Taxonomies of Fault-Detection Techniques

- Conventional taxonomies
- Based on operational characteristics
  - Static vs. Dynamic
- For example,

An Example Taxonomy

- Two dimensions
  - Types of documents
  - Static/dynamic

	Static	*Dynamic*
Requirements	Informal checklists Formal modeling	Functional testing Testing by classes of input data Testing by classes of output data
Design	Static analysis of design documents	Design-based testing
Programs	General information Static error analysis Symbolic execution	Structural testing Expression testing Data-flow testing

Why Taxonomy?

- Well suited to *planning* a series of validation activities
  - Identifies the type of documents required
  - Allows a manager to identify where a technique may fit into the product's lifecycle
- Helps cost estimation
  - Identify resources/needs/documents
  - Static analysis is computationally cheaper than dynamic
    - May be misleading

Observations

- No single testing technique is capable of finding all faults
- Every technique involves a tradeoff
  - Between accuracy and completeness on one hand
  - And tractability on the other
- Various software validation *schemes* have been defined
  - Combine several techniques by applying them in sequence
- Limited success

Drawback of Operational Characterization

- Limited success because of static/dynamic analysis orientation
- Predisposes one to view each technique in isolation
- Obscures the important issues of technique interaction
- Dimensions of tradeoff are orthogonal to the issue of program execution
- Conventional taxonomies do not adequately address tradeoffs between accuracy and computational effort/cost

Practical Testing

- Sampling subset of program behaviors
  - Execute a few program paths
- Folding states together
  - Abstracting away details to create a model
    - Control-flow model
    - Data-flow model
- Discussion

Sampling

- Explore few states
  - Statement
  - Branch
  - Path
    - All feasible paths
  - Exhaustive
    - All inputs

Merely Hopeless

Truly Impossible

- Threshold of tractability!
- Threshold of decidability!

Inaccuracy

- Can we fail to reject an incorrect program?
  - Optimistic inaccuracy
- Can we fail to accept a correct program?
  - Pessimistic inaccuracy
- For practical techniques
  - Admit at least one inaccuracy
- Conservative techniques
  - Pessimistic inaccuracy
  - But no optimistic inaccuracy

Proving Correctness

- Impossible in general
- Construct proofs for some programs by abstracting away details
  - E.G., Flow-graphs, "virtual coarsening"
  - Data-flow
  - Static type checking?
  - If successful, then program *is* (may be) correct
  - Failure to find a proof?
    - Program "may" or "may not" be incorrect
    - Pessimistic inaccuracy

Folding

- Abstracting away details
  - Structural properties
  - Dataflow analysis

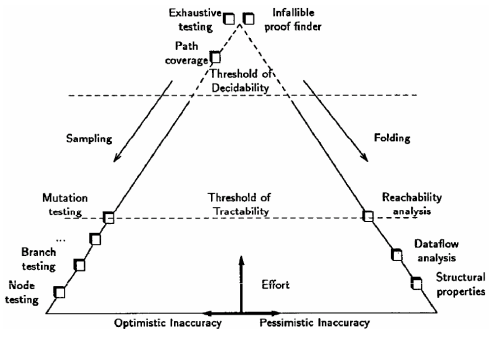
  } *Merely Hopeless*
  - Reachability analysis
  - Infallible proof finder

  } *Truly Impossible*

Combining Folding & Sampling

- First fold states to get a "smaller" state-space
- The sample a part of this state-space
- For example, create a Petri net model and execute it

Summary



Symbolic Evaluation

- Symbolic execution
  - Program flow-graph
    - Nodes for each program statement
    - "If" statement node has two out-edges
    - "While" statement node has two out-edges
  - Execution representation
    - Token represents a thread of control
    - Path expression
      - Program variables <-> symbolic values
    - Path conditions
      - Predicates describing the conditions

Symbolic Execution

- Initialize execution
  - Token on edge leading to first node
  - Path condition is TRUE
  - Path expression: associate each program variable with a unique symbol
- Execute
  - Advance token from in-edge to out-edge
    - Assignment statement: modify path expression
    - "If" and "while" statements: add a term to the path condition

Symbolic Execution

- Program state
  - Path expression & path condition
- State space
  - For a program without loops, what does the state space look like?
    - A tree: can (in principle) be exhaustively explored to check for problems
  - With loops, the state space is infinite. Only some paths may be checked, i.e., Explore a sample of the state space
- Symbolic testing
  - Start from the initial state to a terminal state

Symbolic Execution

- **Can we fail to reject an incorrect program?**
  - How about unexplored paths? What if a fault lies on one of them!!
  - Optimistic inaccuracy