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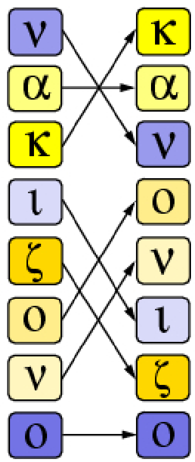
Towards the Prioritization of Regression Test Suites with Data Flow Information



Kanonizo

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Definitions

- **Test Case** – An individual unit test
- **Test Suite** – A tuple of test cases
- **Regression Testing** – Testing that occurs after the completion of development or maintenance activities when a test suite comprised of all accumulated unit tests is executed
- **Test Prioritization** – The process of arranging test cases in a given test suite to facilitate the detection of defects earlier in the execution of the test suite

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Motivation

- Regression testing may account for as much as one-half the cost of software maintenance
- Prioritization is often more feasible than test selection
- Tests that fulfill the *all-DUs* test adequacy criteria are more likely to reveal defects than those that satisfy control flow based criteria

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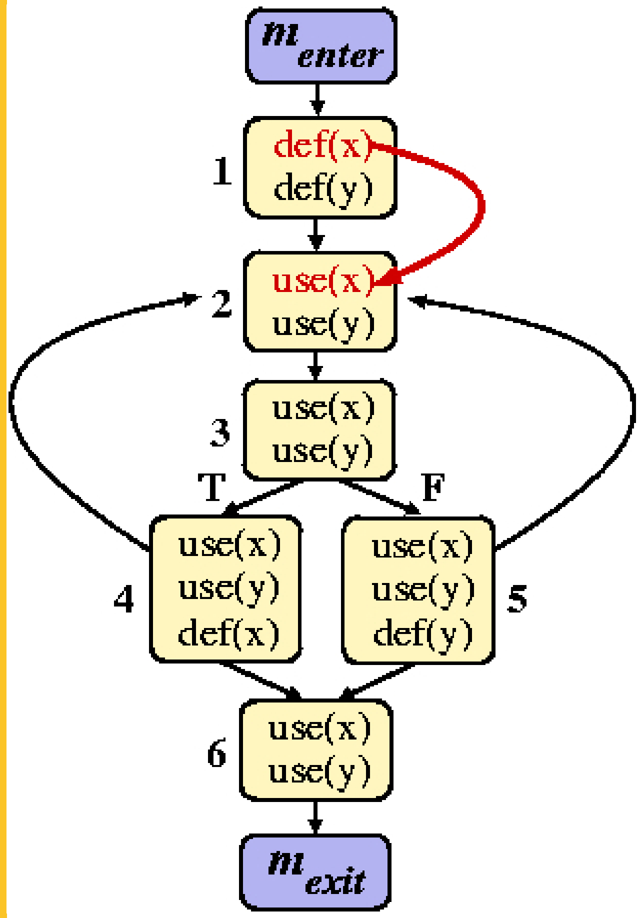
Dataflow



- Model each method in a program as a control flow graph
- Control flow flow family of test criteria (ex: *all-nodes*, *all edges*, *all-paths*)
- Data flow criteria evolved from control flow (ex: *all-DUs*, *all-P-Uses*, *all-C-Uses*)
- Focus on intraprocedural def-use associations

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Metrics

- *APFD* – The rate of fault detection per percentage of test suite execution

$$APFD(T,P) = 1 - \frac{\sum_{i=1}^{g} reveal(i,T)}{rg} + \frac{1}{2r}$$

- *PTR* – Percentage of a given test suite that must be executed for all faults to be detected

$$PTR(T,P) = \frac{r_g}{r}$$

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Metrics Example

Test Case	Faults				
	f_1	f_2	f_3	f_4	f_5
T_1			×	×	
T_2	×	×			
T_3	×	×	×		
T_4			×	×	×
T_5		×	×		

$\sigma_1 = \langle T_1, T_2, T_3, T_4, T_5 \rangle$ $\sigma_2 = \langle T_3, T_4, T_1, T_2, T_5 \rangle$

