Reducing the Cost of Regression Testing by Identifying Irreplaceable Test Cases

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Outline

- Introduction
- Related work
- Reducing the execution cost of a test suite
- Experimental analysis
- Conclusion

Introduction: Software Testing

- Software testing
  - To detect and isolate defects while implementing software systems.
- Test case
  - A set of input data and expected output results which are designed to exercise a specific software function or test requirement.

Test case \ Test requirement	r_1	r_2	r_3
t_1	●	●	
t_2			●
t_3		●	
t_4	●		

Introduction: Test Suite

- It is difficult for a single test case to satisfy all of the specified test requirements.
- A considerable number of test cases are usually generated and collected in a test suite.

Test requirement / Test case	r_1	…	r_{3000}
t_1	●		
t_2			●
:			
$t_?$	●		

Introduction: Regression Testing

- In an attempt to ensure both the correctness of new code and its proper integration into the system, all test case in test suite *T* should be executed.

Introduction: Test Suite Reduction

- To remove the redundant test cases while still ensuring that all test requirements are satisfied.

Test	r_1	r_2	r_3
t_1	●	●	
t_2			●
t_3		●	
t_4	●		

Greedy Algorithm

- A commonly-used method for finding the near-optimal solution to the test suite reduction problem.
- It repeatedly removes the test *t* that has the maximum ***Coverage*(*t*)** from *T* to *RS* until all of the requirements are covered.
  - ***Coverage*(*t*)** is the number of uncovered test requirements satisfied by test case *t*.

Greedy-based Algorithms

- Many test suite reduction algorithms are developed based on Coverage metric.
  - HGS algorithm proposed by Harrold et al. [4]
  - GE and GRE proposed by Chen and Lau [10]

Reduction Using Greedy Algorithm

Test	Cost	r_1	r_2	r_3	*Coverage*(t)
t_1	6	●	●		2
t_2	2			●	1
t_3	1		●		1
t_4	3	●			1

Greedy: $RS = \{t_1, t_2\}$, total cost = 8

Optimal solusion: $RS = \{t_2, t_3, t_4\}$, total cost = 6

Reduction with Ratio

- Ma et al. [11] and Smith and Kapfhammer [12] evaluated the test cases using

$$Ratio(t) = \frac{Coverage(t)}{Cost(t)}$$

where $Cost(t)$ represents the execution cost of the test case t.

- It aims to reduce the cost of running a test suite.

Reduction with Ratio

Test	Cost	r_1	r_2	r_3	*Ratio*(t)
t_1	6	●	●		0.67
t_2	2			●	0.5
t_3	1		●		1
t_4	3	●			0.33

Reduction with Ratio

Test	Cost	r_1	r_2	r_3	*Ratio*(t)
t_1	6	●	-		0.17
t_2	2		-	●	0.5
t_3	1		-		-
t_4	3	●	-		0.33

Reduction with Ratio

Test	Cost	r_1	r_2	r_3	*Ratio*(t)
t_1	6	●	-	-	0.17
$\boxed{t_2}$	2		-	-	-
$\boxed{t_3}$	1		-	-	-
t_4	3	●	-	-	0.33

Reduction with Ratio

Test	Cost	r_1	r_2	r_3	$Ratio(t)$
t_1	6	-	-	-	0
$\boxed{t_2}$	2	-	-	-	-
$\boxed{t_3}$	1	-	-	-	-
$\boxed{t_4}$	3	-	-	-	-

$\text{Greedy}_{\text{WithRatio}}$: $RS=\{t_2, t_3, t_4\}$, total cost = 6

ReduceWithRatio Problems

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	$Ratio(t)$
t_1	4	•	•	•				0.75
t_2	7		•	•	•	•		0.57
t_3	3	•					•	0.67
t_4	4			•			•	0.50

Problem of ReduceWithRatio

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Ratio*(t)
$\boxed{t_1}$	4	-	-	-				-
t_2	7	-	-	-	•	•		0.29
t_3	3	-	-	-			•	0.33
t_4	4	-	-	-			•	0.25

Problem of ReduceWithRatio

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Ratio*(t)
$\boxed{t_1}$	4	-	-	-			-	-
t_2	7	-	-	-	•	•	-	0.29
$\boxed{t_3}$	3	-	-	-			-	-
t_4	4	-	-	-			-	0

Problem of ReduceWithRatio

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Ratio*(t)
t_1	4	-	-	-	-	-	-	-
t_2	7	-	-	-	-	-	-	-
t_3	3	-	-	-	-	-	-	-
t_4	4	-	-	-	-	-	-	0

Greedy$_{\mathrm{WithRatio}}$: $RS=\{t_1, t_2, t_3\}$, total cost = 14

Problem of ReduceWithRatio

t_1 is replaceable

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Ratio*(t)
t_1	4	•	•	•				0.75
t_2	7		•	•	•	•		0.57
t_3	3	•					•	0.67
t_4	4			•			•	0.50

Greedy$_{\text{WithRatio}}$: $RS=\{t_1, t_2, t_3\}$, total cost = 14

Optimal solution : $RS=\{ t_2, t_3 \}$, total cost = 10

Reduction Using Irreplaceability

- Concept:
  - Evaluating a test case by identifying if it is replaceable.
  - We posit that *t* has a higher ***replaceability*** with respect to *r* in this case
    - That is, *t* has a lower ***irreplaceability*** with respect to *r*.

