Do Redundant Mutants Affect the Effectiveness and Efficiency of Mutation Analysis?

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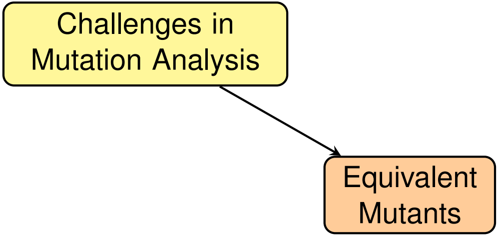
Allegheny College

Overview of the Presentation

Challenges in Mutation Analysis

Overview of the Presentation



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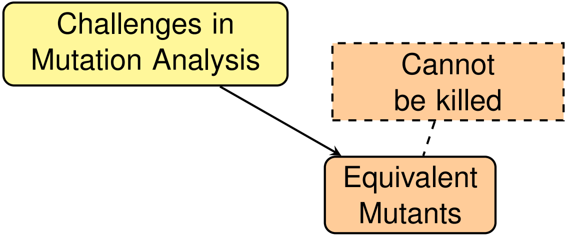

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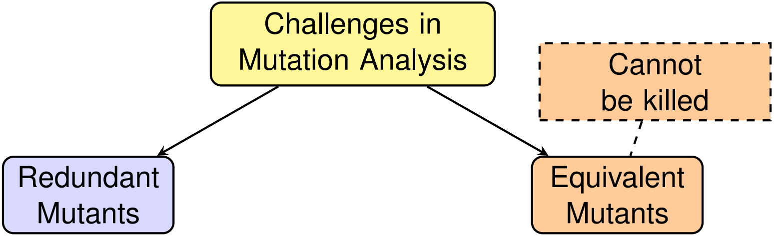

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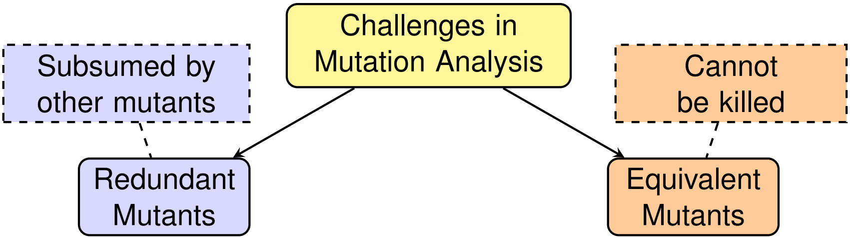

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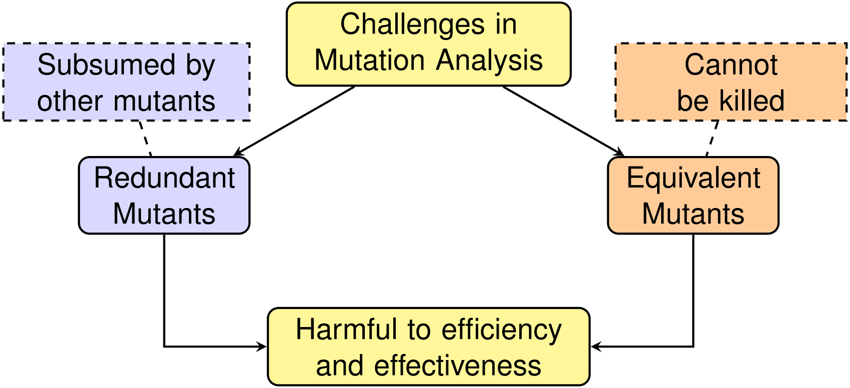


