SPLat: Lightweight Dynamic Analysis for Reducing Combinatorics in Testing Configurable Systems

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presenter name(s) removed for FERPA considerations

Introduction

Same phone, different models

They share some common features and some features vary:

- Screen Size
- Colors
- RAM
- Camera
- so on..

Benefits:

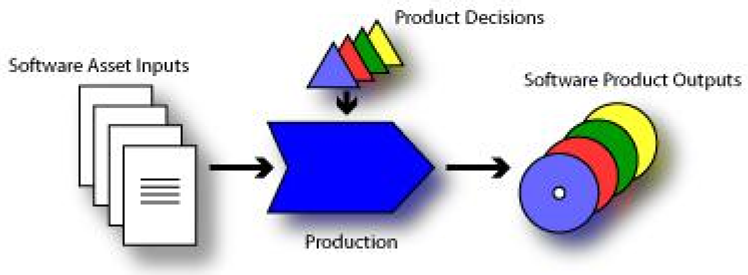
- Satisfies the specific needs of a particular market segment
- Decrease production costs
- Decrease time to market
- Increase quality
- so on..

Introduction

Let’s think of software the same way!

Software Product Line: Family of programs where each program is defined by a unique combination of features.

Idea is to manufacture software from reusable parts



Introduction

- **Problem with SPLs?**

  Testing is expensive: running each test against all possible configurations.

170 boolean configuration variables

Can be deployed in 2^{170} different configurations!!

Introduction

- **Current Solution**

  Test is often independent of many configuration variables and need not be run against every configuration.

  Such irrelevant configurations can be pruned from execution.

  Current techniques:

  - *Sampling* (Random or sophisticated selection of configurations)

    Chance of missing out on bugs!

  - *Exhaustive Exploration* (Static or Heavyweight Dynamic Analysis)

    Too much execution overhead!

Main Contribution

SPLat introduces a,

new *light-weight* technique for analysis of configurable programs

Key Idea

- Some features are never encountered, no matter how the test is executed.
- Combinations of such unreachable features lead to the same *trace.*

For any test,

SPLat runs only the configurations that have a unique trace

Example

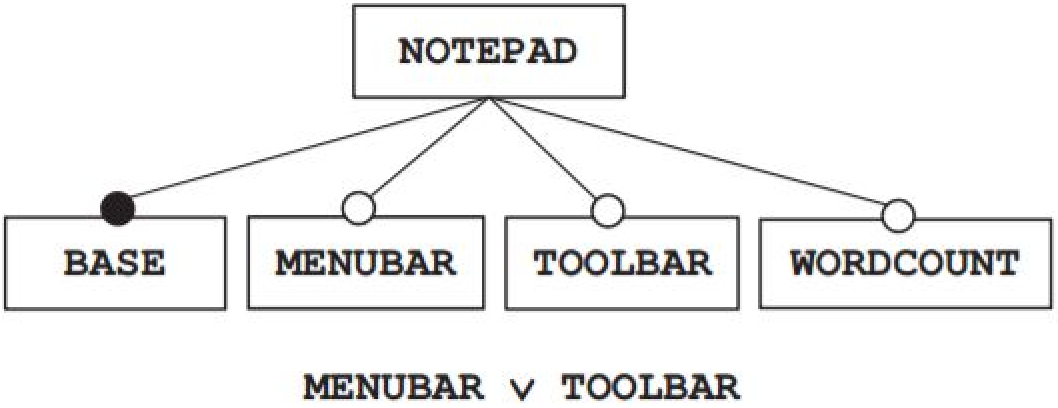
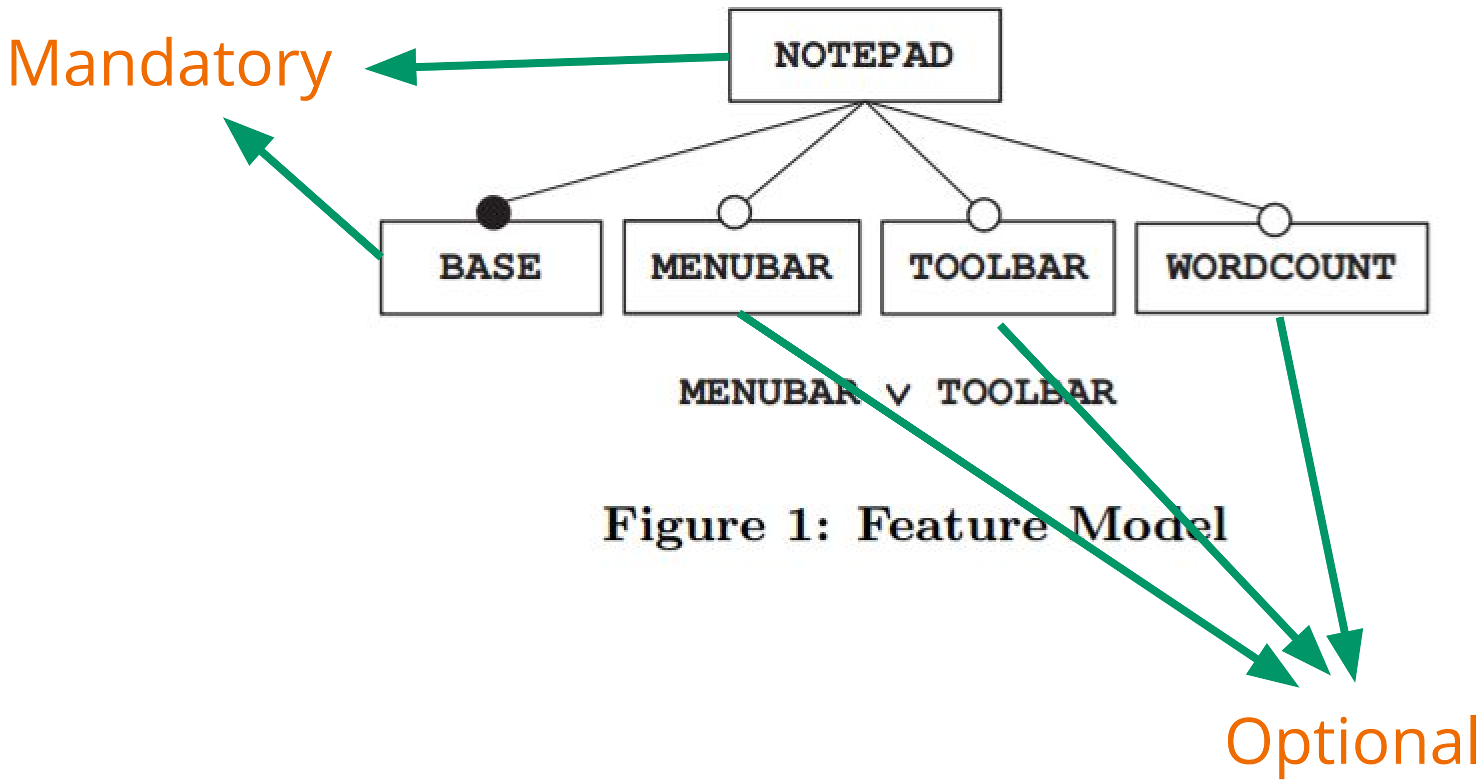


