Set Covers, Knapsacks, and Regression Testing Techniques

Gregory M. Kapfhammer[†]

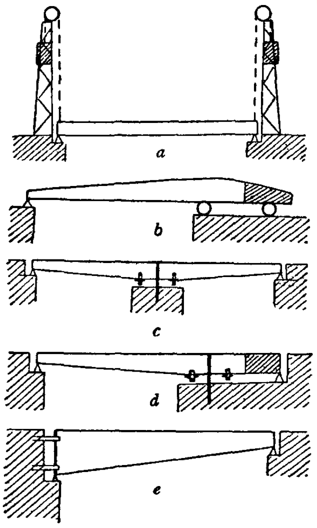
Department of Computer Science
Allegheny College, Pennsylvania, USA
http://www.cs.allegheny.edu/~gkapfham/

Madras Christian College, February 2008

[†] In Conjunction with Mary Lou Soffa, Kristen Walcott (UVa/CS)
Suvarshi Bhadra, Joshua Geiger, Adam Smith, Gavilan Steinman, Yuting Zhang (Allegheny/CS)

Featuring images from the WikiMedia Commons

Presentation Outline



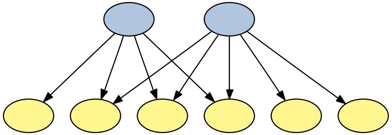
The Challenge of Software Testing

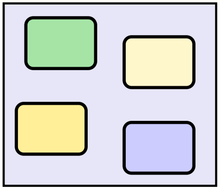
I shall not deny that the construction of these testing programs has been a major intellectual effort: to convince oneself that one has not overlooked “a relevant state” and to convince oneself that the testing programs generate them all is no simple matter. The encouraging thing is that (as far as we know!) it could be done.

Edsger W. Dijkstra, *Communications of the ACM,* 1968

Additional Challenge: understanding the **fundamental** difficulties associated with **practical** testing techniques

NP-Complete Problems



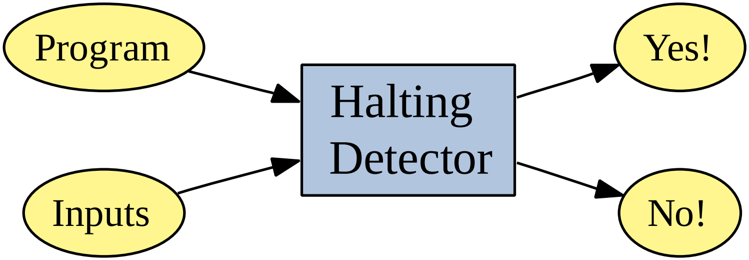


Minimal Set Cover

0/1 Knapsack

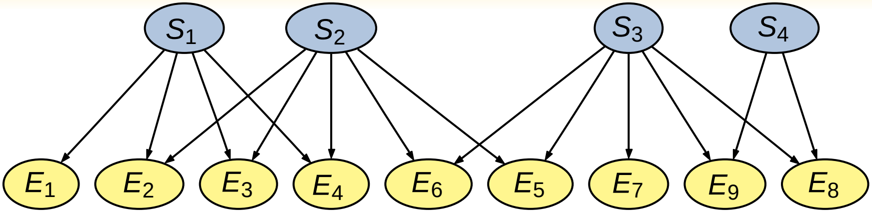
Question: what are the connections between the **theory** and **practice** of computer science?

Halting Problem



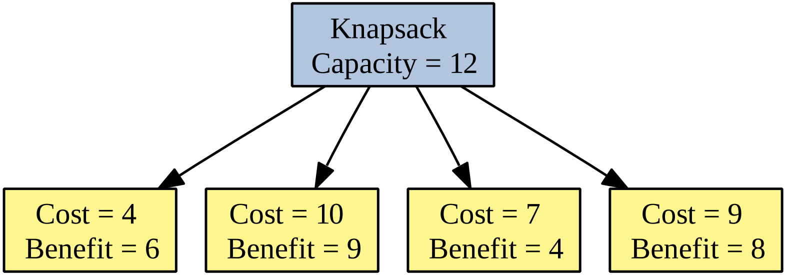
- **Question**: What approach can we take in order to completely implement the halting detector?
- You can assume **any** existing hardware platform (e.g., fast multi-core processor) or software application (e.g., compiler).