Overview of the Presentation

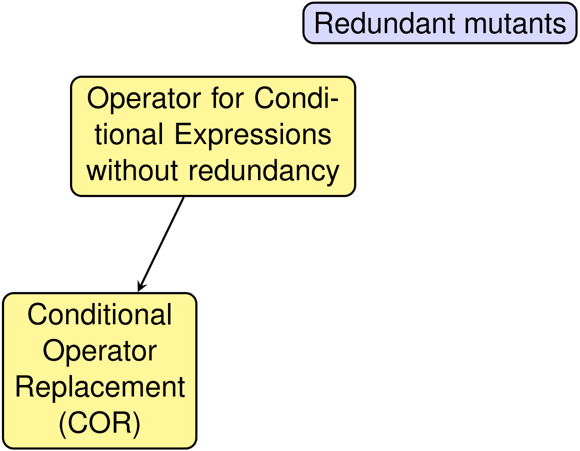
Redundant mutants

Overview of the Presentation

Redundant mutants

Operator for Conditional Expressions without redundancy

Overview of the Presentation



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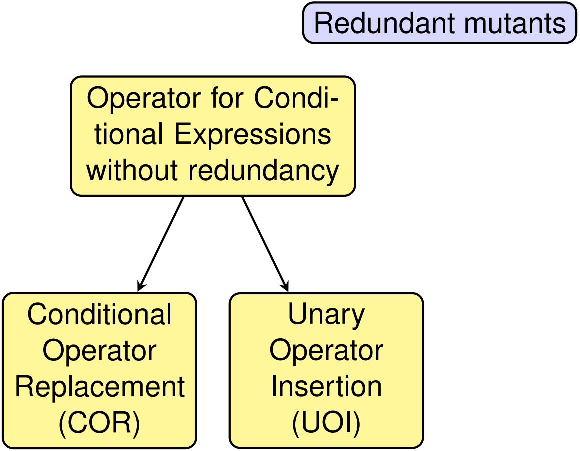

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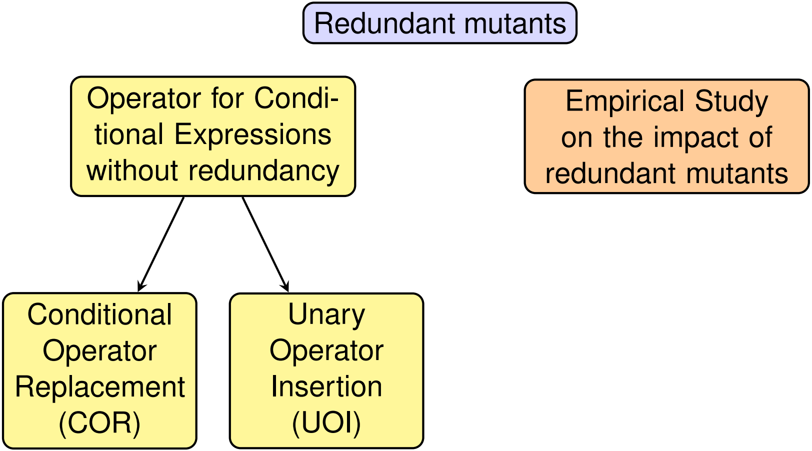

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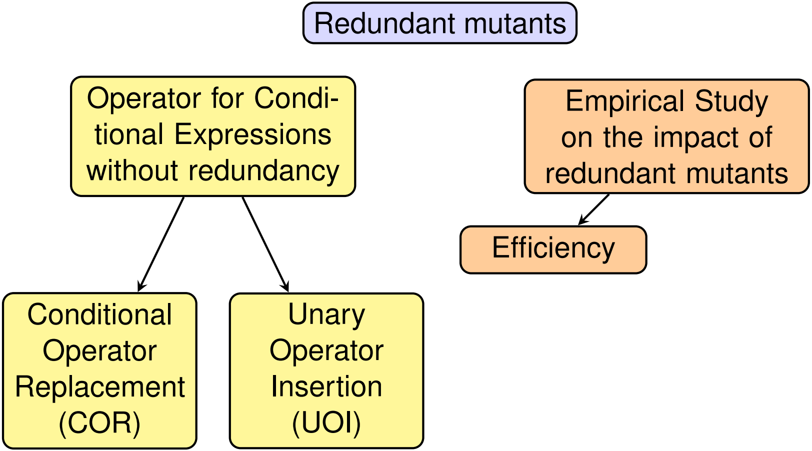