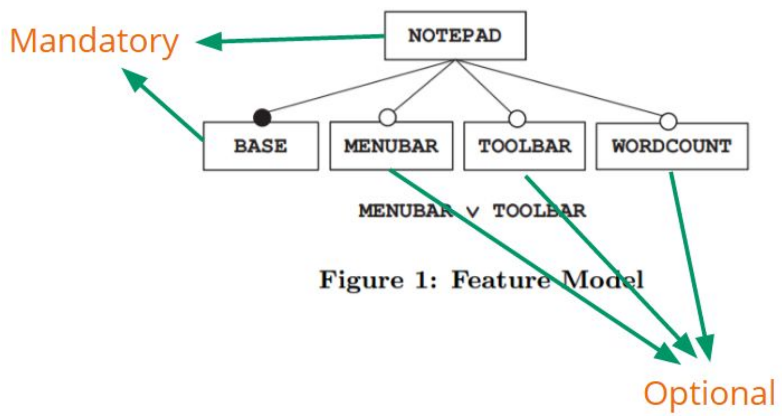
Figure 1: Feature Model

Example



Constraint: Must have a MENUBAR or TOOLBAR

Example



- Mandatory features are always *true*
- Optional features may be set to *true* or *false*
- Configuration = assignment of values to all feature variables
- Constraint
  - Must have a MENUBAR or TOOLBAR

Configuration is valid iff it satifies all constraints the feature model expresses

Example

```
public void test() {
 Notepad n = new Notepad();
 n.createToolBar();

 // Automated GUI testing
 FrameFixture f = newFixture(n);
 f.show();
 String text = "Hello";
 f.textBox().enterText(text);
 f.textBox().requireText(text);
 f.cleanUp();
}
```

(b) Test

```
class Notepad extends JFrame {
 Notepad() {
  getContentPane().add(newJTextArea());
 }

 void createToolBar() {
  if(TOOLBAR) {
   JToolBar toolBar = new JToolBar();
   getContentPane().add
                 ("North", toolBar);
   if(WORDCOUNT) {
    JButton button = new
           JButton("wordcount.gif");
    toolBar.add(button);
   }
  }
 }

 void createMenuBar() {
  if(MENUBAR) {
   JMenuBar menuBar = new JMenuBar();
   setJMenuBar(menuBar);
   if(WORDCOUNT) {
    JMenu menu = new
                JMenu("Word Count");
    menuBar.add(menu);
   }
  }
 }
}
```

(a) Code

Example

Without SPLat :

3 Optional Variables = *8 configurations*

M: MENUBAR

T: TOOLBAR

W: WORDCOUNT

MTW = 000
MTW = 001

MTW = 100
MTW = 101

MTW = 110
MTW = 010

MTW = 011
MTW = 111

Example

With SPLat :

3 Optional Variables = ***6** configurations*

M: MENUBAR

T: TOOLBAR

W: WORDCOUNT

Prune invalid configurations

MTW = 000 ✖

MTW = 001 ✖

Both M and T false, constraint not satisfied

MTW = 100

MTW = 101

MTW = 110

MTW = 010

MTW = 011

MTW = 111

Constraint: Must have a MENUBAR or TOOLBAR

Example

With SPLat :

