# T-Wise Sampling Operations on Binary Decision Diagrams

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SoftVarE

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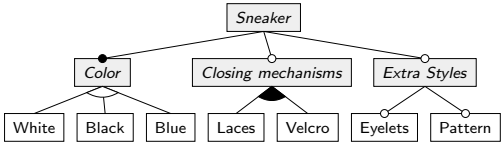


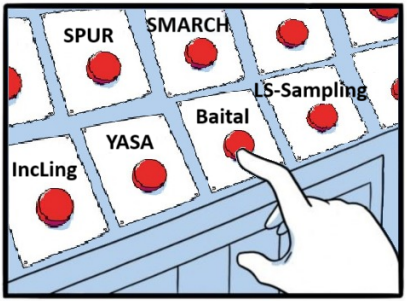

Laces $\Rightarrow$ Eyelets
Pattern $\Rightarrow$ Blue
Laces $\wedge$ Velcro $\Rightarrow \neg$ Pattern

**Example Configuration**

$\{\neg Bc, Bu, Ey, L, \neg P, \neg V, \neg W\}$

**2-wise Interactions**

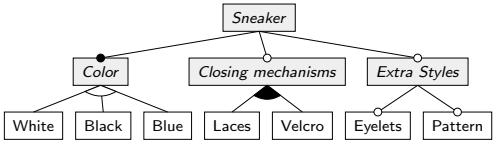
Interactions between Eyelets (E) and Pattern (P):
$\{E, P\}, \{E, \neg P\}, \{\neg E, P\}, \{\neg E, \neg P\}$


SPUR
SMARCH
LS-Sampling
Baital
YASA
IncLing


WHICH
SAMPLE TO USE?
imgflip.com

# Binary Decision Diagrams

## Sneaker Feature Model

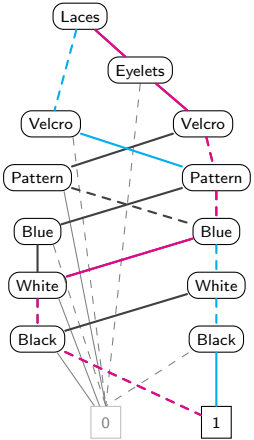



Laces ⇒ Eyelets
Pattern ⇒ Blue
Laces ∧ Velcro ⇒ ¬ Pattern

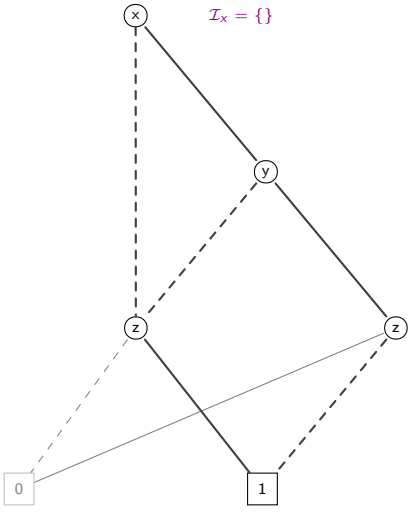
## Example Sample

$\{\neg Bc, Bu, Ey, L, \neg P, \neg V, \neg W\}$
$\{Bc, \neg Bu, Ey, \neg L, \neg P, V, \neg W\}$

## Sneaker Binary Decision Diagram



# 2-wise Counting on BDDs



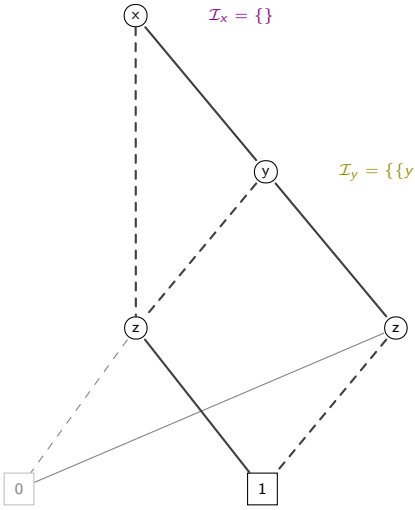

**Legend**

$\mathcal{I}_{literal}$ = interactions with *literal*

**Interactions**

$\{y, x\}$, $\{y, \neg x\}$, $\{\neg y, x\}$, $\{\neg y, \neg x\}$, $\{z, x\}$, $\{z, \neg x\}$, $\{z, y\}$, $\{z, \neg y\}$, $\{\neg z, x\}$, $\{\neg z, y\}$