- $APFD(T_1, P) = 1 - .4 + .1 = .7$
- $PTR(T_1, P) = \frac{4}{5}$
- $APFD(T_2, P) = 1 - .2 + .1 = .9$
- $PTR(T_2, P) = \frac{2}{5}$

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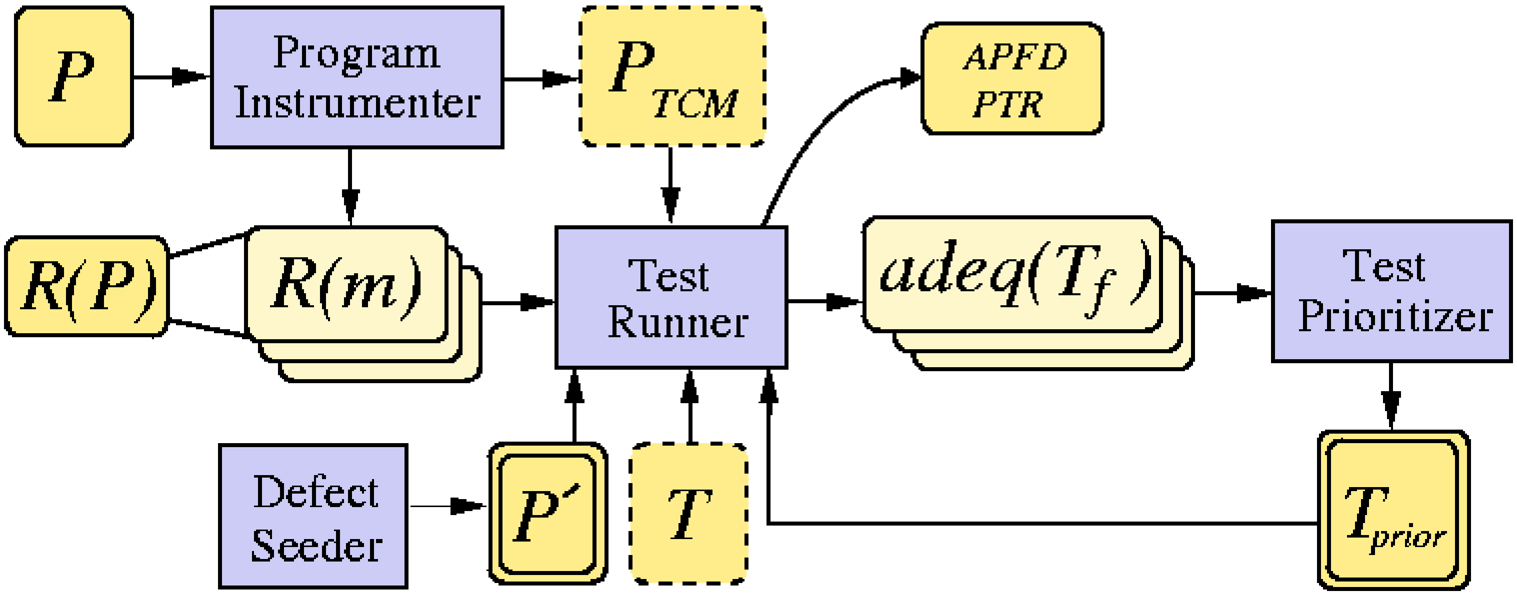
Experiment Design



InstrumentandEnumerate

- Calculate the set of test requirements for program *P*
- Introduce test coverage monitoring instrumentation
- Execute test suites and report *APFD* and *PTR* calculations