Minimal Set Cover Problem



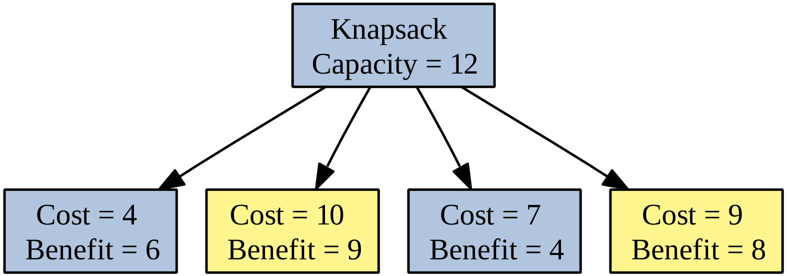
- Sets contain elements (e.g., $S_2 \rightarrow E_4$ means that set S_2 contains the element E_4)
- **Question**: Can you find a **subset** of the sets that will contain all of the elements?
- This problem is **NP-complete** (see Garey and Johnson) and yet it has many practical applications in software testing

0/1 Knapsack Problem



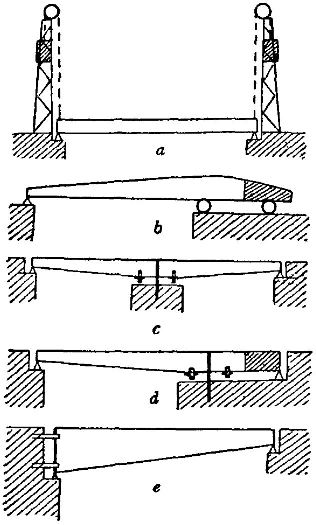
- **Question**: Can you select items so that you **maximize** the benefit while ensuring that the cost does not **exceed** the capacity?
- This problem is **NP-complete** (see Garey and Johnson) and yet it also has many practical applications in both software and finance

0/1 Knapsack Problem

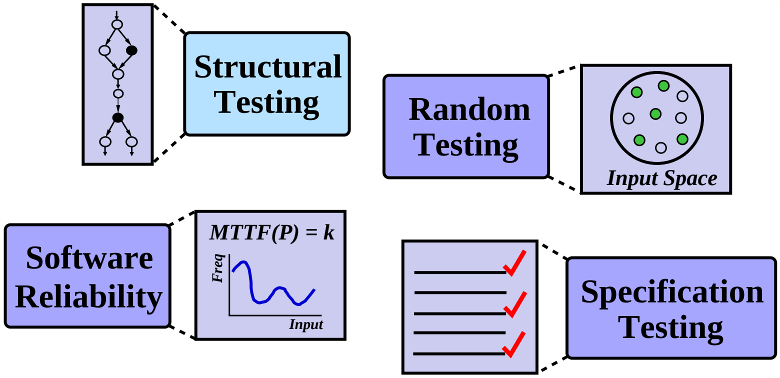


- **Question**: Can you select items so that you **maximize** the benefit while ensuring that the cost does not **exceed** the capacity?
- This problem is **NP-complete** (see Garey and Johnson) and yet it also has many practical applications in both software and finance