3 Optional Variables = ***5** configurations*

M: MENUBAR

T: TOOLBAR

W: WORDCOUNT

Remove valid configurations that are unnecessary

MTW = 000 ✖
MTW = 001 ✖

Both M and T false, constraint not satisfied

MTW = 100 ✓
MTW = 101 ✖

Non-unique trace, same as 100

MTW = 110
MTW = 010

MTW = 011
MTW = 111

```
public void test() {
 Notepad n = new Notepad();
 n.createToolBar();

 // Automated GUI testing
 FrameFixture f = newFixture(n);
 f.show();
 String text = "Hello";
 f.textBox().enterText(text);
 f.textBox().requireText(text);
 f.cleanUp();
}
```

Test only calls *createToolBar()* which is empty in both configurations.

Example

With SPLat :

3 Optional Variables = ~~*8 configurations*~~ ***3 configurations!***

M: MENUBAR

T: TOOLBAR

W: WORDCOUNT

MTW = 000 ✖ Both M and T false, constraint not satisfied
MTW = 001 ✖

MTW = 100 ✔
MTW = 101 ✖ Non-unique trace, same as 100

MTW = 010 ✔
MTW = 110 ✖

MTW = 011 ✔
MTW = 111 ✖

Technique

Main Algorithm Overview:

1) Run **initial instance** of a test for the SPL

2) **Set features**
    - Mandatory features - true
    - Optional features - true or false. Defaulted to false

3) **Explore**, **backtrack**, and **explore more**
    - New features are pushed onto a stack as they are encountered

4) **Prune invalid** configurations until exploration is done

Technique

M: MENUBAR — 0 : False

T: TOOLBAR — 1 : True

W: WORDCOUNT — - : “don’t care”

Applied Example - Notepad:

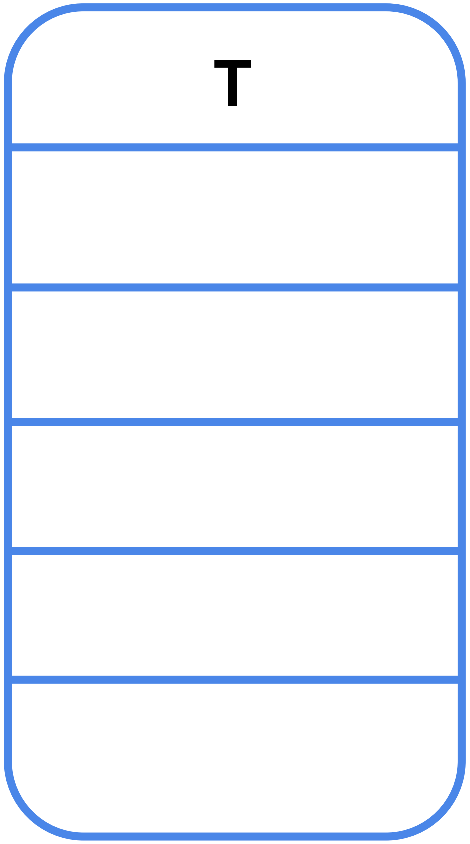
1) **Define a stack** to hold unexplored features

2) Run an **initial test** and gather set of partial assignments

   T is encountered first, push it on to the stack

   Stack: [T]

   Set T=0 → MTW = -0-



Technique

M: MENUBAR 0 : False
T: TOOLBAR 1 : True
W: WORDCOUNT - : “don’t care”

Applied Example - Notepad:

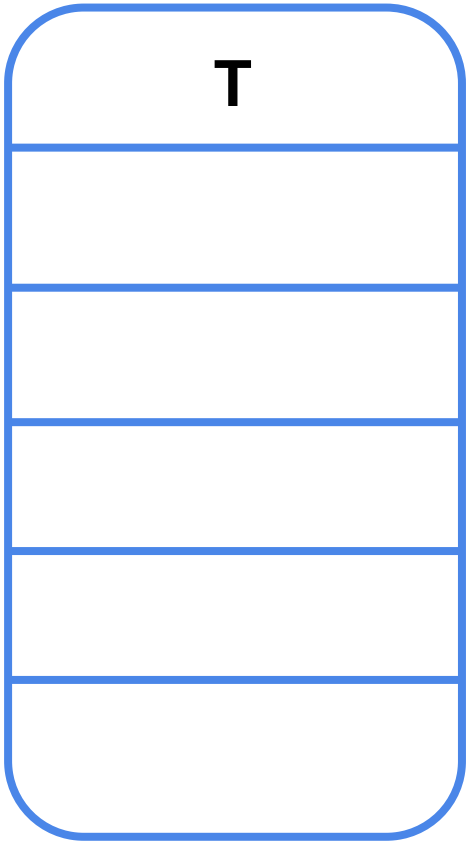
3) Explore **initial set of assignments**

Explore MTW=-0-:

Recognize that MTW=00- is invalid →

Two combinations eliminated!