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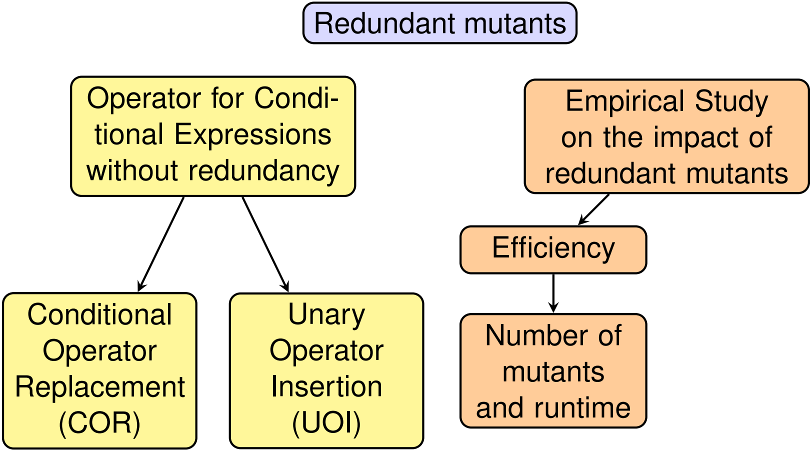

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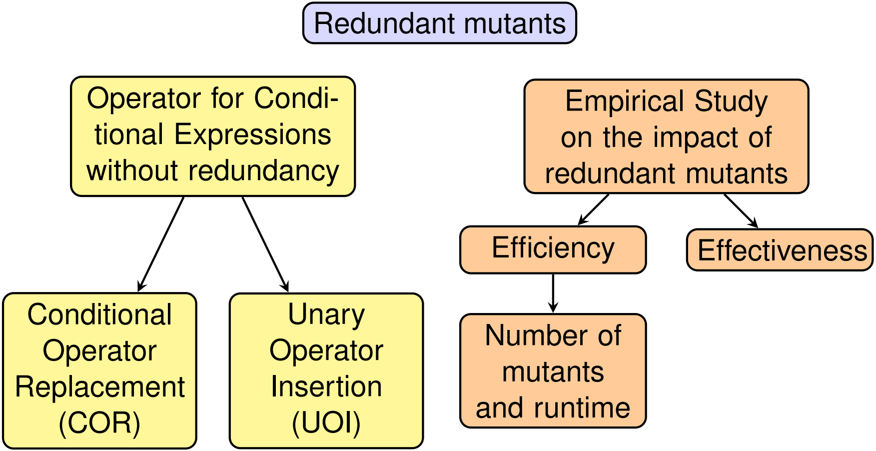

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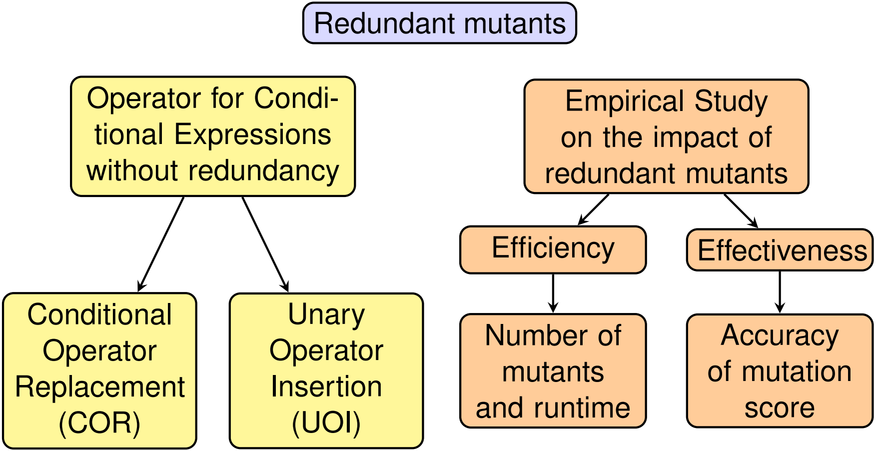
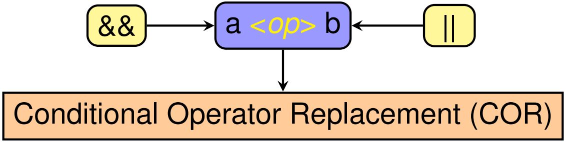