Evaluating the Irreplaceability

- The irreplaceability of t with respect to the requirement R={r_1, r_2, r_3, ..., r_m} can be defined as

$$Irreplaceability(t) = \frac{\sum_{i=1}^{m} Contribution(t, r_i)}{Cost(t)}$$

where

$$Contribution(t, r_i) = \begin{cases} 0, \text{if } t \text{ cannot satisfy } r_i \\ \dfrac{1}{\text{the number of test cases that satisfy } r_i}, \text{if } t \text{ satisfies } r_i \end{cases}$$

Reduction with Irreplaceability

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Irreplaceability*(t)
t_1	4	•	•	•				0.33
t_2	7		•	•	•	•		0.40
t_3	3	•					•	0.33
t_4	4			•			•	0.21

Reduction with Irreplaceability

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Irreplaceability*(t)
t_1	4	•	-	-	-	-		0.13
$\boxed{t_2}$	7		-	-	-	-		-
t_3	3	•	-	-	-	-	•	0.33
t_4	4		-	-	-	-	•	0.13

Reduction with Irreplaceability

Test	Cost	r_1	r_2	r_3	r_4	r_5	r_6	*Irreplaceability*(t)
t_1	4	-	-	-	-	-	-	0
$\boxed{t_2}$	7	-	-	-	-	-	-	-
$\boxed{t_3}$	3	-	-	-	-	-	-	-
t_4	4	-	-	-	-	-	-	0

Greedy$_{\text{WithIrreplaceability}}$: $RS = \{ t_2, t_3 \}$, total cost = 10

Optimal solution: $RS = \{ t_2, t_3 \}$, total cost = 10

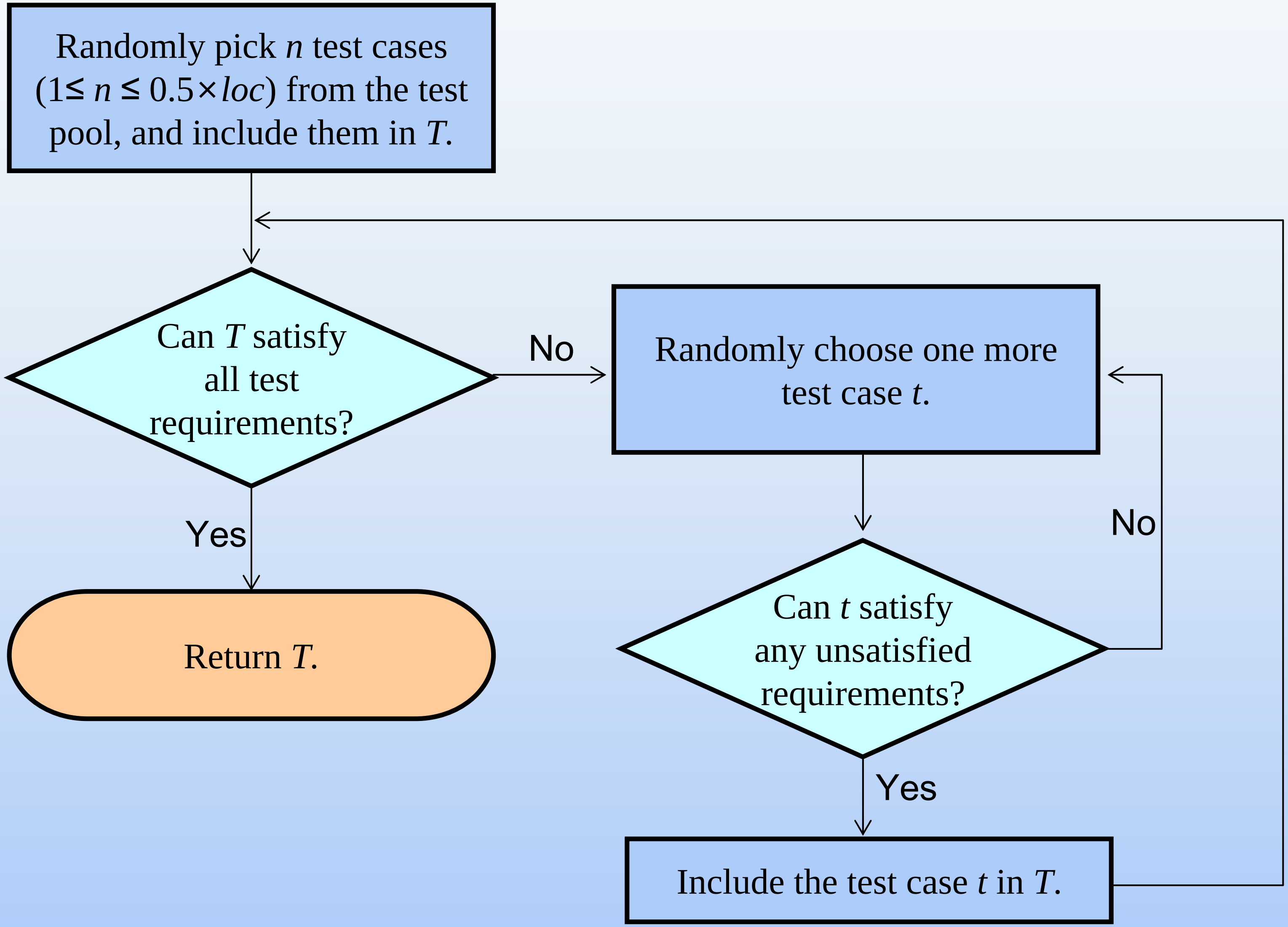
Greedy$_{\text{WithRatio}}$: $RS = \{t_1, t_2, t_3\}$, total cost = 14