Presentation Outline

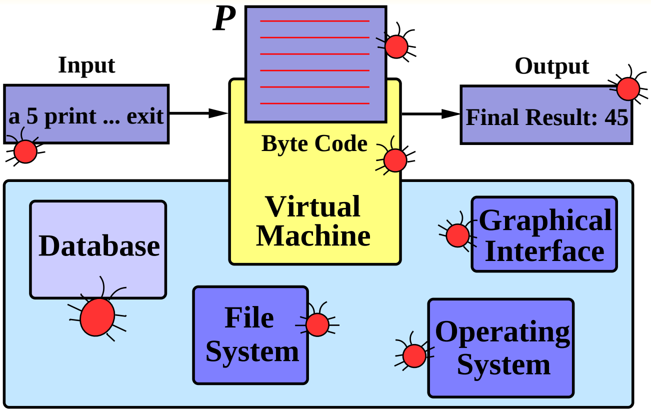


Approaches to Software Testing



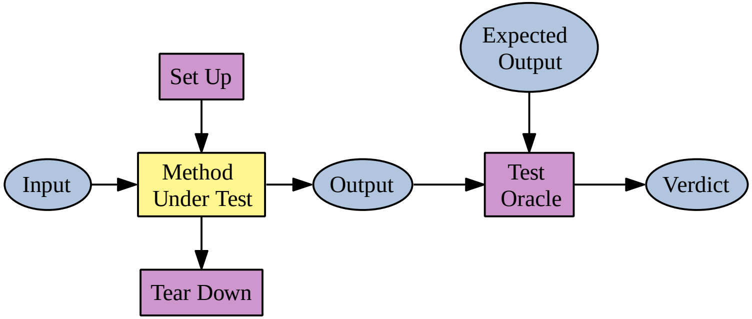
Testing **isolates defects** and establishes a **confidence in the correctness** of a software application

Where are Defects Located?



Defects may exist in the individual **components** or the **interactions**

What is a Test Case?



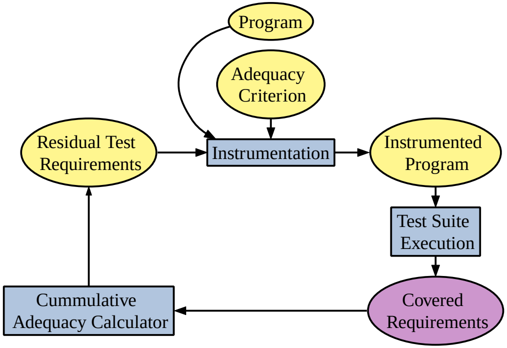
- Test suite executor runs each test case **independently**
- Each test invokes a method within the program and then compares the **actual** and **expected** output values

Using Tests to Find Faults

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

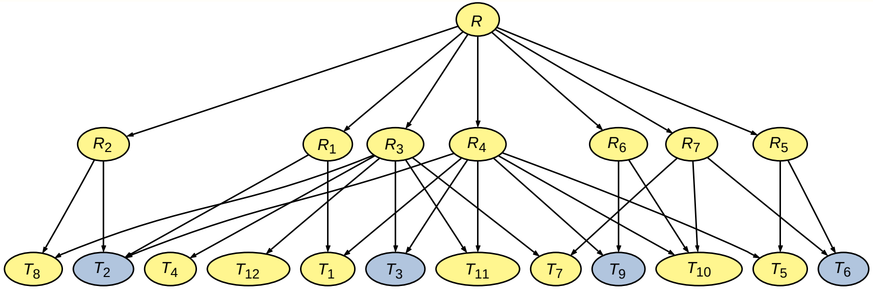
- **The Importance of Test Ordering**: $\langle T_3, T_4, T_1, T_2, T_5 \rangle$ detects faults more rapidly than $\langle T_1, T_2, T_3, T_4, T_5 \rangle$
- Since we do not have **a priori** knowledge of the faults that exist within a program, we must use a proxy like **coverage**