Mutating Conditional Expressions

a <*op*> b

Mutating Conditional Expressions

Mutating Conditional Expressions



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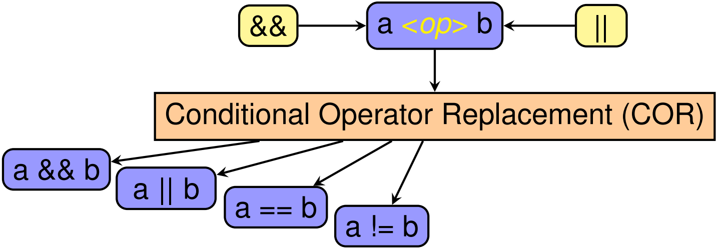

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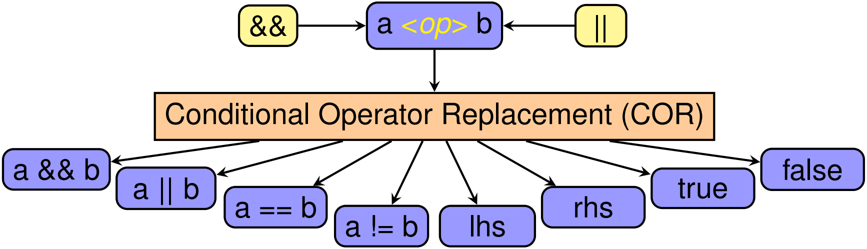

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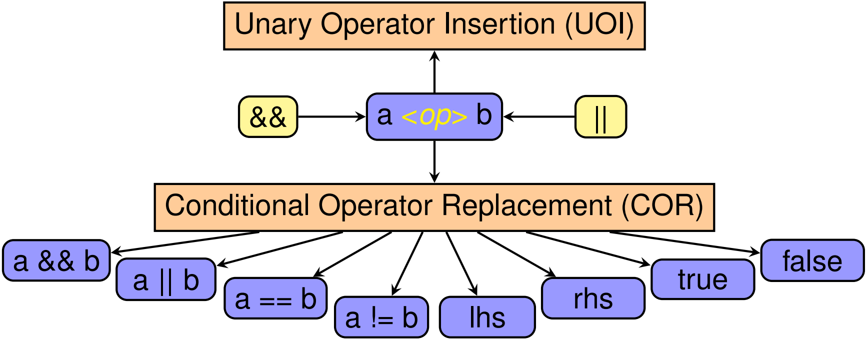

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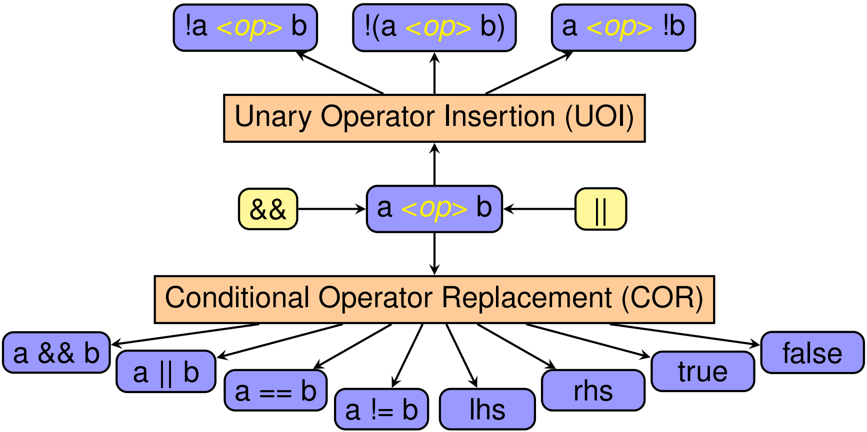

