



A Survey of UML-Based Coverage Criteria for Software Testing

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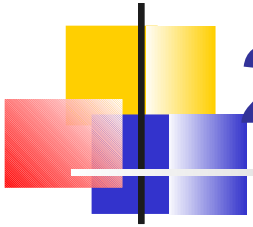
Overview

- Motivation
- Software Testing
- Adequacy Criteria
- Coverage Criteria
- UML-Based Coverage Criteria
- Discussion
- Future Work



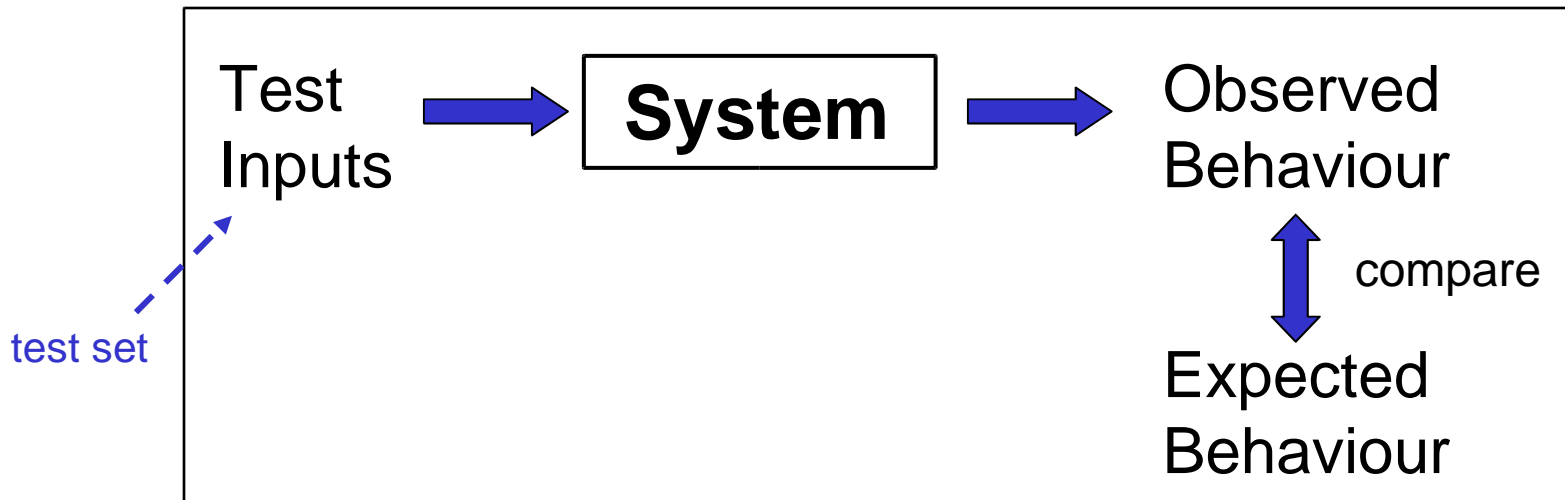
1 Motivation

- Investigate what coverage criteria exist
- Effectiveness of the coverage criteria
- Comparison of the coverage criteria



2 Software Testing

- Software testing
- Testing strategy





2.1 Adequate Testing

- How do you decide when enough testing has been done?
- How do you decide if a test set is adequate?





Adequacy Criterion

- An adequacy criterion is a rule or set of rules that specify the requirements that a test set must satisfy
- For example
 - Generate all inputs
 - Seed with faults
 - Cause certain parts of the system to be exercised



2.2 Coverage Criterion

- An adequacy criterion that specifies the elements of the system that must be exercised during testing
- An example
 - Statement Coverage
 - $x = -5$
 - $x = -5, x = 9$

```
public boolean foo(int x){  
    if(x < 0){  
        return false;  
    }  
    else{  
        return true;  
    }  
}
```



2.3 Importance of Adequacy Criteria

- Play an important role in software testing
 - Adequacy measurement
 - Measured in terms of coverage
 - Stopping rule
 - Derive test cases