# 2-wise Counting on BDDs




4

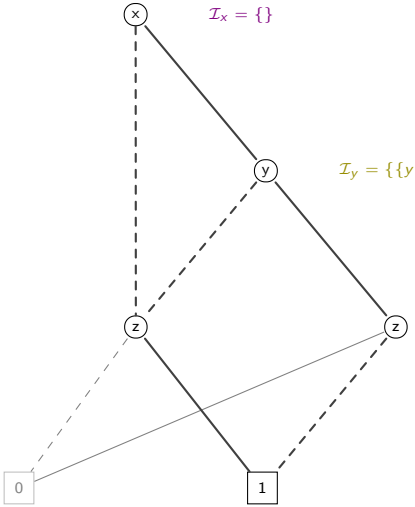
**Legend**

$\mathcal{I}_{literal}$ = interactions with *literal*

**Interactions**

$\{y, x\}$, $\{y, \neg x\}$, $\{\neg y, x\}$, $\{\neg y, \neg x\}$, $\{z, x\}$, $\{z, \neg x\}$, $\{z, y\}$, $\{z, \neg y\}$, $\{\neg z, x\}$, $\{\neg z, y\}$

# 2-wise Counting on BDDs




**Legend**

$\mathcal{I}_{literal}$ = interactions with *literal*

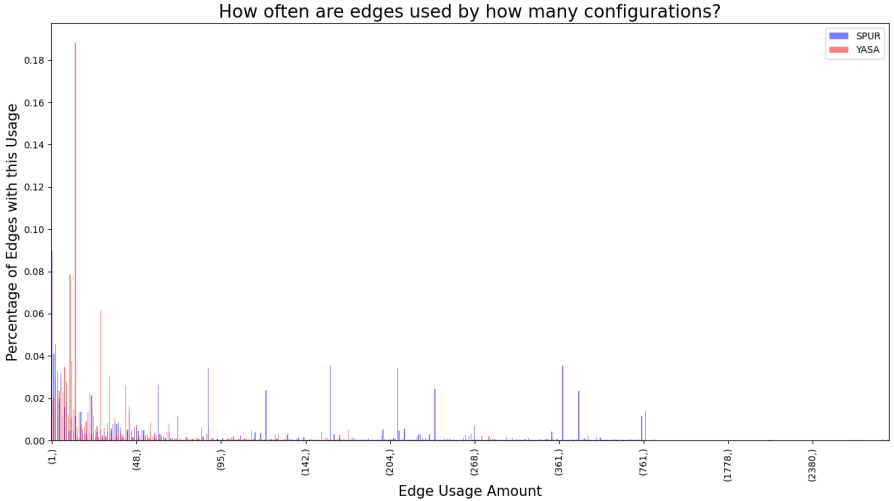
**Interactions**

$\{y, x\}$, $\{y, \neg x\}$, $\{\neg y, x\}$,
$\{\neg y, \neg x\}$, $\{z, x\}$, $\{z, \neg x\}$,
$\{z, y\}$, $\{z, \neg y\}$, $\{\neg z, x\}$, $\{\neg z, y\}$