Mutating Conditional Expressions

Literals		Expression
a	b	a && b
0	0	0
0	1	0
1	0	0
1	1	1

Literals		Expression
a	b	a || b
0	0	0
0	1	1
1	0	1
1	1	1

Mutating Conditional Expressions

Literals		Expression										
a	b	a && b	false	lhs	rhs	a == b	a || b	a != b	true	!a && b	!(a && b)	a && !b
0	0	0	0	0	0	1	0	0	1	0	1	0
0	1	0	0	0	1	0	1	1	1	1	1	0
1	0	0	0	1	0	0	1	1	1	0	1	1
1	1	1	0	1	1	1	1	0	1	0	0	0

Literals		Expression										
a	b	a || b	a != b	rhs	lhs	true	a && b	a == b	false	!a || b	!(a || b)	a || !b
0	0	0	0	0	0	1	0	1	0	1	1	1
0	1	1	1	1	0	1	0	0	0	1	0	0
1	0	1	1	0	1	1	0	0	0	0	0	1
1	1	1	0	1	1	1	1	1	0	1	0	1

Mutating Conditional Expressions

Literals		**Expression**	**Sufficient mutations**				**Subsumed mutations**			**Subsumed operator UOI**		
a	b	a && b	false	lhs	rhs	a == b	a || b	a != b	true	!a && b	!(a && b)	a && !b
0	0	0	0	0	0	1	0	0	1	0	1	0
0	1	0	0	0	1	0	1	1	1	1	1	0
1	0	0	0	1	0	0	1	1	1	0	1	1
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Mutating Conditional Expressions

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UOI Operator completely subsumed

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A reduction of exactly 60% ?

Mutating Conditional Expressions

Two common patterns for short-circuit operators

Mutating Conditional Expressions

Two common patterns for short-circuit operators

```
public void foo(int x){
Var v;
    if(flag&&(v=getVar())!=null)
    {
        v.bar(x);
    }
    ...
}
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Properly handled by MAJOR

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```

Properly handled by MAJOR

```
public void foo(int x){
Var v;
    if(flag||(v=getVar())==null)
    {
        return;
    }
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```

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Mutating Conditional Expressions

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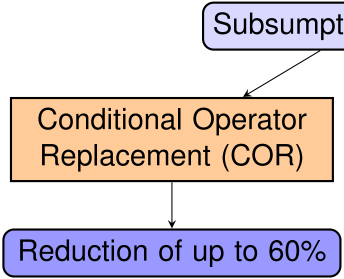
A reduction of up to 60%

COR and ROR Mutation Operators



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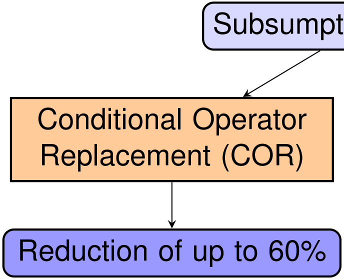

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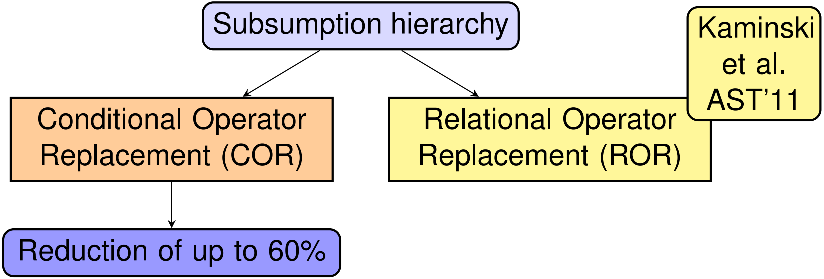