Test Coverage Monitoring



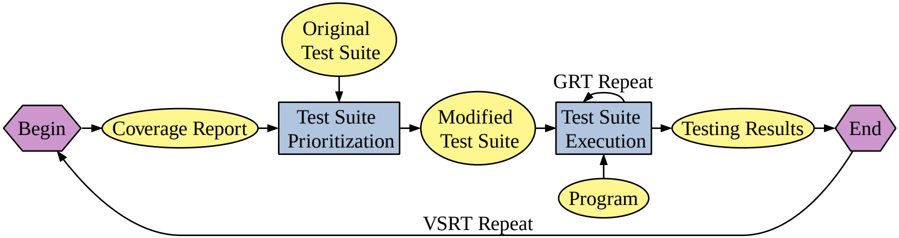
- Structural **adequacy criteria** focus on the coverage of nodes, edges, paths, and definition-use associations
- Instrumentation **probes** track the coverage of test requirements

Finding the Overlap in Coverage



- $R_j \rightarrow T_i$ means that requirement R_j is **covered by** test T_i
- $T = \langle T_2, T_3, T_6, T_9 \rangle$ covers **all** of the test requirements
- Test suite **reduction** discards the test cases that **redundantly** cover the test requirements

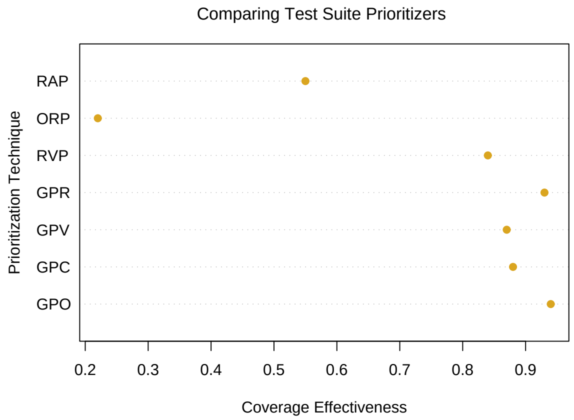
Regression Test Suite Prioritization



Overview

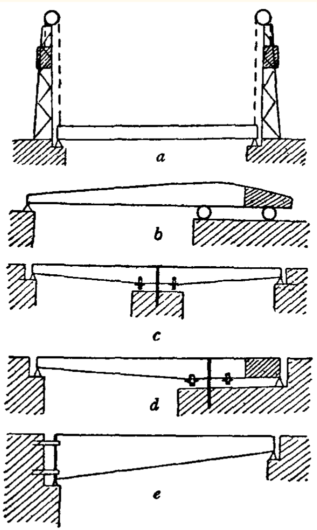
- Prioritization **re-orders** the tests so that they cover the requirements more effectively
- **GRT** uses the **same** prioritization across multiple runs of the test suite whereas **VSRT** creates a **new** prioritization for each test run

Comparing Prioritization Techniques



Which prioritization technique is the **best**?

Presentation Outline



Time-Aware Orderings (Fault Data)

	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8
T_1	X	X		X	X	X	X	X
T_2	X							
T_3	X				X			
T_4		X	X				X	
T_5				X		X		X
T_6		X		X		X		

- It is very common to confront a testing **time budget**
- **Question**: If fault information is **known** and there is a testing time **limit**, then what is the **best** ordering?

Time-Aware Orderings (Faults and Costs)

	# Faults	Time Cost	Avg. Faults per Min.
T_1	7	9	0.778
T_2	1	1	1.000
T_3	2	3	0.667
T_4	3	4	0.750
T_5	3	4	0.750
T_6	3	4	0.750

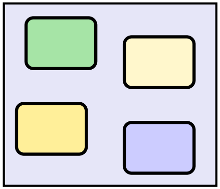
- When test case cost **varies**, then some tests are able to detect fault more **rapidly** than the others
- **Question**: What is the best ordering for this test suite?