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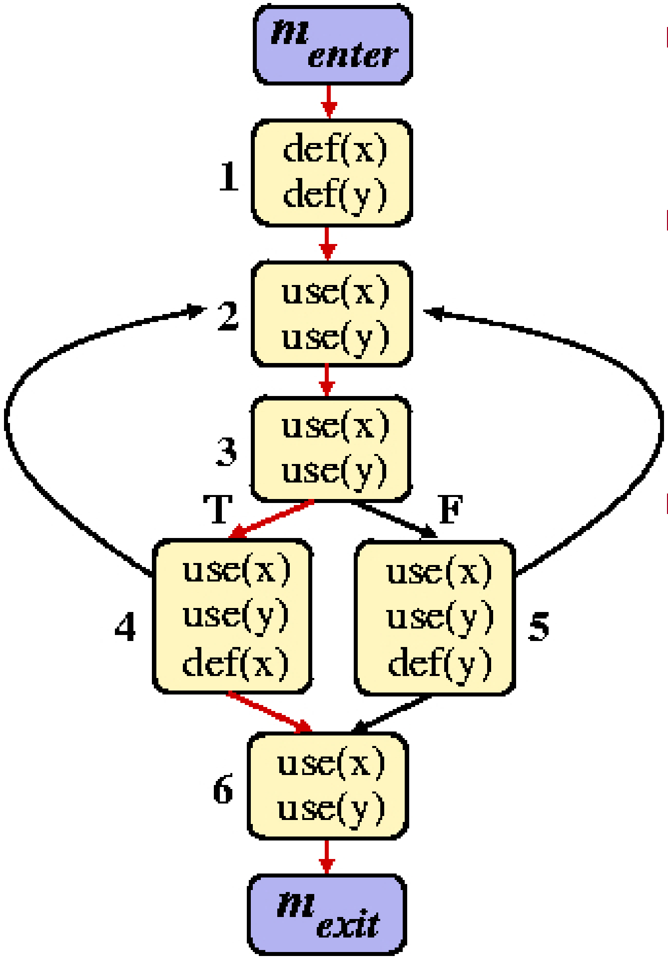
Cumulative Adequacy of a Test Case

- When a test case has covered both a *def* and corresponding *use* statement, the coverage of that association is stored
- **Test case adequacy** – The ratio between the number of covered test requirements and the total number of test requirements for all of the methods under test

$$adeq(T_f) = \frac{\sum_{k=1}^{h} |R_c(m_k)|}{\sum_{k=1}^{h} |R(m_k)|}$$

Cumulative Adequacy Example



- Model each method in a program as a control flow graph
- T_f enters method *m* and executes the **`true`** branch of node 3
- $$adeq(T_f) = \frac{7}{16} = 43.75\%$$

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Experimentation Statistics

- Experiments conducted on a GNU/Linux workstation with dual 1GHz Pentium III Xeon processors, 512 MB of main memory

Case study applications:

- **`Bank`** – 1 class, 53 def-use associations, 5 methods, 7 test cases, 4 seeded errors
- **`Identifier`** – 3 classes, 81 def-use associations, 13 methods, 11 test cases, 2 sets of 3 seeded errors
- **`Money`** – 3 classes, 302 def-use associations, 33 methods, 21 test cases, 3 sets of 3 seeded errors

