Specification Based Testing – Part 2

Combinatorial Coverage as an Aspect of Test Quality

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Objective

Objective

Apply combinatorial test coverage to assess test quality

Assessing Test Quality

- Numerous approaches exist for assessing test quality including:
  - Combinatorial coverage
  - Mutation testing
- Combinatorial coverage looks at how combinations of parameter values are tested together

- Various studies show that most failures can be detected with combinations of a small number of parameters

https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=917352

Total t-way Coverage

- For a given test set of "n" variables and values, proportion of t-way variable-value combinations that are executed
- E.g. Assume we are testing a function with 3 variables:
  - Variable a: has values 0 and 1
  - Variable b: has value 0 and 1
  - Variable c: has values 0 and 1

- What is the total 2-way variable-value configuration coverage achieved by the following tests:

  a=0; b=0; c=0

  a=1; b=1; c=1

  a=1; b=0; c=0

Summary

Specification Based Testing – Part 2

Design of Experiments

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Objective

Objective

Apply Design of Experiments to develop tests

Background

- Design of Experiments (DOE) is a systematic approach for evaluating a system or process
- DOE is heavily utilized in manufacturing and quality engineering
- DOE enables efficient investigation of the behavior of a system

Traditional Experimentation

Traditional evaluation of the behavior of a system involves designing an experiment in which one factor is modified and the behavior on the system is assessed

For example, consider varying oven temperature on the impact of the quality of a pizza

Weakness of Traditional Approach

- The behavior of most systems is impacted by many factors
- Factors may also combine to create interactions

- In the pizza case, additional factors include:
  - Rack positioning
  - Cook time

DOE Advantages

- DOE enables examination of the impact of a single factor as well as combinations of factors
- Values / ranges must be determined for each factor to investigate
- Experiments (runs) are made with combinations of the factors being considered and their impact on the system

Pizza Example Factors

- **Cook time**
  - Low / Med / High
- **Rack position**
  - 1 / 2 / 3 / 4 / 5
- **Temperature**
  - 350 / 375 / 400

Full DOE Combinations

45 Runs

DOE Classification

Full factorial design

- Tests for every factor value combination
- Pizza example

Fractional factorial design

- Only a fraction of all combinations are addressed
- Orthogonal arrays often used to address limited combinations of factors

Design of Experiments Pairwise Combinations

1. Identify the parameters that define each configuration
2. Partition each of the parameters
3. Specify constraints prohibiting particular combinations of configuration partitions

Design of Experiments Pairwise Combinations

4. **Specify configurations to test which cover all pairwise combinations of configuration parameter partitions satisfying the constraint**
   - "For any two parameters P1 and P2 and for any partition value V1 for P1 and V2 for P2, there is a specified configuration where P1 has the value V1 and P2 has the value V2. "

Pizza Example

1	Med	350
2	Low	350
3	High	350
4	Low	350
5	Low	350
1	Low	375
2	High	375
3	Med	375
4	Med	375
5	Med	375
1	High	400
2	Med	400
3	Low	400
4	High	400
5	High	400

Experiences with DOE in Software Testing

- Several companies have used DOE in software testing and have reported good results

- DOE has been shown to achieve reasonable code coverage

Warning

- Many software functions contain many parameters and factors

- Pairwise combination testing may leave many functions untested with normal, everyday scenarios

Summary

Specification Based Testing – Part 2

Mutation Testing

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Objective

Objective

Understand
Metamorphic
Testing

Test Oracle Problem

- A set of tests has been developed by an organization
- The organization executes the tests against a program
- All of the tests pass
- What can we conclude?

Mutation Testing

- Introduce defects (mutants) into program undergoing test
- Check to see if test cases can detect the mutant
- Work began in early 70's but was not widely adopted due to cost
- Today's automated testing environments make mutation testing feasible