Assert MTW=10-: valid



Technique

M: MENUBAR 0 : False

T: TOOLBAR 1 : True

W: WORDCOUNT - : “don’t care”

Applied Example - Notepad:

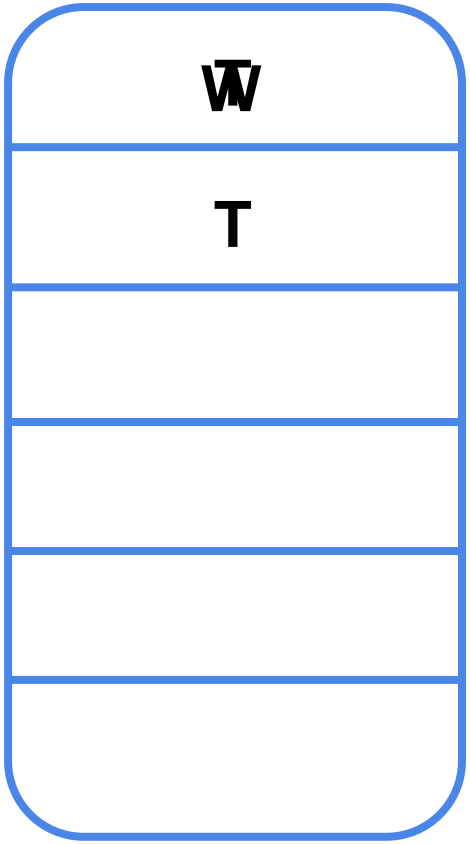
4) **Bubble up** and explore alternate path of configurations

    Set T=1, explore path (MTW=-1-):

        Next, we encounter W. Push W. (Stack: [W, T])

            MTW=-10: valid

            MTW=-11: valid



Technique

M: MENUBAR 0 : False

T: TOOLBAR 1 : True

W: WORDCOUNT - : “don’t care”

Applied Example - Notepad:

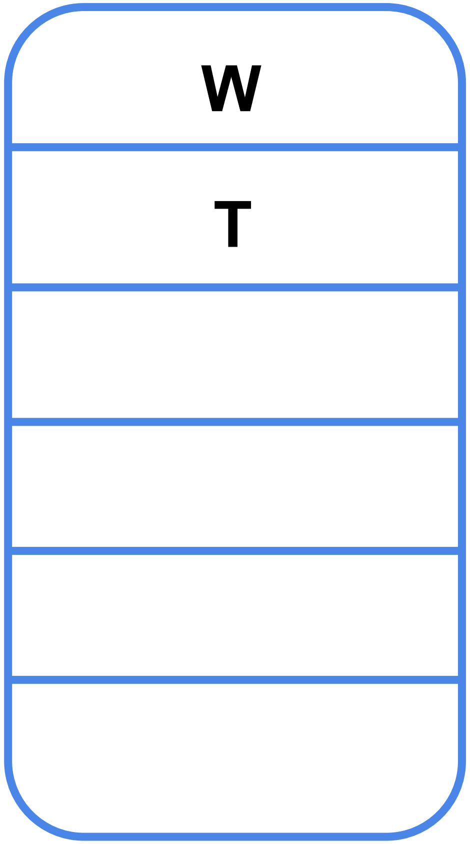
5) **Pop out** fully explored features

W & T have been fully explored at this point

Pop W.

Pop T.

Stack is empty, end SPLat



Technique

M: MENUBAR — 0 : False

T: TOOLBAR — 1 : True

W: WORDCOUNT — - : “don’t care”

Applied Example - Notepad:

6) **Collect results**

MTW=10-, MTW=-10, and MTW=-11 are all covered in 3 test executions

Thus, 6 feasible combinations were fully explored in 3 configurations!

Evaluation

- **RQ1:** Compare with other methods
- **RQ2:** Overhead?
- **RQ3:** Scale to industry code?

RQ1 & RQ2: Experiment on SPL

- 10 software product lines (SPLs) as test subjects

Table 1: Subject SPLs

SPL	*Features*	*Confs*	*LOC*
101Companies	11	192	2,059
Elevator	5	20	1,046
Email	8	40	1,233
GPL	14	73	1,713
JTopas	5	32	2,031
MinePump	6	64	580
Notepad	23	144	2.074
Prevayler	5	32	2,844
Sudoku	6	20	853
XStream	7	128	14,480

- Comare with:
- **Naive approach:** run on *all* valid configurations
  - **NewJVM**: spawn a new JVM for each test run
  - **ReuseJVM**: require an explicit reset function
- **Static approach:**
  - **SRA** (Static Reachablility Analysis): determine reachable configurations by static analysis

JVM: Java Virtual Machine
Required for running Java
Consumes time to create

No comparison with other dynamic approaches!