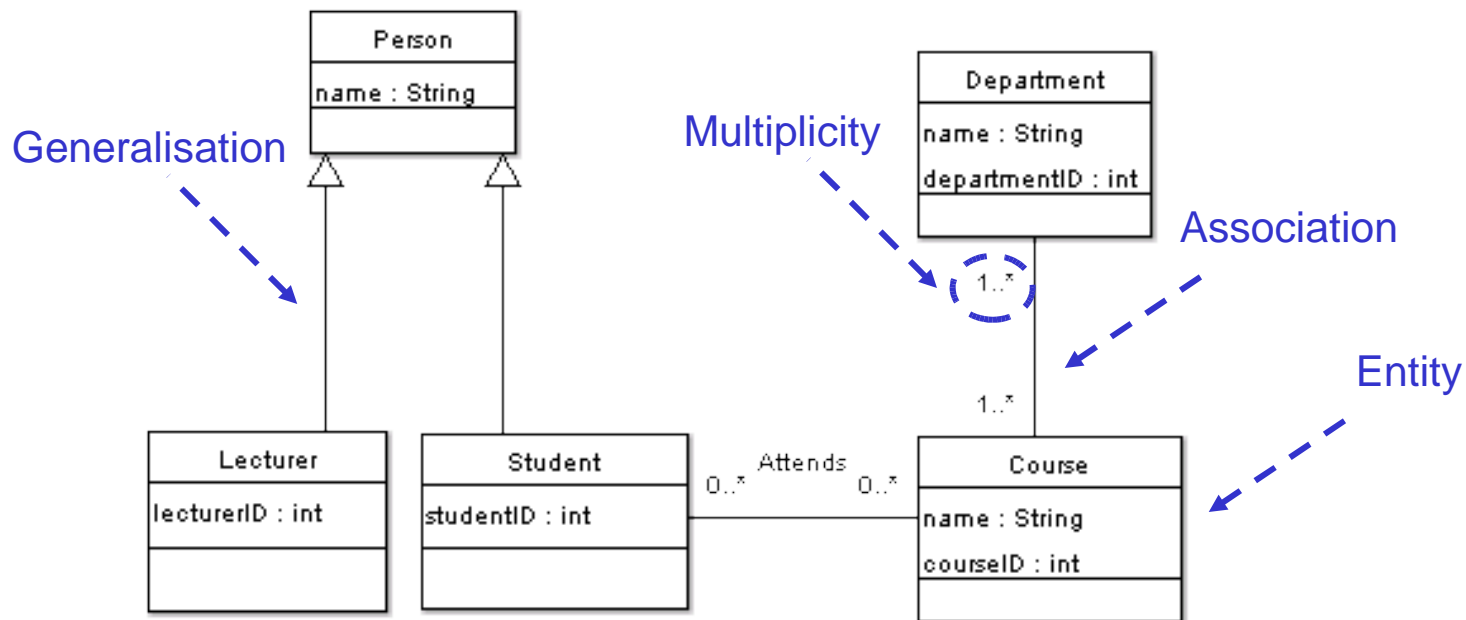


3 UML and Testing

- OO software presents a variety of new challenges for testing, compared to testing for procedural software
- UML used to model OO systems
- Investigate how UML can be used in the testing phase of the software development process
- UML-Based coverage criteria proposed
- Different approaches
 - Testing UML models
 - Testing the implementation
 - Diagrams statically reverse engineered
 - Diagrams dynamically reverse engineered

3.1 Class Diagram

- Shows the static structure of a system





Class Diagram Criteria

- Andrews *et al.*, Test Adequacy Criteria for UML Design Models. *Software Testing, Verification and Reliability*. 2003.
- Propose coverage criteria for class diagrams
 - Association-end Multiplicity Criterion
 - Generalization Criterion
 - Class Attribute Criterion
- Criteria used when testing UML design models

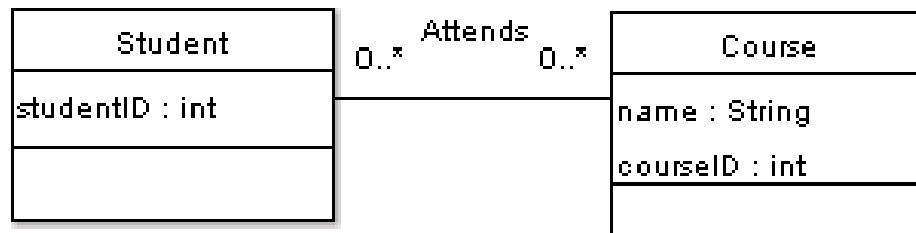
Association-end Multiplicity Criterion

- Given a test set T and a system model SM , T must cause each representative multiplicity-pair in SM to be created.
- For each association
 - Partition the multiplicity domains into equivalence classes
 - Select one value from each class to create a set of representative multiplicities
 - Create a set of multiplicity pairs from the cartesian product of the multiplicity sets