Experimental Data Set

- The Siemens suite of programs from the SIR are frequently chosen benchmarks for evaluating test suite reduction methods [15].

Program	Test pool	Test requirements
printtokens	4,130	140
printtokens2	4,115	138
replace	5,542	126
schedule	2,650	46
schedule2	2,710	72
tcas	1,608	16
totinfo	1,052	44

Experimental Setup



Evaluating the Reduction Capability

- Criterion

$$\mathrm{SCR}(T, RS) = \frac{Cost(T) - Cost(RS)}{Cost(T)} \times 100\%$$

where

$Cost(T)$: the cost required to execute the original test suite T;

$Cost(RS)$: the cost associated with running the representative set RS.

Experiment Result

Test Suite / Program	Original	RS_{Greedy}		$RS_{WithRatio}$		$RS_{WithIrreplaceability}$	
	Cost*	Cost*	SCR	Cost*	SCR	Cost*	SCR
Printtokens	914.67	117.32	87.17%	115.04	87.42%	81.73	91.06%
printtokens2	717.84	58.29	91.88%	56.19	92.17%	48.53	93.24%
Replace	1068.90	88.28	91.74%	81.06	92.42%	76.06	92.88%
Schedule	493.77	18.71	96.21%	16.35	96.69%	15.32	96.90%
schedule2	651.82	40.14	93.84%	28.60	95.61%	26.80	95.89%
Tcas	219.39	23.74	89.18%	21.53	90.19%	20.74	90.55%
Totinfo	690.97	52.15	92.45%	26.43	96.17%	26.14	96.22%

* The cost is measured in millisecond(ms).

- Both ReduceWithIrreplaceability and ReduceWithRatio exhibit excellent cost reduction capabilities.
- The SCR scores of ReduceWithRatio are not as good as those of ReduceWithIrreplaceability.

Summary of Contribution

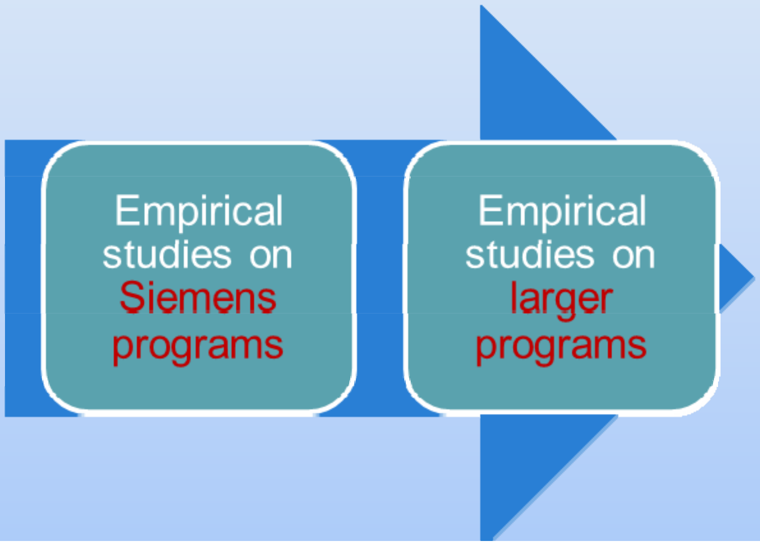
- Key motivators
  - Most existing test suite reduction algorithms attempt to minimize the size of a regression test suite.
  - Reduction using Ratio metric does not always perform in a satisfactory manner.
- Method
  - Evaluating a test case by identifying if it is replaceable.
  - It repeatedly picks the test *t* that has the maximum *Irreplaceability* (*t*).

Summary of Contribution

- Empirical studies reveals that
  - Reduction using Irreplaceability is the best method for decreasing the cost of test suite execution.

Future Work


Improving Greedy by Irreplaceability
Improving HGS and GRE by Irreplaceability


Empirical studies on Siemens programs
Empirical studies on larger programs