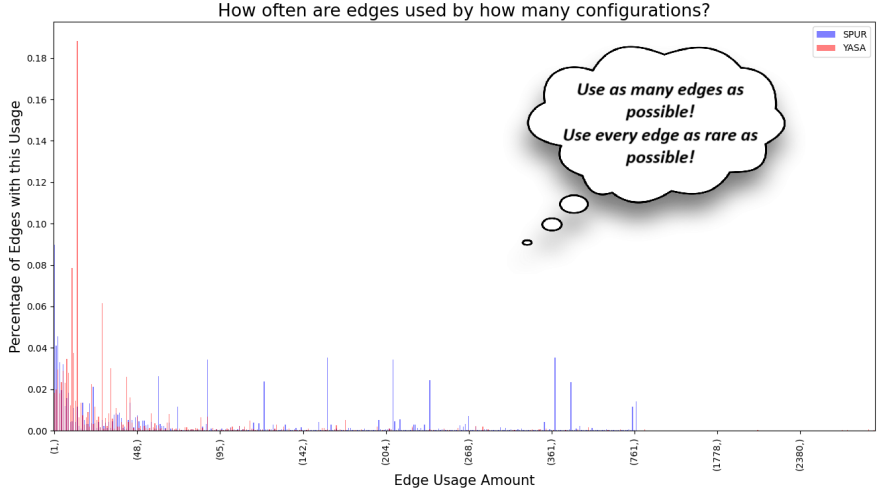
# Results

| Feature Model | #2-wise Interactions | Runtime (s) | YASA Time (s) |
|---|---|---|---|
| jhipster | 3,151 | 0.0058 | 0.4961 |
| berkeleydb | 10,115 | 0.0227 | 0.5395 |
| toybox | 256,494 | 0.0298 | 1.3214 |
| embtoolkit | 1,938,278 | 0.2865 | 7.2589 |
| fiasco | 2,427,068 | 0.2992 | 20.4074 |
| sandwich | 596 | 0.0003 | 0.4560 |
| financialservices01 | 917,150 | 0.9585 | 9.4991 |
| automotive01 | 11,082,088 | 36.3714 | 12.0693 |
| automotive02_v4 | 627,784,994 | 104.2016 | – |

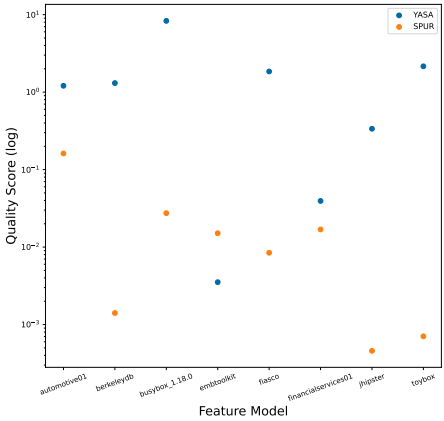
# YASA vs. SPUR

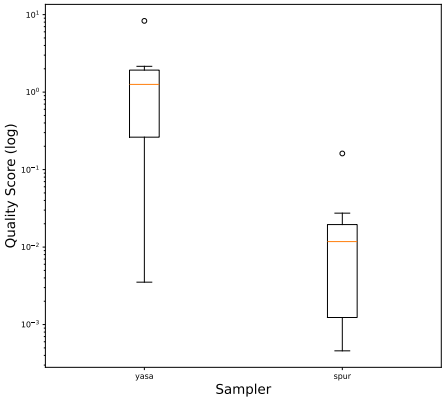

How often are edges used by how many configurations?
SPUR
YASA
Percentage of Edges with this Usage
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
(1.)
(48.)
(95.)
(142.)
(204.)
(268.)
(361.)
(761.)
(1778.)
(2380.)
Edge Usage Amount

# YASA vs. SPUR

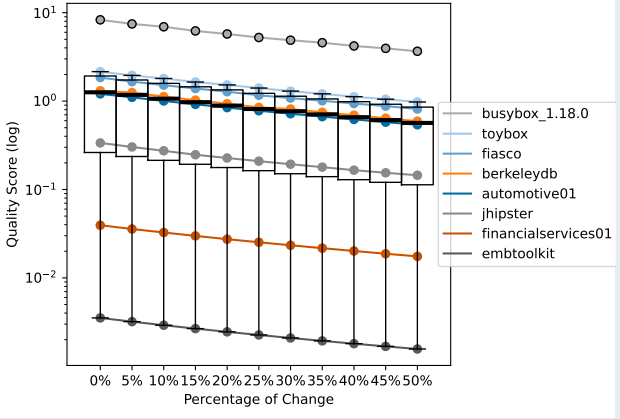

How often are edges used by how many configurations?
SPUR
YASA
Use as many edges as possible!
Use every edge as rare as possible!
Percentage of Edges with this Usage
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
(1,)
(48,)
(95,)
(142,)
(204,)
(268,)
(361,)
(761,)
(1778,)
(2380,)
Edge Usage Amount

# Results YASA vs. SPUR



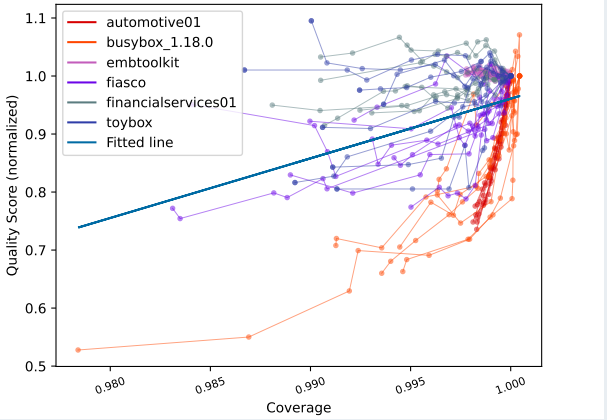



# Results Correlation Coefficient – Size




$\varrho = -0.9857;\ p = 3 * 10^{-8}$

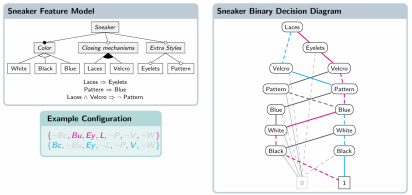
# Results Correlation Coefficient – Coverage