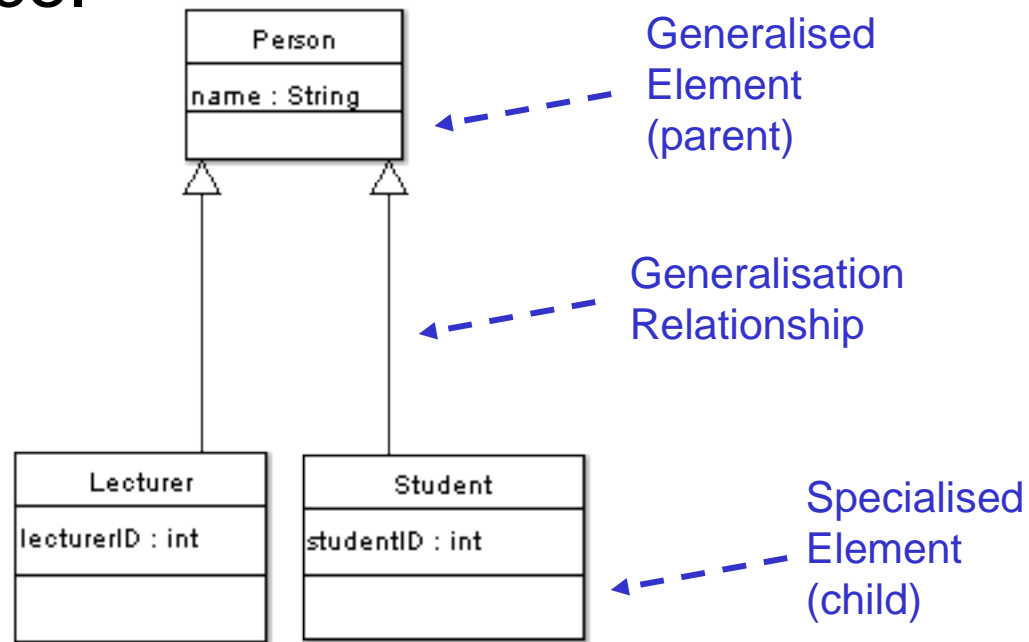
An Example

- Equivalence classes $\{0\}, \{1, \dots, n-1\}, \{n\}$
- Equivalence classes $\{0\}, \{1, \dots, m-1\}, \{m\}$
- Possible Multiplicity Set for class `Student` is $\{0, u, n\}$
- Possible Multiplicity Set for class `Course` is $\{0, v, m\}$
- Set of representative multiplicity pairs:
 $\{(0, 0), (0, v), (0, m), (u, 0), (u, v), (u, m), (n, 0), (n, v), (n, m)\}$



Generalisation

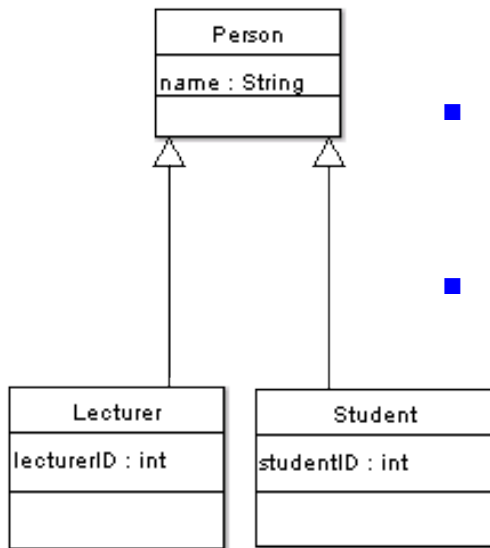
- Generalisation is typically implemented as inheritance.