Creating Mutants

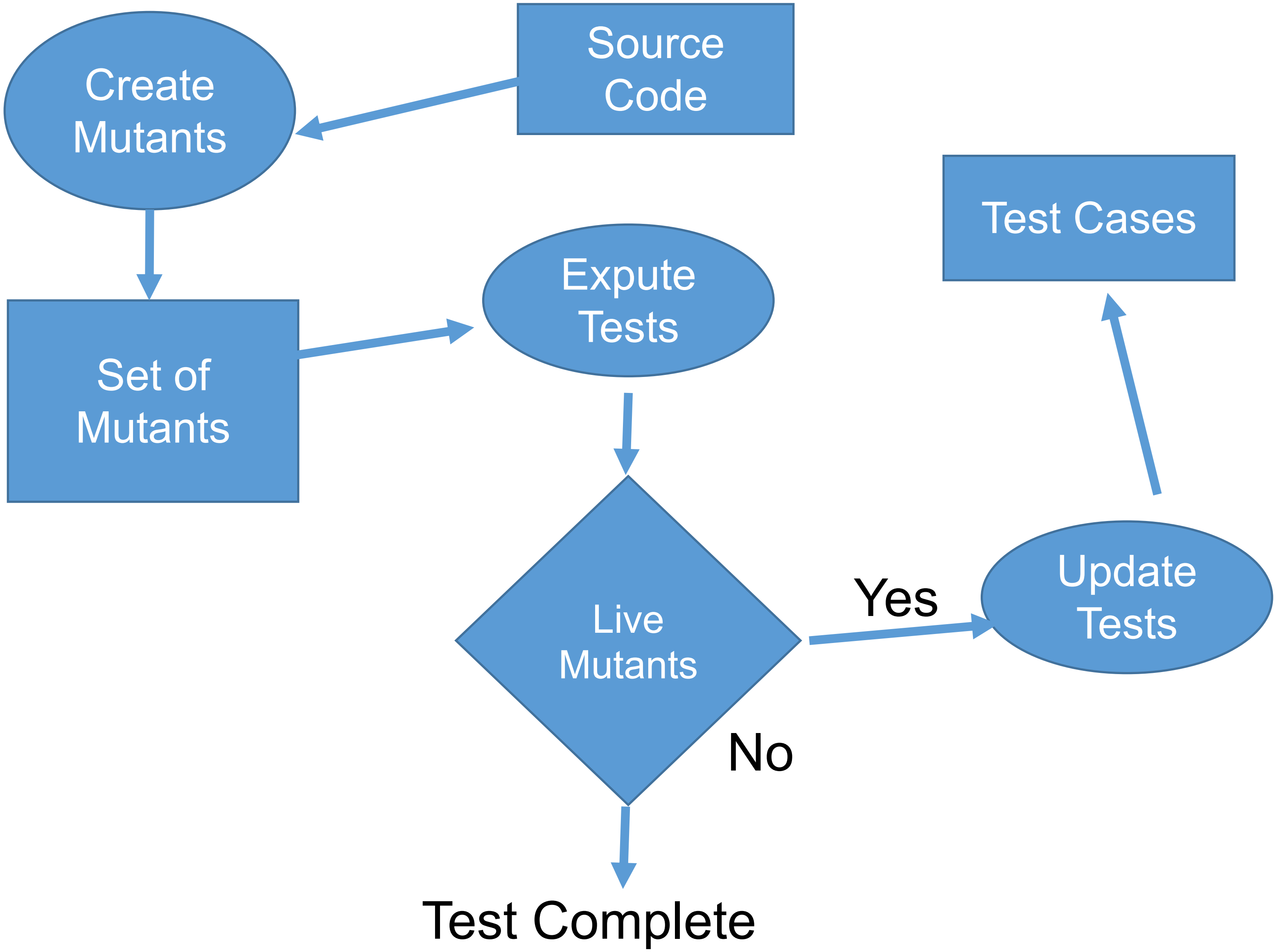
- Mutants are typically created via syntactical modifications of source code
- Mutation generation tools exist for this

- Examples of mutations
  - Modify Boolean expressions (< vs <=)
  - Delete Statement
  - Modify Variable
  - Modify arithmetic operation

Mutation Testing Assumptions

- **The Competent Programmer Hypothesis**
  - Programmers generally create code that is close to being correct reflecting only minor errors
- **The Coupling Effect**
  - Belief that test data that can detect small errors can also detect complex errors

The Mutation Testing Process



Summary

Specification Based Testing – Part 2

Fuzz Testing

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Objective

Objective

Understand Fuzz Testing

Fuzz Testing

- Approach to testing where invalid, random or unexpected inputs are automatically generated
- Often used by hackers to find vulnerability of the system
- Test oracle is not needed
  - Only monitor for crashes or undesirable behavior
- Fuzzing tool used to generate inputs

Two Types of Test Generators

Mutation Based

Generation Based

Mutation Based Fuzzing

- Generates test inputs by random modifications of valid test data
- Doesn't require knowledge of the inputs
- Modifications may be totally random or follow some pattern tied to frequent error types such as:
  - Long or blank strings
  - Maximum or minimum values
  - Special characters
- Some tools use "bit flipping" - corrupt input by changing random bits in input

Generation Based Fuzzing

- Generates random test data based on specification of test input format
- Anomalies are added to each possible spot in the inputs
- Knowledge of protocol should give better results than random fuzzing

When to Stop Fuzz Testing?