$\varrho = -0.9181$; $p = 0.0195$

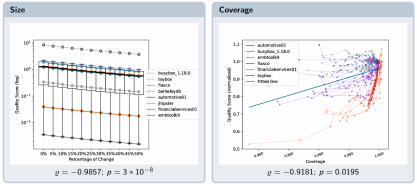
# Summary

**Binary Decision Diagrams**





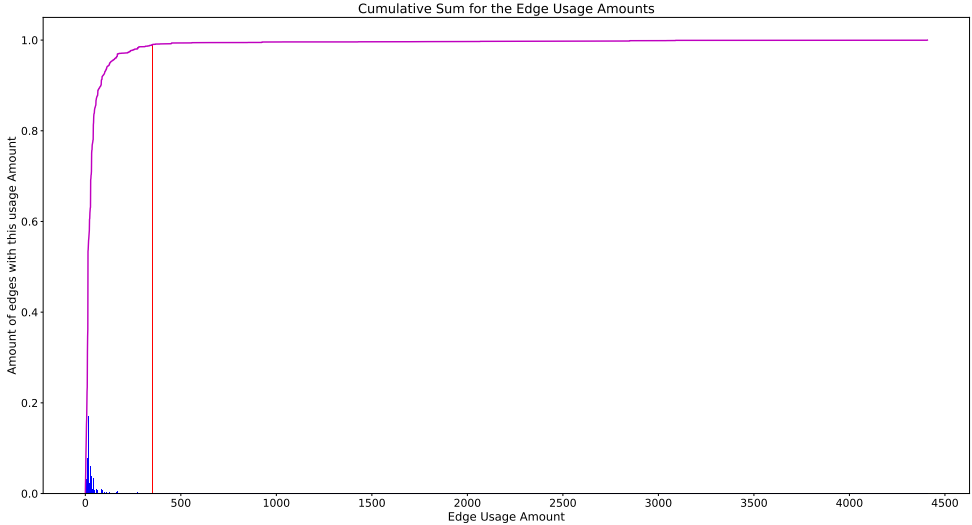

**Results Correlation Coefficient**






- Sample Quality without coverage calculation
  $\Rightarrow$ Metric 20 seconds vs Coverage 24+ hours
- Counting and generating interactions 5 minutes vs 24+ hours

# Score

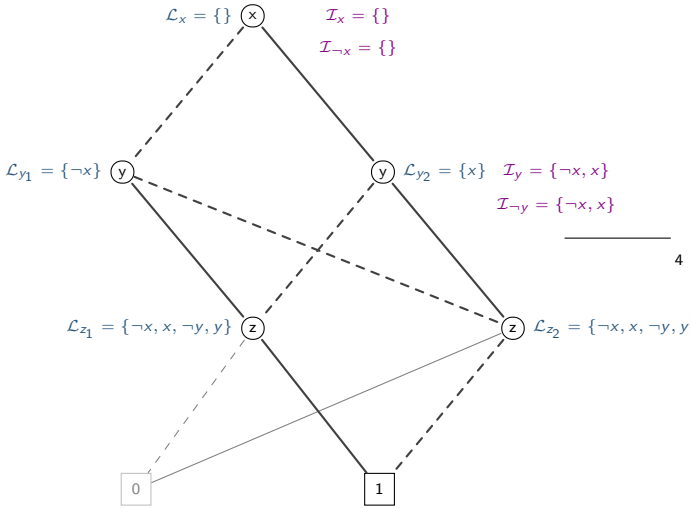

Cumulative Sum for the Edge Usage Amounts
Amount of edges with this usage Amount
Edge Usage Amount
0.0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500

# Score

$$score(sample) = \frac{\#edges(sample)}{\#configurations(sample)} \cdot \frac{cumsum_{mean}}{mean}$$

**Higher is Better!**

# Counting Algorithm




**Legend**

$\mathcal{L}_{node}$ = ingoing literals of *node*
$\mathcal{I}_{literal}$ = interactions with *literal*