Generalisation Criterion

- Given a test set T and a system model SM , T must cause every specialisation defined in a generalisation relationship to be created

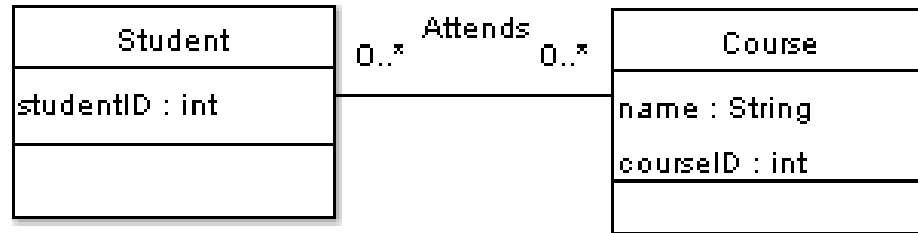


- Create an instance of the `Lecturer` class
- Create an instance of the `Student` class



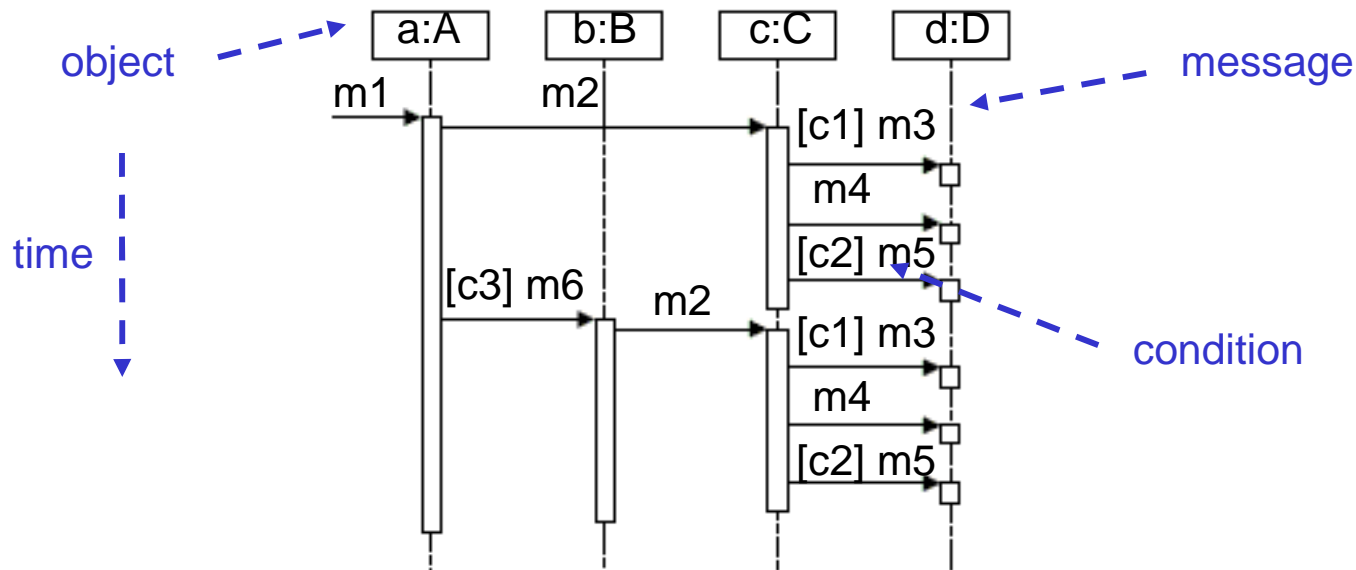
Class Attribute Criterion

- Given a test set T , a system model SM , and a class C , T must cause a set of representative attribute value combinations in each instance of class C to be created.



3.2 Sequence Diagram

- Depicts the exchange of messages between a set of objects
- Emphasis is on the time ordering of the messages