Table 2: Experimental Results for Various Techniques

	All Valid			SPLat							Static Reachability (SRA)		
Test	*NewJVM*	*ReuseJVM*		*Confs*		*SPLatTime*		*IdealTime*	*Overhead*		*Confs*	*Overhead*	*Time*
101Companies (192 configs)													
LOW	35.46	2.13	(6%)	32	(16%)	1.64	(77%)	0.72	0.92	(127%)	96	84.04	1.28
MED	49.37	3.90	(7%)	160	(83%)	6.84	(175%)	3.58	3.26	(91%)	192	82.54	3.99
HIGH	283.69	45.26	(15%)	176	(91%)	47.6	(105%)	41.59	6.01	(14%)	192	81.93	45.16
Elevator (20 configs)													
LOW	10.74	5.17	(48%)	2	(10%)	1.33	(25%)	0.71	0.62	(87%)	2	23.29	0.76
MED	50.97	46.65	(91%)	10	(50%)	23.62	(50%)	23.14	0.48	(2%)	20	23.74	46.17
HIGH	62.57	59.48	(95%)	20	(100%)	60.71	(102%)	59.28	1.43	(2%)	20	24.38	60.43
Email (40 configs)													
LOW	40.63	10.74	(26%)	1	(2%)	1.00	(9%)	0.87	0.13	(14%)	1	23.62	0.87
MED	57.56	48.87	(84%)	30	(75%)	36.99	(75%)	37.14	-0.15	(0%)	40	22.81	49.02
HIGH	58.02	48.93	(84%)	40	(100%)	48.96	(100%)	49.26	-0.31	(0%)	40	23.84	49.16
GPL (73 configs)													
LOW	19.21	2.23	(11%)	6	(8%)	0.79	(35%)	0.29	0.49	(168%)	6	104.97	0.30
MED	190.53	171.62	(90%)	55	(75%)	130.87	(76%)	128.52	2.35	(1%)	55	99.41	128.69
HIGH	314.20	285.89	(90%)	70	(95%)	278.77	(97%)	277.48	1.29	(0%)	73	103.52	286.28
JTopas (32 configs)													
LOW	26.59	16.83	(63%)	8	(25%)	6.29	(37%)	4.49	1.80	(40%)	32	86.87	16.44
MED	29.04	18.55	(63%)	16	(50%)	13.16	(70%)	9.71	3.46	(35%)	32	86.87	18.70
HIGH	28.92	18.93	(65%)	32	(100%)	25.31	(133%)	18.43	6.88	(37%)	32	86.87	18.48
MinePump (64 configs)													
LOW	23.71	7.53	(31%)	9	(14%)	3.65	(48%)	1.90	1.75	(91%)	64	22.69	7.49
MED	59.72	14.78	(24%)	24	(37%)	10.43	(70%)	6.26	4.17	(66%)	64	22.38	15.35
HIGH	13.72	5.75	(41%)	48	(75%)	37.80	(657%)	4.81	32.99	(685%)	64	22.18	5.77
Notepad (144 configs)													
LOW	398.22	135.60	(34%)	2	(1%)	3.06	(2%)	2.45	0.61	(24%)	144	80.40	135.47
MED	418.23	156.27	(37%)	96	(66%)	104.95	(67%)	104.91	0.04	(0%)	144	80.62	156.35
HIGH	419.99	153.39	(36%)	144	(100%)	153.11	(99%)	152.16	0.94	(0%)	144	81.29	151.94
Prevayler (32 configs)													
LOW	65.34	40.23	(61%)	12	(37%)	22.49	(55%)	22.8	-0.31	(-1%)	32	205.54	45.39
MED	121.38	96.50	(79%)	24	(75%)	102.49	(106%)	105.86	-3.37	(-3%)	32	214.67	111.37
HIGH	149.08	120.7	(80%)	32	(100%)	127.17	(105%)	131.37	-4.20	(-3%)	32	290.66	135.61
Sudoku (20 configs)													
LOW	51.11	48.10	(94%)	4	(20%)	42.72	(88%)	24.12	18.6	(77%)	10	31.87	24.28
MED	118.14	105.67	(89%)	10	(50%)	58.31	(55%)	54.16	4.15	(7%)	10	31.75	53.67
HIGH	489.60	334.82	(68%)	20	(100%)	316.47	(94%)	332.36	-15.89	(-4%)	20	31.74	338.48
Xstream (128 configs)													
LOW	111.26	30.04	(27%)	2	(1%)	1.57	(5%)	1.08	0.49	(45%)	2	106.50	1.06
MED	105.10	9.04	(8%)	64	(50%)	5.77	(63%)	5.26	0.51	(9%)	64	109.22	5.14
HIGH	101.66	8.68	(8%)	128	(100%)	9.16	(105%)	8.59	0.57	(6%)	128	105.68	8.74