- Utilize code coverage tools

Summary

Specification Based Testing – Part 2

Metamorphic Testing

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Objective

Objective

Understand Metamorphic Testing

Test Oracle Problem

- For many applications it is difficult to determine the expected results
  - Graphics applications
  - Complex processing
  - Machine Learning
  - Big Data

- Fuzz testing can be used to detect crashes

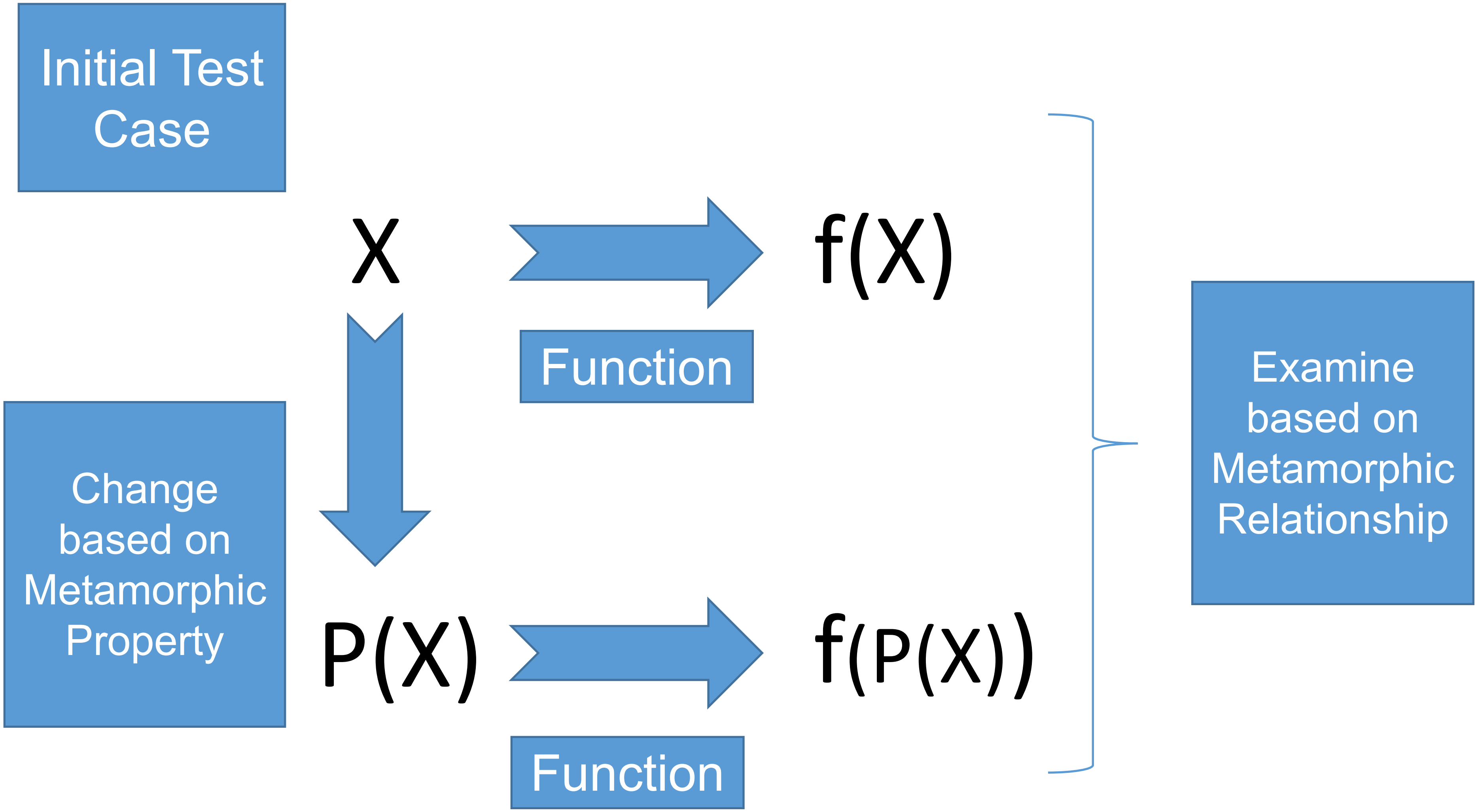
- Metamorphic testing can assist

Assumptions

- Some programs have properties such that when changes are made to inputs it is possible to predict changes on outputs (metamorphic properties)

- Consider a service that calculates the variance of a sequence of numbers
  - What is the relationship of changing the order?
  - What is the relationship of adding 10 to teach number?