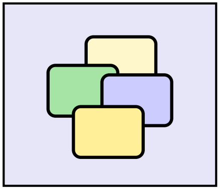
Time-Aware Orderings (Comparison)

	Time Limit: 12 minutes			
	Fault	Time	APFD	Intelligent
	T_1	T_2	T_2	T_5
		T_3	T_1	T_4
		T_4		T_3
		T_5		
Tot. Faults	7	8	7	8
Tot. Time	9	12	10	11

- The **existence** of a time limit **prevents** the use of traditional minimal set cover solvers that only look at **overlap**
- When fault information is **not** available, we can use **coverage**

Comparing Time-Aware Prioritizers



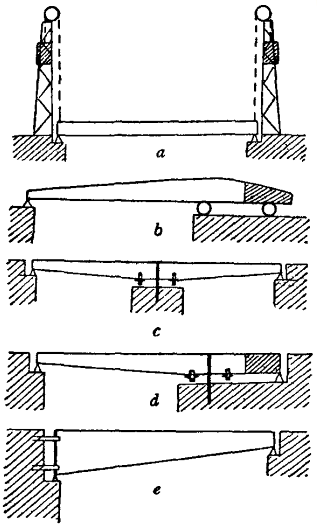


Traditional 0/1 Knapsack Solvers

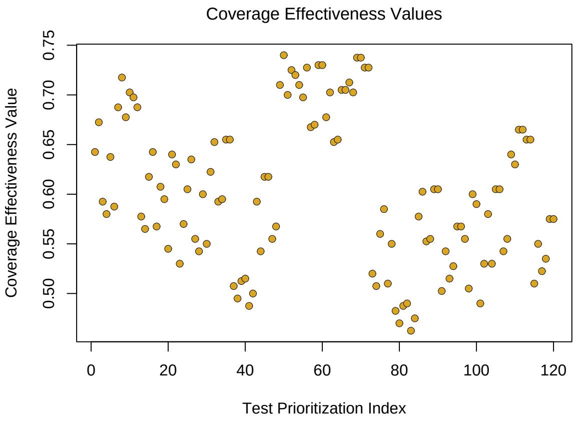
Genetic Algorithm Techniques

Empirical Results: prioritizers that consider coverage **overlap** take **longer** to re-order, but they arrive at **good** orderings

Presentation Outline

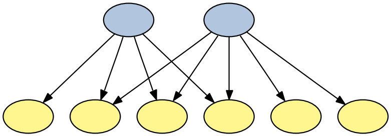


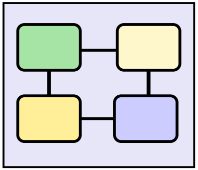
Search-Based Test Suite Prioritization



Use **heuristic search** (HC, SANN, GA) to prioritize the test suite

Detailed Empirical Evaluations



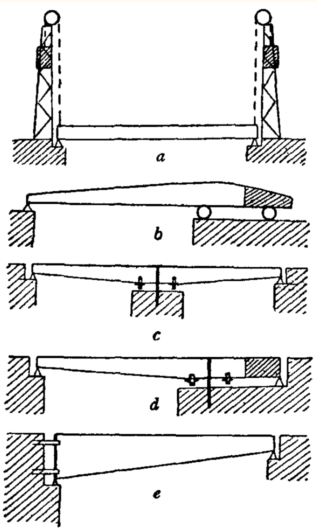


Synthetic Test Suites

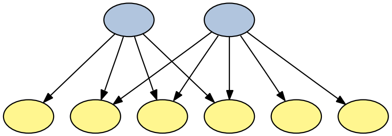
Real World Programs

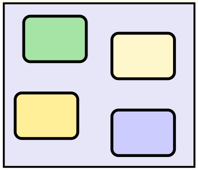
Conduct experiments to **systematically** study the trade-offs associated with testing techniques by using both **synthetic** coverage and **real world** applications

Presentation Outline



Concluding Remarks





Minimal Set Cover

0/1 Knapsack

- Establishes a **connection** between **practical** regression testing challenges and **NP-complete** problems
- Many approaches to testing are now **ready** for integration into frameworks such as **JUnit**

Personal Reflections

So now, come back to your God! Act on the principles of love and justice, and always live in confident dependence on your God.

Hosea 12:6 (New Living Translation)

Please keep in touch!

http://www.cs.allegheny.edu/~gkapfham/