System : Hierarchy of modules
- Modules coded separately
- Integration can start from bottom or top
- Bottom-up requires test drivers
- Top-down requires stubs
- Both may be used, e.g. for user interfaces top-down; for services bottom-up
- Drivers and stubs are code pieces written only for testing

Levels of Testing

- The code contains requirement defects, design defects, and coding defects
- Nature of defects is different for different injection stages
- One type of testing will be unable to detect the different types of defects
- Different levels of testing are used to uncover these defects


User needs
Acceptance testing
Requirement specification
System testing
Design
Integration testing
code
Unit testing

Unit Testing

- Different modules tested separately
- Focus: defects injected during coding
- Essentially a code verification technique, covered in previous chapter
- UT is closely associated with coding
- Frequently the programmer does UT; coding phase sometimes called "coding and unit testing"

Integration Testing

- Focuses on interaction of modules in a subsystem
- Unit tested modules combined to form subsystems
- Test cases to “exercise” the interaction of modules in different ways
- May be skipped if the system is not too large

System Testing

- Entire software system is tested
- Focus: does the software implement the requirements?
- Validation exercise for the system with respect to the requirements
- Generally the final testing stage before the software is delivered
- May be done by independent people
- Defects removed by developers
- Most time consuming test phase

Acceptance Testing

- Focus: Does the software satisfy user needs?
- Generally done by end users/customer in customer environment, with real data
- Only after successful AT software is deployed
- Any defects found,are removed by developers
- Acceptance test plan is based on the acceptance test criteria in the SRS

Other forms of testing

- Performance testing
  - tools needed to “measure” performance
- Stress testing
  - load the system to peak, load generation tools needed
- Regression testing
  - test that previous functionality works alright
  - important when changes are made
  - Previous test records are needed for comparisons
  - Prioritization of testcases needed when complete test suite cannot be executed for a change

Test Plan

- Testing usually starts with test plan and ends with acceptance testing
- Test plan is a general document that defines the scope and approach for testing for the whole project
- Inputs are SRS, project plan, design
- Test plan identifies what levels of testing will be done, what units will be tested, etc in the project

Test Plan…

- Test plan usually contains
  - Test unit specs: what units need to be tested separately
  - Features to be tested: these may include functionality, performance, usability,…
  - Approach: criteria to be used, when to stop, how to evaluate, etc
  - Test deliverables
  - Schedule and task allocation

Test case specifications

- Test plan focuses on approach; does not deal with details of testing a unit
- Test case specification has to be done separately for each unit
- Based on the plan (approach, features,..) test cases are determined for a unit
- Expected outcome also needs to be specified for each test case

Test case specifications…

- Together the set of test cases should detect most of the defects
- Would like the set of test cases to detect any defects, if it exists
- Would also like set of test cases to be small - each test case consumes effort
- Determining a reasonable set of test case is the most challenging task of testing

Test case specifications…

- The effectiveness and cost of testing depends on the set of test cases
- Q: How to determine if a set of test cases is good? I.e. the set will detect most of the defects, and a smaller set cannot catch these defects
- No easy way to determine goodness; usually the set of test cases is reviewed by experts
- This requires test cases be specified before testing – a key reason for having test case specs
- Test case specs are essentially a table

Test case specifications...

Seq.No	Condition to be tested	Test Data	Expected result	successful

Test case specifications…

- So for each testing, test case specs are developed, reviewed, and executed
- Preparing test case specifications is challenging and time consuming
  - Test case criteria can be used
  - Special cases and scenarios may be used
- Once specified, the execution and checking of outputs may be automated through scripts
  - Desired if repeated testing is needed
  - Regularly done in large projects

Test case execution and analysis

- Executing test cases may require drivers or stubs to be written; some tests can be auto, others manual
  - A separate test procedure document may be prepared
- Test summary report is often an output – gives a summary of test cases executed, effort, defects found, etc
- Monitoring of testing effort is important to ensure that sufficient time is spent
- Computer time also is an indicator of how testing is proceeding