Metamorphic Testing


Initial Test Case
X
f(X)
Function
Change based on Metamorphic Property
P(X)
f(P(X))
Function
Examine based on Metamorphic Relationship

Standard Deviation Example

- **Initial Test: 10, 20, 30, 40, 50**
  - Result: 14.142
- **Second Test: 20, 30, 40, 50, 60**
  - Result: 14.142
- **Third Test: 10, 30, 50, 70, 90**
  - Result: 28.284

Summary

Specification Based Testing – Part 2

Defect Based Testing

Objective

Objective

Apply Defect
Based Testing
Technique

Defect Based Testing

- Utilizes defect taxonomies to derive test cases
- A taxonomy is a system of hierarchical categories for classification
- Defect taxonomies provide a classification of software defects
- Numerous defect taxonomies exist
- Typically developed and evolved from defects detected in the past

Beizer Generic Defect Taxonomy Categories

- Requirements defects
- Feature defects
- Structure defects
- Data defects
- Implementation and coding defects
- Integration defects
- System and software architecture defects
- Test definition and execution defects
- Unclassified defects

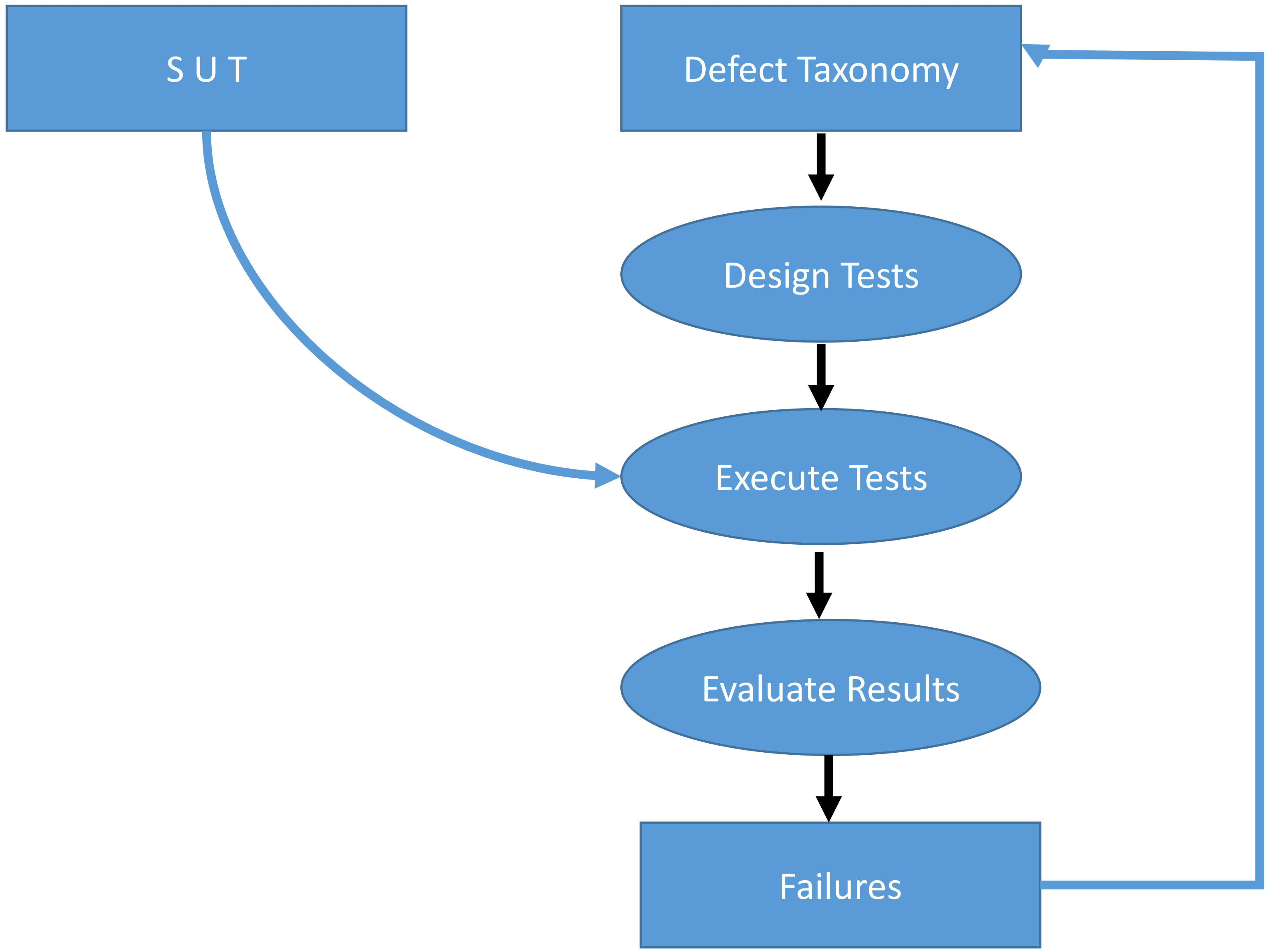
Community-Developed List of Software Weaknesses

- http://cwe.mitre.org/data/definitions/699.html

Defect Based Testing Approach

- Derive test cases to target specific defect categories
- Can be applied at any level of testing
- Example: consider developing tests to target divide by zero error in calculation

Defect Based Testing Process



Summary