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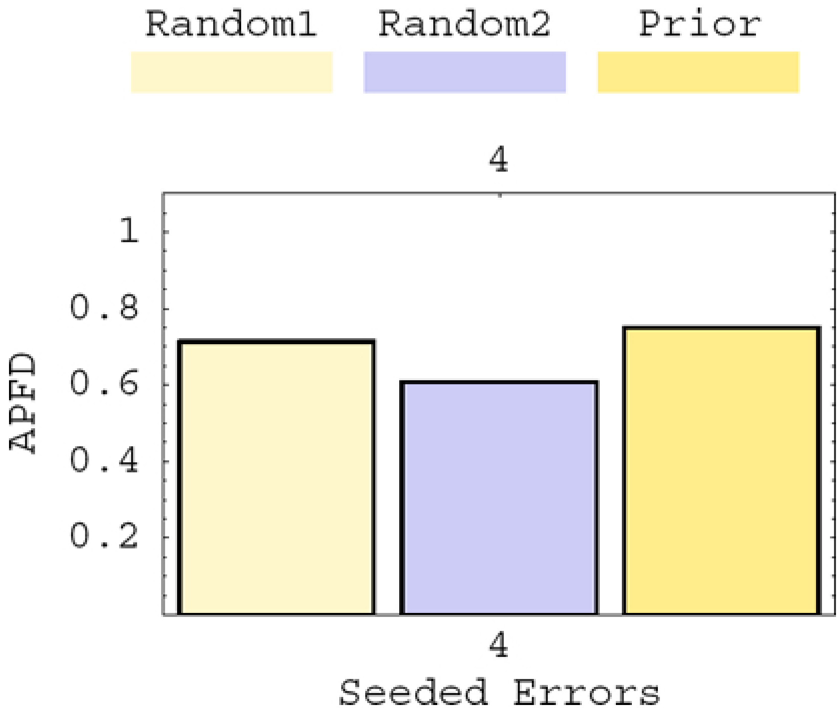
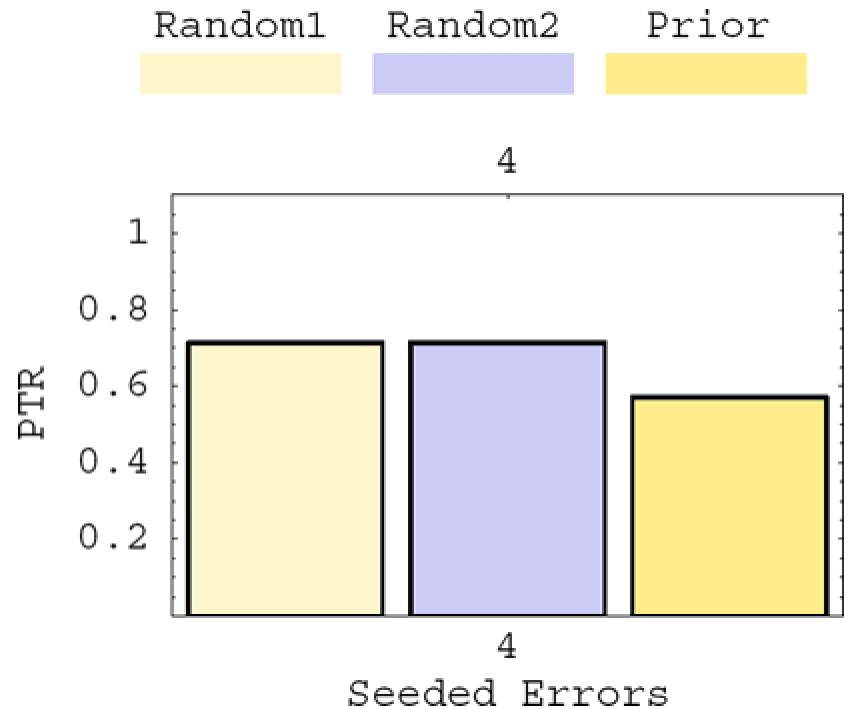
Bank *APFD* and *PTR* Measurements



Bank *APFD*



Bank *PTR*

- Prioritized suite has best *PTR* value
- Prioritized suite has the best *APFD* value, slightly better than Random1