Table 2: Experimental Results for Various Techniques

Test	All Valid: NewJVM	All Valid: ReuseJVM		SPLat: Confs		SPLat: SPLatTime		SPLat: IdealTime	SPLat: Overhead		Static Reachability (SRA): Confs	Static Reachability (SRA): Overhead	Static Reachability (SRA): Time
101Companies (192 configs)													
LOW	35.46	2.13	(6%)	32	(16%)	1.64	(77%)	0.72	0.92	(127%)	96	84.04	1.28
MED	49.37	3.90	(7%)	160	(83%)	6.84	(175%)	3.58	3.26	(91%)	192	82.54	3.99
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Elevator (20 configs)													
LOW	10.74	5.17	(48%)	2	(10%)	1.33	(25%)	0.71	0.62	(87%)	2	23.29	0.76
MED	50.97	46.65	(91%)	10	(50%)	23.62	(50%)	23.14	0.48	(2%)	20	23.74	46.17
HIGH	62.57	59.48	(95%)	20	(100%)	60.71	(102%)	59.28	1.43	(2%)	20	24.38	60.43
Email (40 configs)													
LOW	40.63	10.74	(26%)	1	(2%)	1.00	(9%)	0.87					
MED	57.56	48.87	(84%)	30	(75%)	36.99	(75%)	37.14					
HIGH	58.02	48.93	(84%)	40	(100%)	48.96	(100%)	49.26					
GPL (73 configs)													
LOW	19.21	2.23	(11%)	6	(8%)	0.79	(35%)	0.29					
MED	190.53	171.62	(90%)	55	(75%)	130.87	(76%)	128.52					
HIGH	314.20	285.89	(90%)	70	(95%)	278.77	(97%)	277.48					
JTopas (32 configs)													
LOW	26.59	16.83	(63%)	8	(25%)	6.29	(37%)	4.49					
MED	29.04	18.55	(63%)	16	(50%)	13.16	(70%)	9.71					
HIGH	28.92	18.93	(65%)	32	(100%)	25.31	(133%)	18.43					
MinePump (64 configs)													
LOW	23.71	7.53	(31%)	9	(14%)	3.65	(48%)	1.90					
MED	59.72	14.78	(24%)	24	(37%)	10.43	(70%)	6.26					
HIGH	13.72	5.75	(41%)	48	(75%)	37.80	(657%)	4.81					
Notepad (144 configs)													
LOW	398.22	135.60	(34%)	2	(1%)	3.06	(2%)	2.45					
MED	418.23	156.27	(37%)	96	(66%)	104.95	(67%)	104.91					
HIGH	419.99	153.39	(36%)	144	(100%)	153.11	(99%)	152.16	0.94	(0%)	144	81.29	151.94
Prevayler (32 configs)													
LOW	65.34	40.23	(61%)	12	(37%)	22.49	(55%)	22.8	-0.31	(-1%)	32	205.54	45.39
MED	121.38	96.50	(79%)	24	(75%)	102.49	(106%)	105.86	-3.37	(-3%)	32	214.67	111.37
HIGH	149.08	120.7	(80%)	32	(100%)	127.17	(105%)	131.37	-4.20	(-3%)	32	290.66	135.61
Sudoku (20 configs)													
LOW	51.11	48.10	(94%)	4	(20%)	42.72	(88%)	24.12	18.6	(77%)	10	31.87	24.28
MED	118.14	105.67	(89%)	10	(50%)	58.31	(55%)	54.16	4.15	(7%)	10	31.75	53.67
HIGH	489.60	334.82	(68%)	20	(100%)	316.47	(94%)	332.36	-15.89	(-4%)	20	31.74	338.48
Xstream (128 configs)													
LOW	111.26	30.04	(27%)	2	(1%)	1.57	(5%)	1.08	0.49	(45%)	2	106.50	1.06
MED	105.10	9.04	(8%)	64	(50%)	5.77	(63%)	5.26	0.51	(9%)	64	109.22	5.14
HIGH	101.66	8.68	(8%)	128	(100%)	9.16	(105%)	8.59	0.57	(6%)	128	105.68	8.74

Efficiency

NewJVM vs. ReuseJVM:

Reusing JVM saves time

Table 2: Experimental Results for Various Techniques

Test	All Valid			SPLat							Static Reachability (SRA)		
	NewJVM	*ReuseJVM*		*Confs*		*SPLatTime*		*IdealTime*	*Overhead*		*Confs*	*Overhead*	*Time*
101Companies (192 configs)													
LOW	35.46	2.13	(6%)	32	(16%)	1.64	(77%)	0.72	0.92	(127%)	96	84.04	1.28
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LOW	10.74	5.17	(48%)	2	(10%)	1.33	(25%)	0.71	0.62	(87%)	2	23.29	0.76
MED	50.97	46.65	(91%)	10	(50%)	23.62	(50%)	23.14	0.48	(2%)	20	23.74	46.17
HIGH	62.57	59.48	(95%)	20	(100%)	60.71	(102%)	59.28	1.43	(2%)	20	24.38	60.43
Email (40 configs)													
LOW	40.63	10.74	(26%)	1	(2%)	1.00	(9%)	0.87					
MED	57.56	48.87	(84%)	30	(75%)	36.99	(75%)	37.14					
HIGH	58.02	48.93	(84%)	40	(100%)	48.96	(100%)	49.26					
GPL (73 configs)													
LOW	19.21	2.23	(11%)	6	(8%)	0.79	(35%)	0.29					
MED	190.53	171.62	(90%)	55	(75%)	130.87	(76%)	128.52					
HIGH	314.20	285.89	(90%)	70	(95%)	278.77	(97%)	277.48					
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MED	29.04	18.55	(63%)	16	(50%)	13.16	(70%)	9.71					
HIGH	28.92	18.93	(65%)	32	(100%)	25.31	(133%)	18.43					
MinePump (64 configs)													
LOW	23.71	7.53	(31%)	9	(14%)	3.65	(48%)	1.90					
MED	59.72	14.78	(24%)	24	(37%)	10.43	(70%)	6.26					
HIGH	13.72	5.75	(41%)	48	(75%)	37.80	(657%)	4.81					
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HIGH	101.66	8.68	(8%)	128	(100%)	9.16	(105%)	8.59	0.57	(6%)	128	105.68	8.74