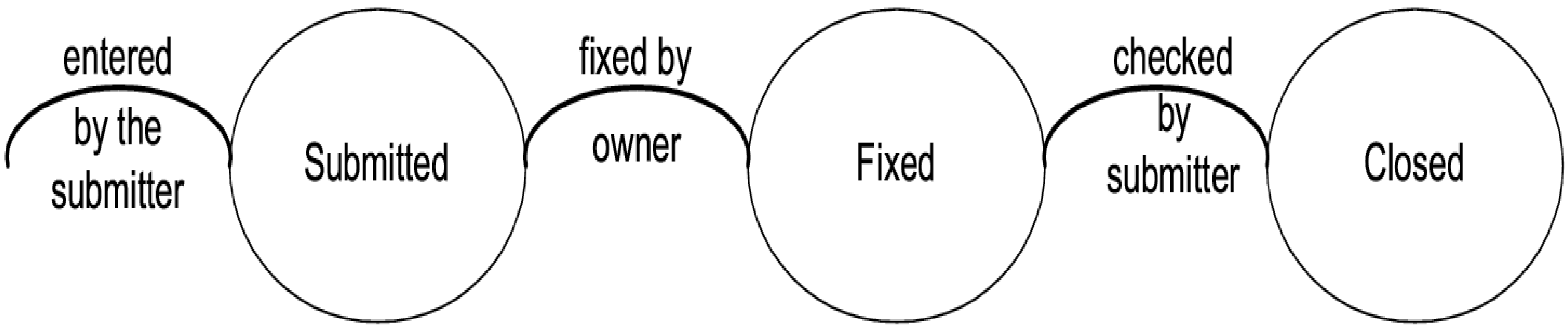
Defect logging and tracking

- A large software may have thousands of defects, found by many different people
- Often person who fixes (usually the coder) is different from who finds
- Due to large scope, reporting and fixing of defects cannot be done informally
- Defects found are usually logged in a defect tracking system and then tracked to closure
- Defect logging and tracking is one of the best practices in industry

Defect logging…

- A defect in a software project has a life cycle of its own, like
  - Found by someone, sometime and logged along with info about it (submitted)
  - Job of fixing is assigned; person debugs and then fixes (fixed)
  - The manager or the submitter verifies that the defect is indeed fixed (closed)
- More elaborate life cycles possible

Defect logging…



Defect logging…

- During the life cycle, info about defect is logged at diff stages to help debug as well as analysis
- Defects generally categorized into a few types, and type of defects is recorded
  - ODC is one classification
  - Some std categories: Logic, standards, UI, interface, performance, documentation,..