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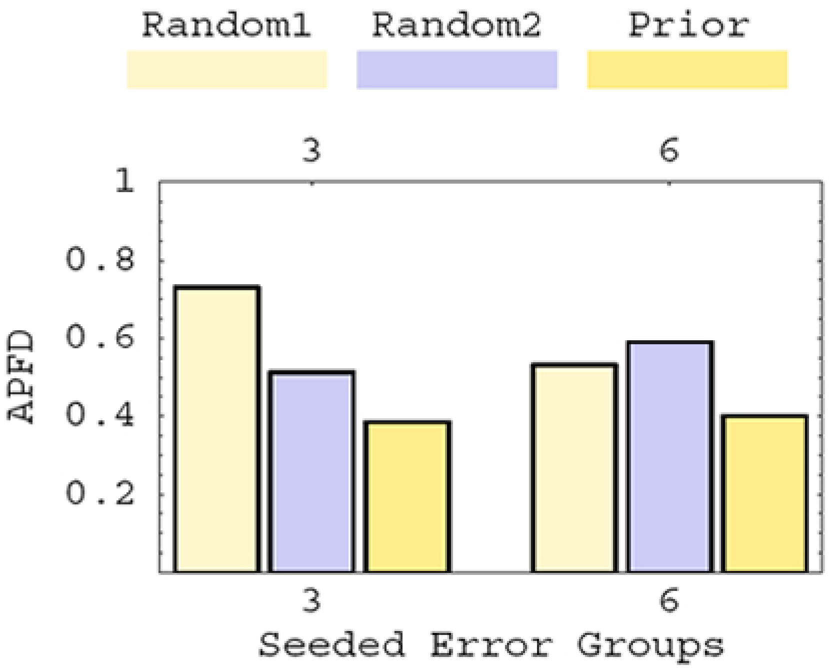
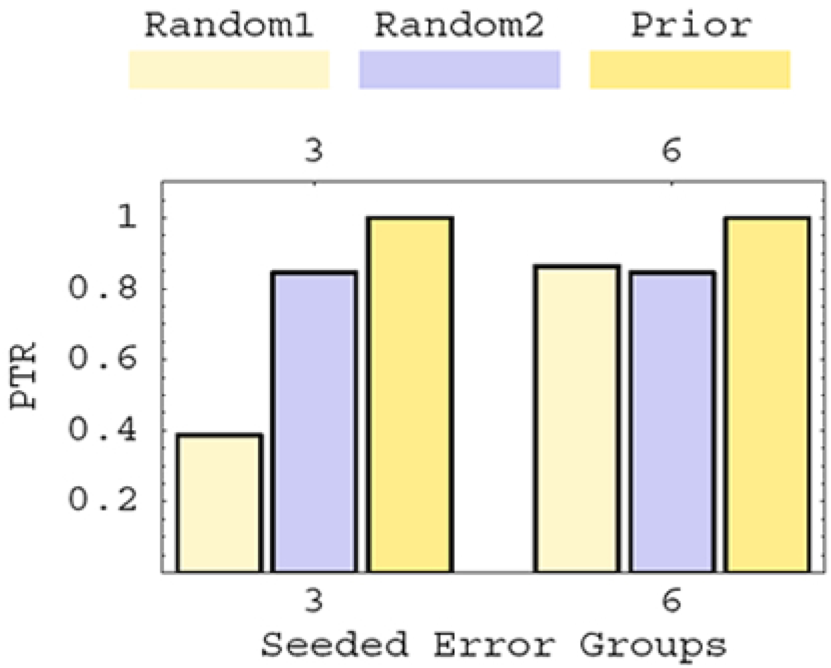
Identifier *APFD* and *PTR* Measurements



Identifier *APFD*



Identifier *PTR*

- Prioritized suite has the worst *PTR* value
- Prioritized suite has the worst *APFD* value