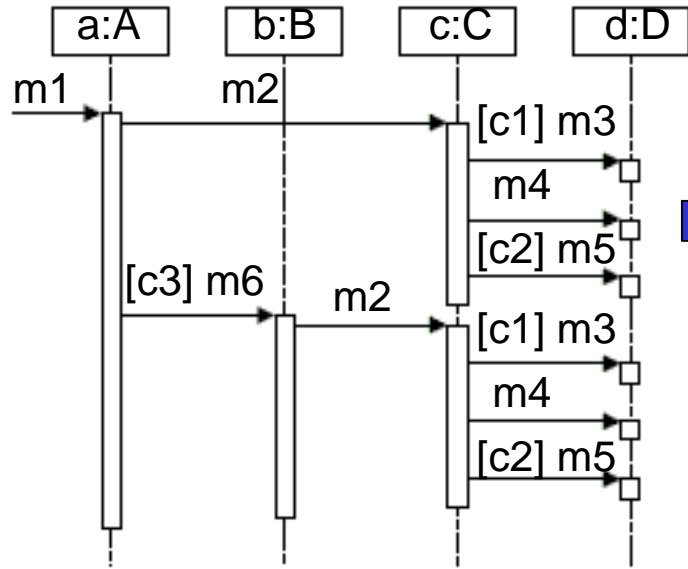




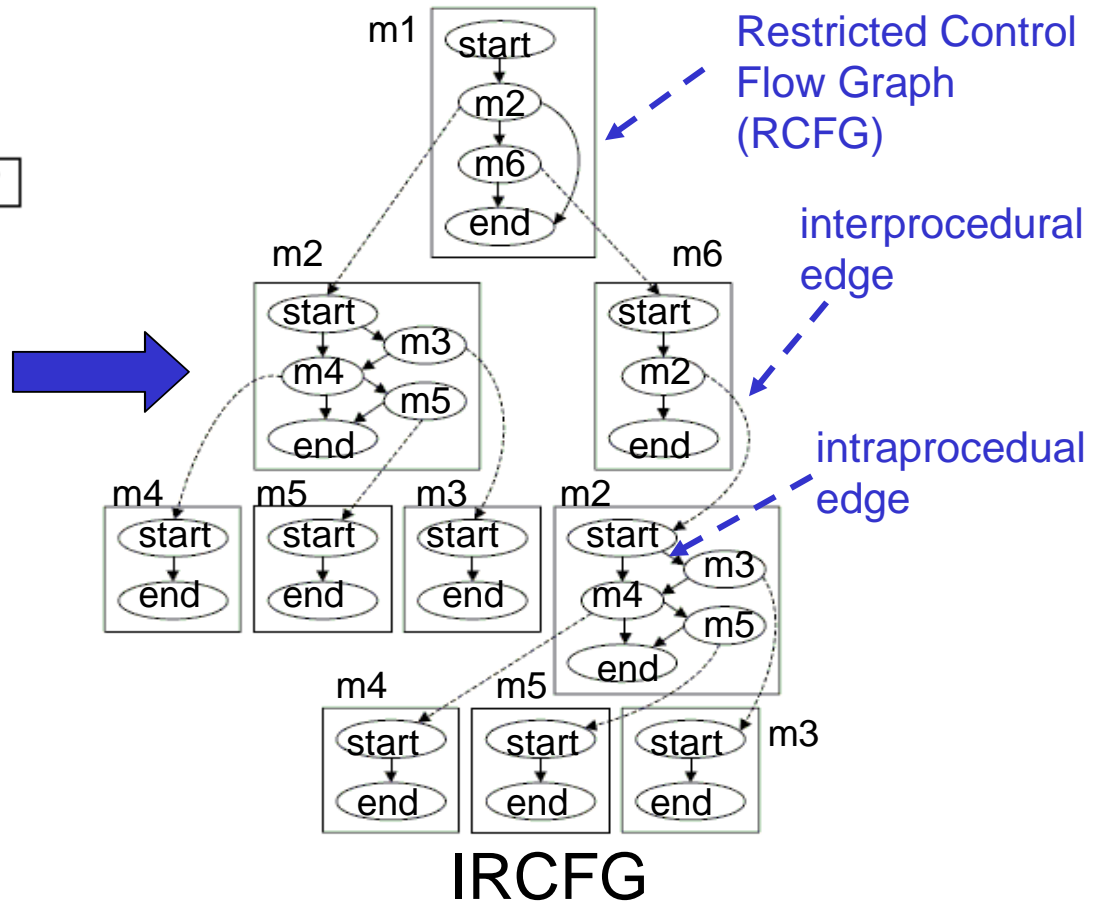
Sequence Diagram Criteria

- Rountev *et al.*, Coverage Criteria for Testing of Object Interactions in Sequence Diagrams. In *Fundamental Approaches to Software Engineering*. 2005.
- Propose coverage criteria for sequence diagrams
 - All-IRCFG-Paths Criterion
 - All-RCFG-Paths Criterion
 - All-RCFG-Branched Criterion
 - All-Unique-Branched Criterion
- Used in testing the implementation
- Statically reverse engineered