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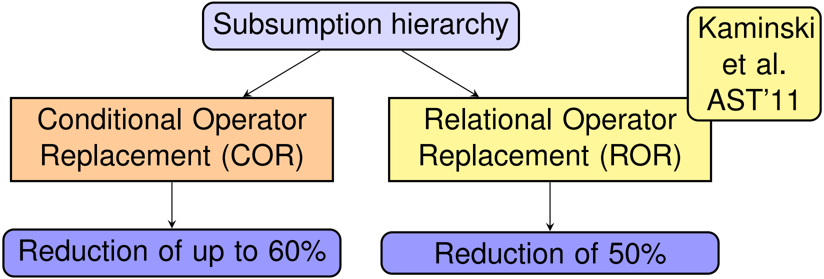

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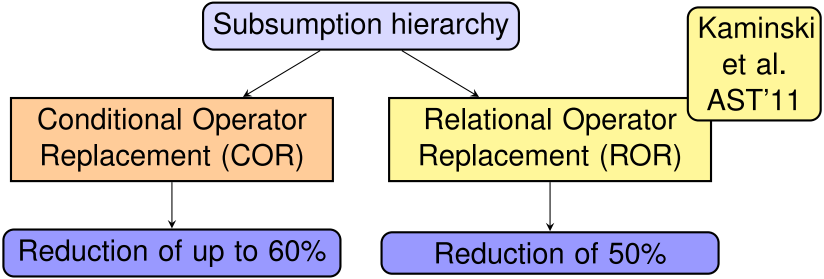

How prevalent are COR and ROR mutants?

Investigated Applications

	Files	LOC	Tests	Mutants Generated	Mutants Covered
commons-math	408	39,991	2,169	80,372	72,203
commons-lang	99	19,495	2,039	31,130	29,069
commons-io	100	7,908	309	9,547	4,935
numerics4j	73	3,647	218	6,835	6,547

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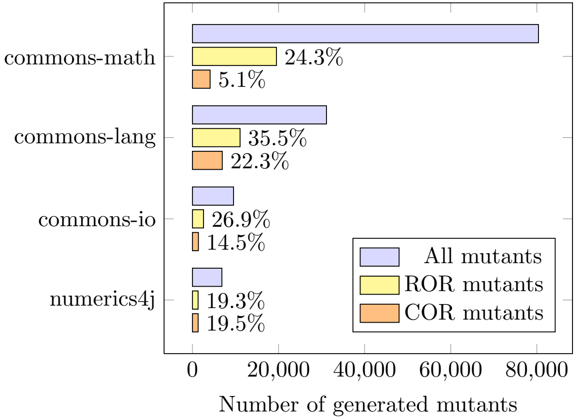

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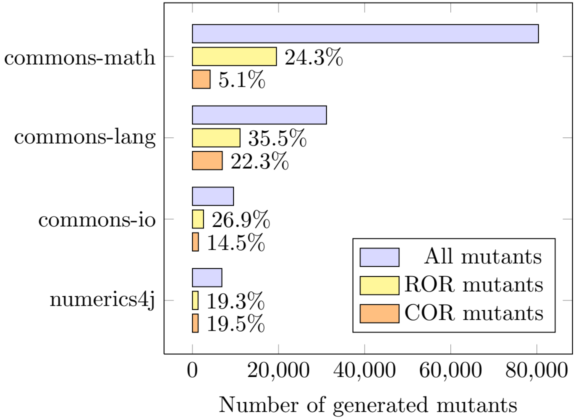

COR and ROR generate up to 58% of all mutants

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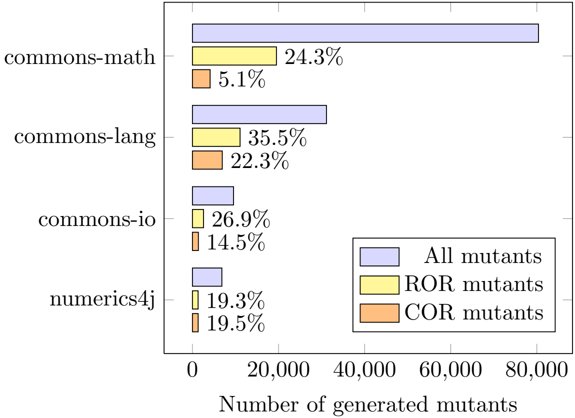