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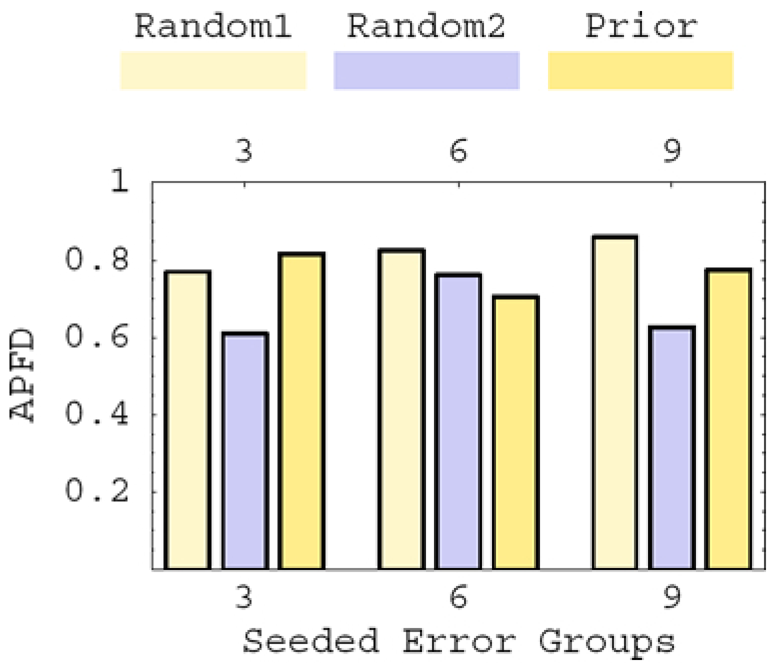
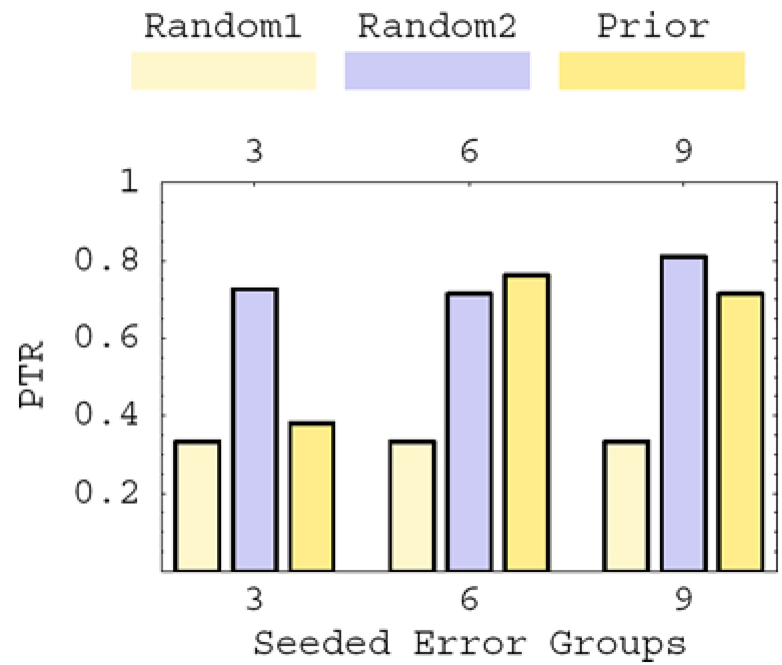
Money *APFD* and *PTR* Measurements



Money *APFD*



Money *PTR*

- Prioritized suite has best *APFD* for 3 errors, worst for 6 errors, medium for 9 errors
- Prioritized suite has medium *APFD* for 3 errors, slightly worse than Random1, worst for 6 errors, medium for 9 errors

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Time and Memory Requirements

Program	Time (ms)	Space (bytes)
`Bank`	3,210	1,084,648
`Identifier`	3,351	2,170,871
`Money`	9,176	4,984,648

Time and Memory for *InsturmentandEnumerate* Algorithm

- Test case monitoring did not cause significant increases in the time required to execute test cases

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Conclusions

- Test suites can be prioritized according to *all-DUs* with minimal time and space overhead
- Preliminary results indicate that data flow-based prioritizations are not always more effective than random prioritizations
- Successfully created a low-overhead framework for performing test prioritization which can be used in future studies

Future Work

- Incorporation of control flow-based and mutation-based adequacy into **`Kanonizo`**
- The comparison of our prioritization approach to other prioritization schemes beyond random
- The calculation of *APFD* and *PTR* for all permutations of an application's test suite
- Experimentation with additional case studies that have larger program segments and test suites
- The investigation of prioritization techniques for test suites that must be executed within a specified time constraint

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Related Work

- Sebastian Elbaum et al. Prioritizing test cases for regression testing. *Proceedings of the International Symposium on Software Testing and Analysis*. ACM Press, August 2000.
- Phyllis G. Frankl et al. An applicable family of data flow testing criteria. *IEEE Transactions on Software Engineering*, October 1988.
- G. Rothermel et al. A framework for evaluating regression test selection techniques. Proceedings of the 16th International Conference on Software Engineering, *IEEE Computer Society Press*, May 1994.

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Resources

- Kanonizo Research Group: http://cs.allegheny.edu/~gkapfham/research/kanonizo.
- Gregory M. Kapfhammer *The Computer Science Handbook* Chapter “Software Testing”. CRC Press, June 2004.
- Matthew Rummel, Greg Kapfhammer, and Andrew Thall Towards the Prioritzation of Regression Test Suites with Data Flow Information. *Proceedings of the ACM SIGAPP Symposium on Applied Computing*, Santa Fe, New Mexico, March 2005.