Interprocedural Restricted Control Flow Graph (IRCFCG)



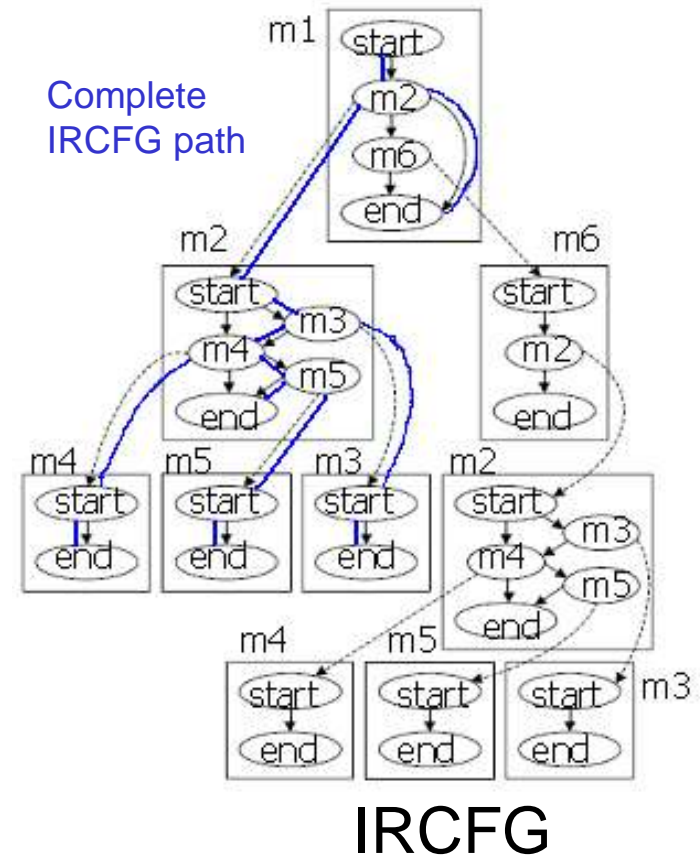
Sequence Diagram



IRCFCG

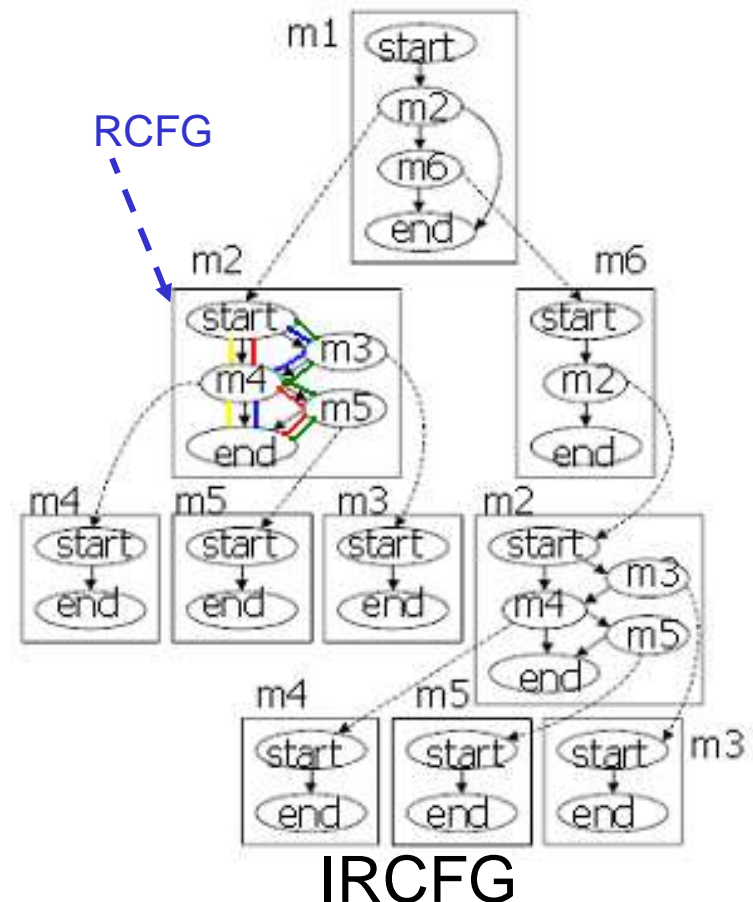
All-IRCFG-Paths Criterion

- IRCFG path corresponds to a complete start-to-end traversal of the IRCFG
- Equivalent to a start-to-end path in the sequence diagram
- A set of IRCFG paths P satisfies the all-IRCFG-paths coverage criterion if and only if P contains all IRCFG paths
- 20 complete IRCFG paths