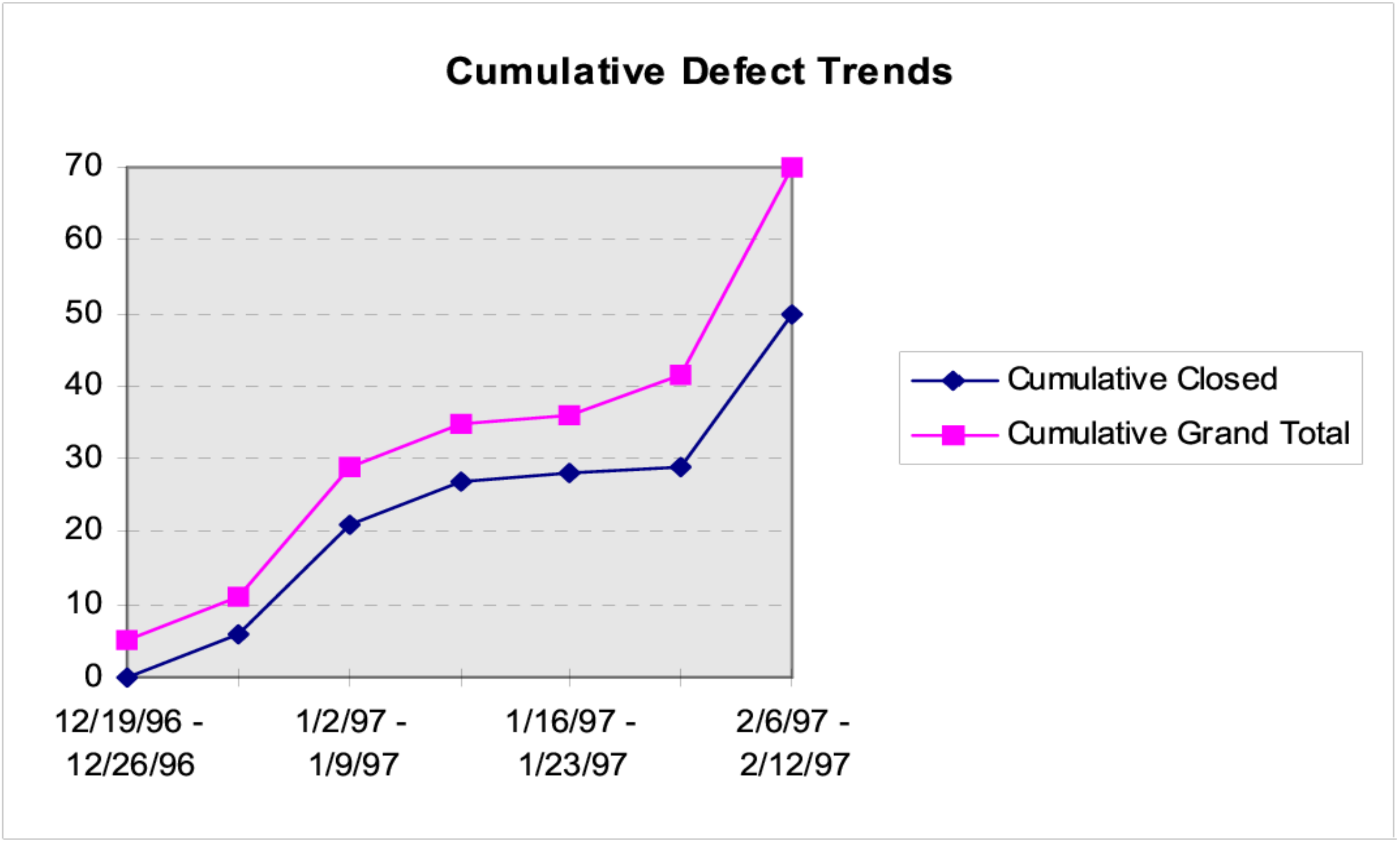
Defect logging…

- Severity of defects in terms of its impact on sw is also recorded
- Severity useful for prioritization of fixing
- One categorization
  - Critical: Show stopper
  - Major: Has a large impact
  - Minor: An isolated defect
  - Cosmetic: No impact on functionality

Defect logging and tracking…

- Ideally, all defects should be closed
- Sometimes, organizations release software with known defects (hopefully of lower severity only)
- Organizations have standards for when a product may be released
- Defect log may be used to track the trend of how defect arrival and fixing is happening

Defect arrival and closure trend



Defect analysis for prevention

- Quality control focuses on removing defects
- Goal of defect prevention is to reduce the defect injection rate in future
- DP done by analyzing defect log, identifying causes and then remove them
- Is an advanced practice, done only in mature organizations
- Finally results in actions to be undertaken by individuals to reduce defects in future

Metrics - Defect removal efficiency

- Basic objective of testing is to identify defects present in the programs
- Testing is good only if it succeeds in this goal
- Defect removal efficiency of a QC activity = % of present defects detected by that QC activity
- High DRE of a quality control activity means most defects present at the time will be removed

Defect removal efficiency …

- DRE for a project can be evaluated only when all defects are know, including delivered defects
- Delivered defects are approximated as the number of defects found in some duration after delivery
- The *injection stage* of a defect is the stage in which it was introduced in the software, and *detection stage* is when it was detected
  - These stages are typically logged for defects
- With injection and detection stages of all defects, DRE for a QC activity can be computed

Defect Removal Efficiency …

- DREs of different QC activities are a process property - determined from past data
- Past DRE can be used as expected value for this project
- Process followed by the project must be improved for better DRE

Metrics – Reliability Estimation

- High reliability is an important goal being achieved by testing
- Reliability is usually quantified as a probability or a failure rate
- For a system it can be measured by counting failures over a period of time
- Measurement often not possible for software as due to fixes reliability changes, and with one-off, not possible to measure

Reliability Estimation…

- Sw reliability estimation models are used to model the failure followed by fix model of software
- Data about failures and their times during the last stages of testing is used by these model
- These models then use this data and some statistical techniques to predict the reliability of the software
- A simple reliability model is given in the book

Summary

- Testing plays a critical role in removing defects, and in generating confidence
- Testing should be such that it catches most defects present, i.e. a high DRE
- Multiple levels of testing needed for this
- Incremental testing also helps
- At each testing, test cases should be specified, reviewed, and then executed

Summary …

- Deciding test cases during planning is the most important aspect of testing
- Two approaches – black box and white box
- Black box testing - test cases derived from specifications.
  - Equivalence class partitioning, boundary value, cause effect graphing, error guessing
- White box - aim is to cover code structures
  - statement coverage, branch coverage

Summary…

- In a project both used at lower levels
  - Test cases initially driven by functional
  - Coverage measured, test cases enhanced using coverage data
- At higher levels, mostly functional testing done; coverage monitored to evaluate the quality of testing
- Defect data is logged, and defects are tracked to closure
- The defect data can be used to estimate reliability, DRE