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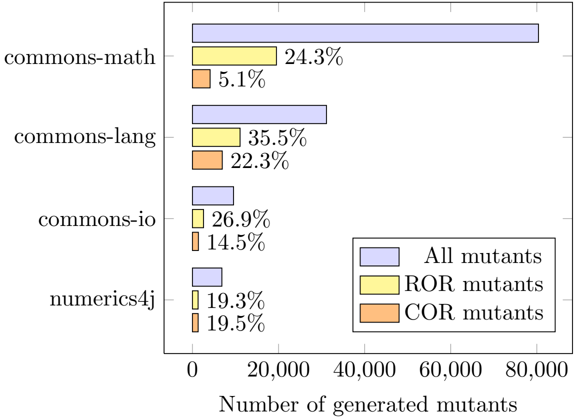

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How much is the overall reduction?

Decrease in Number of Mutants

	Generated (original set)	Generated (reduced set)	Covered (original set)	Covered (reduced set)
commons-math	80,372	66,787 (-16.9%)	72,203	59,195 (-18.0%)
commons-lang	31,130	21,074 (-32.3%)	29,069	19,112 (-34.3%)
commons-io	9,547	7,319 (-23.3%)	4,935	4,168 (-15.5%)
numerics4j	6,835	5,437 (-20.5%)	6,547	5,149 (-21.4%)

Decrease in Number of Mutants

Overall reduction of up to 34%

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How much is the saving in runtime?

Runtime Improvement

	Runtime (original set)	**Runtime (reduced set)**
commons-math	300.77	271.10 (-09.9%)
commons-lang	28.25	18.70 (-33.8%)
commons-io	6.95	4.58 (-34.1%)
numerics4j	2.85	2.08 (-26.9%)

Runtime Improvement

Divergence due to differences in test suite runtime and coverage

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Significant speed-up for all applications

Accuracy of the Mutation Score

	Mutation Score (original set)	**Mutation Score (reduced set)**
commons-math	0.77	0.73 (- 4.5%)
commons-lang	0.76	0.67 (-10.7%)
commons-io	0.41	0.44 (8.3%)
numerics4j	0.69	0.65 (- 5.9%)

Accuracy of the Mutation Score

Mutation Score up to 10% overestimated

	Mutation Score (original set)	Mutation Score (reduced set)
commons-math	0.77	0.73 (- 4.5%)
commons-lang	0.76	0.67 (-10.7%)
commons-io	0.41	0.44 (8.3%)
numerics4j	0.69	0.65 (- 5.9%)

Accuracy of the Mutation Score

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Low mutation coverage may lead to underestimation

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commons-lang	0.76	0.67 (-10.7%)
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Accuracy of the Mutation Score

Mutation Score up to 10% overestimated

Low mutation coverage may lead to underestimation

	Mutation Score (original set)	**Mutation Score (reduced set)**
commons-math	0.77	0.73 (- 4.5%)
commons-lang	0.76	0.67 (-10.7%)
commons-io	0.41	0.44 (8.3%)
numerics4j	0.69	0.65 (- 5.9%)

Redundant mutants tend to overestimate the mutation score

Conclusion and Future Work

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- Operator for conditional expressions without redundancy
- Decreased number of mutants and improved runtime
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Future Work:

- Investigate redundancies in other mutation operators
- Analyze whether sufficient mutants tend to be equivalent
- Apply constraint solver to identify equivalent mutants

Do Redundant Mutants Affect the Effectiveness and Efficiency of Mutation Analysis?

Thank you for your attention!

Questions?

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