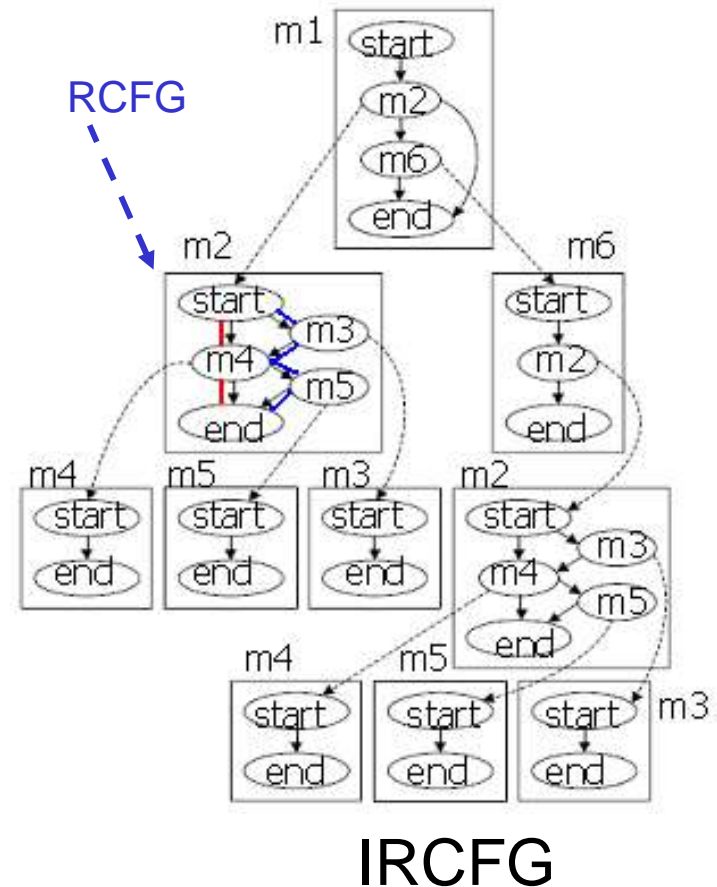
All-RCFG-Paths Criterion

- An RCFG path is complete traversal of the RCFG
- A set of IRCFG paths P satisfies the all-RCFG-paths coverage criterion if and only if P contains all RCFG paths
- 5 complete IRCFG paths



All-RCFG-Branched Criterion

- A set of IRCFG paths P satisfies the all-RCFG-branches coverage criterion if and only if for all edges e in each RCFG, there is at least one path p in P such that p contains the edge e .
- 3 complete IRCFG paths



3.3 Collaboration Diagram Criteria

- Andrews *et al.*, Test Adequacy Criteria for UML Design Models. *Software Testing, Verification and Reliability*. 2003.
- Abdurazik *et al.*, Using UML Collaboration Diagrams for Static Checking and Test Generation. In *Third International Conference on the Unified Modelling Language*. 2000.



3.4 Statechart Diagram Criteria

- Kim *et al.*, Test Cases Generation from UML State Diagrams. *IEEE Software Engineering*. 1999.
- Viera *et al.*, Object-Oriented Specification-Based Testing Using UML Statechart Diagrams. In *Proceedings of the ICSE Workshop on Automated Program Analysis, Testing and Verification*. 2000.



More...

- J. A. McQuillan and J. F. Power. A Survey of UML-Based Coverage Criteria for Software Testing. *Technical Report*. Department of Computer Science, NUI Maynooth. 2005.



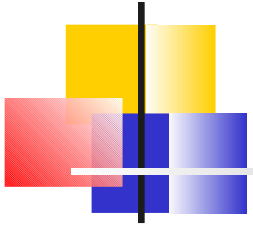
4 Discussion

- Lack of empirical evidence to demonstrate the fault revealing capabilities of the criteria
- Lack of empirical evidence comparing the criteria



5 Future Work

- Important topics for future investigation
- Propose new criteria



Thank You!