Efficiency

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ReuseJVM vs. SPLat:

SPLat reduces time when #Confs is reduced

Table 2: Experimental Results for Various Techniques

	All Valid			SPLat							Static Reachability (SRA)		
Test	*NewJVM*	*ReuseJVM*		*Confs*		*SPLatTime*		*IdealTime*	*Overhead*		*Confs*	*Overhead*	*Time*
				101Companies (192 configs)									
				32	(16%)	1.64	(77%)	0.72	0.92	(127%)	96	84.04	1.28
				160	(83%)	6.84	(175%)	3.58	3.26	(91%)	192	82.54	3.99
				176	(91%)	47.6	(105%)	41.59	6.01	(14%)	192	81.93	45.16
				Elevator (20 configs)									
				2	(10%)	1.33	(25%)	0.71	0.62	(87%)	2	23.29	0.76
				10	(50%)	23.62	(50%)	23.14	0.48	(2%)	20	23.74	46.17
				20	(100%)	60.71	(102%)	59.28	1.43	(2%)	20	24.38	60.43
				Email (40 configs)									
				1	(2%)	1.00	(9%)	0.87	0.13	(14%)	1	23.62	0.87
				30	(75%)	36.99	(75%)	37.14	-0.15	(0%)	40	22.81	49.02
				40	(100%)	48.96	(100%)	49.26	-0.31	(0%)	40	23.84	49.16
				GPL (73 configs)									
				6	(8%)	0.79	(35%)	0.29	0.49	(168%)	6	104.97	0.30
				55	(75%)	130.87	(76%)	128.52	2.35	(1%)	55	99.41	128.69
				70	(95%)	278.77	(97%)	277.48	1.29	(0%)	73	103.52	286.28
				JTopas (32 configs)									
				8	(25%)	6.29	(37%)	4.49	1.80	(40%)	32	86.87	16.44
				16	(50%)	13.16	(70%)	9.71	3.46	(35%)	32	86.87	18.70
				32	(100%)	25.31	(133%)	18.43	6.88	(37%)	32	86.87	18.48
				MinePump (64 configs)									
LOW	23.71	7.33	(31%)	9	(14%)	3.65	(48%)	1.90	1.75	(91%)	64	22.69	7.49
MED	59.72	14.78	(24%)	24	(37%)	10.43	(70%)	6.26	4.17	(66%)	64	22.38	15.35
				48	(75%)	37.80	(657%)	4.81	32.99	(685%)	64	22.18	5.77
				Notepad (144 configs)									
				2	(1%)	3.06	(2%)	2.45	0.61	(24%)	144	80.40	135.47
				96	(66%)	104.95	(67%)	104.91	0.04	(0%)	144	80.62	156.35
				144	(100%)	153.11	(99%)	152.16	0.94	(0%)	144	81.29	151.94
				Prevayler (32 configs)									
				12	(37%)	22.49	(55%)	22.8	-0.31	(-1%)	32	205.54	45.39
				24	(75%)	102.49	(106%)	105.86	-3.37	(-3%)	32	214.67	111.37
				32	(100%)	127.17	(105%)	131.37	-4.20	(-3%)	32	290.66	135.61
				Sudoku (20 configs)									
				4	(20%)	42.72	(88%)	24.12	18.6	(77%)	10	31.87	24.28
				10	(50%)	58.31	(55%)	54.16	4.15	(7%)	10	31.75	53.67
				20	(100%)	316.47	(94%)	332.36	-15.89	(-4%)	20	31.74	338.48
				Xstream (128 configs)									
				2	(1%)	1.57	(5%)	1.08	0.49	(45%)	2	106.50	1.06
				64	(50%)	5.77	(63%)	5.26	0.51	(9%)	64	109.22	5.14
HIGH	101.66	8.68	(8%)	128	(100%)	9.16	(105%)	8.59	0.57	(6%)	128	105.68	8.74

SPLat vs. SRA

SPLat is more precise:

SPLat.Confs <

SRA.Confs

SPLat is more efficient:

SPLat.Overhead

< SRA.Overhead;

SPLat.IdealTime

< SRA.Time

Answer to QR1: comparison

SPLat is more efficient than ReuseJVM and SRA

SPLat prunes configurations faster and more precisely than SRA

Table 2: Experimental Results for Various Techniques

	All Valid			SPLat							Static Reachability (SRA)		
Test	*NewJVM*	*ReuseJVM*		*Confs*		*SPLatTime*		*IdealTime*	*Overhead*		*Confs*	*Overhead*	*Time*
101Companies (192 configs)													
LOW	35.46	2.13	(6%)	32	(16%)	1.64	(77%)	0.72	0.92	(127%)	96	84.04	1.28
MED	49.37	3.90	(7%)	160	(83%)	6.84	(175%)	3.58	3.26	(91%)	192	82.54	3.99
HIGH	283.69	45.26	(15%)	176	(91%)	47.6	(105%)	41.59	6.01	(14%)	192	81.93	45.16
Elevator (20 configs)													
LOW	10.74	5.17	(48%)	2	(10%)	1.33	(25%)	0.71	0.62	(87%)	2	23.29	0.76
MED	50.97	46.65	(91%)	10	(50%)	23.62	(50%)	23.14	0.48	(2%)	20	23.74	46.17
HIGH	62.57	59.48	(95%)	20	(100%)	60.71	(102%)	59.28	1.43	(2%)	20	24.38	60.43
Email (40 configs)													
LOW	40.63	10.74	(26%)	1	(2%)	1.00	(9%)	0.87	0.13	(14%)	1	23.62	0.87
MED	57.56	48.87	(84%)	30	(75%)	36.99	(75%)	37.14	-0.15	(0%)	40	22.81	49.02
HIGH	58.02	48.93	(84%)	40	(100%)	48.96	(100%)	49.26	-0.31	(0%)	40	23.84	49.16
GPL (73 configs)													
LOW	19.21	2.23	(11%)	6	(8%)	0.79	(35%)	0.29	0.49	(168%)	6	104.97	0.30
MED	190.53	171.62	(90%)	55	(75%)	130.87	(76%)	128.52	2.35	(1%)	55	99.41	128.69
HIGH	314.20	285.89	(90%)	70	(95%)	278.77	(97%)	277.48	1.29	(0%)	73	103.52	286.28
JTopas (32 configs)													
				8	(25%)	6.29	(37%)	4.49	1.80	(40%)	32	86.87	16.44
				16	(50%)	13.16	(70%)	9.71	3.46	(35%)	32	86.87	18.70
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				2	(1%)	3.06	(2%)	2.45	0.61	(24%)	144	80.40	135.47
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				144	(100%)	153.11	(99%)	152.16	0.94	(0%)	144	81.29	151.94
Prevayler (32 configs)													
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				24	(75%)	102.49	(106%)	105.86	-3.37	(-3%)	32	214.67	111.37
				32	(100%)	127.17	(105%)	131.37	-4.20	(-3%)	32	290.66	135.61
Sudoku (20 configs)													
				4	(20%)	42.72	(88%)	24.12	18.6	(77%)	10	31.87	24.28
				10	(50%)	58.31	(55%)	54.16	4.15	(7%)	10	31.75	53.67
HIGH	489.60	334.82	(68%)	20	(100%)	316.47	(94%)	332.36	-15.89	(-4%)	20	31.74	338.48
Xstream (128 configs)													
LOW	111.26	30.04	(27%)	2	(1%)	1.57	(5%)	1.08	0.49	(45%)	2	106.50	1.06
MED	105.10	9.04	(8%)	64	(50%)	5.77	(63%)	5.26	0.51	(9%)	64	109.22	5.14
HIGH	101.66	8.68	(8%)	128	(100%)	9.16	(105%)	8.59	0.57	(6%)	128	105.68	8.74

Answer to QR2: Overhead

Large relative overhead for short tests (*LOW*)

Small for long tests (*HIGH*)

→ Can save total time even with large overhead

RQ3: Test on Groupon codebase

- **Groupon PWA:**
  - >171K lines of Ruby code
  - >170 (boolean) feature variables → 2^{170} configurations
  - Test code: >231K lines
  - >19K Rspec tests, each under one configuration

- **Apply SPLat:**
  - Allow varying features

    → #Configurations each test covers? (upperbound 16)

    → #Features each test encounters?

RQ3: Test on Groupon codebase

Total:
>170 features
>19K tests

Table 3: Reachable Configurations

Configs	*Tests*	*Configs*	*Tests*
1	11,711	2	1,757
3	332	4	882
5	413	6	113
7	19	8	902
9	207	10	120
11	29	12	126
13	6	14	32
15	10	16	349
17	2,695	-	-

"17" means >16

#Configs << 2^{170}

Table 4: Accessed Features

Vars	*Tests*	*Vars*	*Tests*	*Vars*	*Tests*
0	11,711	1	1,757	2	1,148
3	1,383	4	705	5	389
6	466	7	323	8	425
9	266	10	140	11	86
12	80	13	34	14	28
15	54	16	62	17	1
19	14	20	260	21	109
22	45	23	19	24	22
25	9	26	2	27	14
28	17	29	6	30	8
31	24	32	6	33	14
34	31	35	11	36	15
37	8	38	2	39	2
40	3	42	2	43	2

The maximum is 43: << 170

Answer to RQ3:

SPLat can scale to large industrial code with low implementation cost

Critiques:

- Introduced **upperbound (16) for #configs** to simplify the problem
- Assumed **no constraints** among features
- Didn't report **time cost**

Discussion

Question 1:

How do the previously mentioned critiques affect the validity of SPLat scaling to large codebases?

Discussion

Question 2:

Can SPLat scale to non-boolean variables? How?

Discussion

Question 3:

What will SPLat do if a feature is encountered but its code has no effect?

Discussion

Question 4:

Can you think of any potential optimization to improve the efficiency of SPLat?

Discussion

Question 5:

What needs to be done to apply SPLat to an SPL program?

References

1. http://www.methodsandtools.com/archive/archive.php?id=45
2. http://www.sei.cmu.edu/productlines/
3. http://resources.sei.cmu.edu/asset_files/Presentation/2008_017_001_24246.pdf

Thank you!