# CSB: A Counting and Sampling tool for Bitvectors

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[2] University of Toronto, Canada

## Problem Statement

### Counting

Bitvector formula F on variables X

Sol(F) set of assignment on X, that satisfy F

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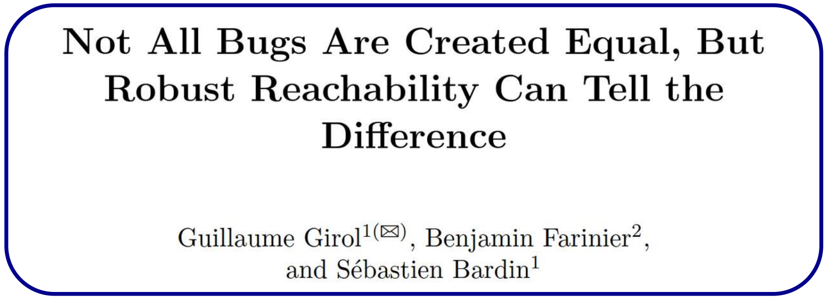
$$\frac{1}{(1+\varepsilon)|\mathsf{Sol(F)}|} \leq \Pr(\sigma) \leq \frac{(1+\varepsilon)}{|\mathsf{Sol(F)}|}$$

## Why counting and sampling in bit-vectors?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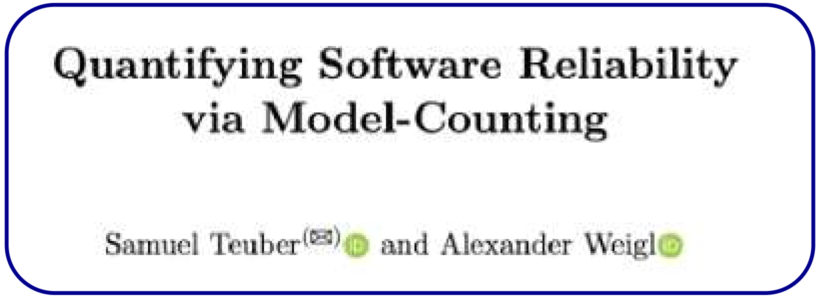
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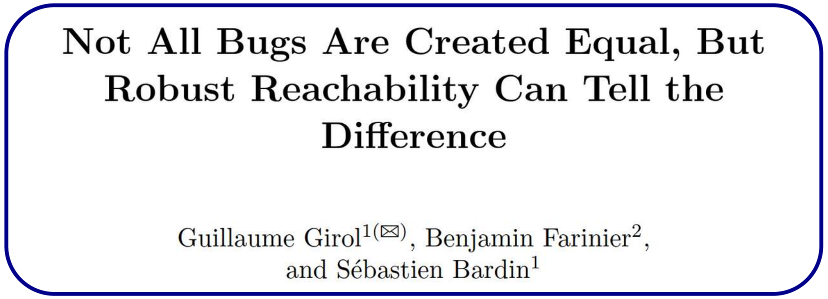

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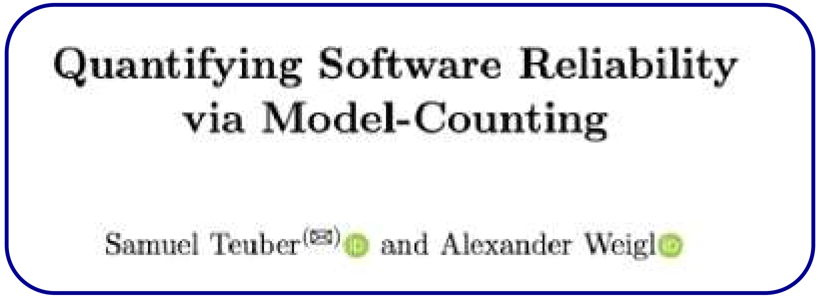

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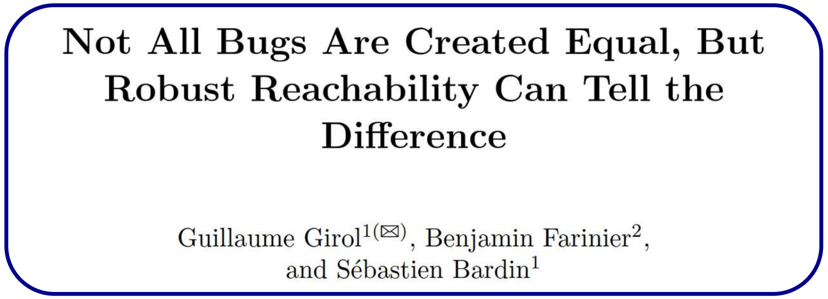
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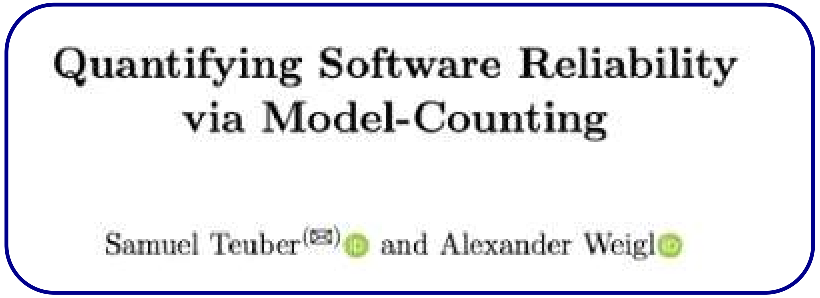
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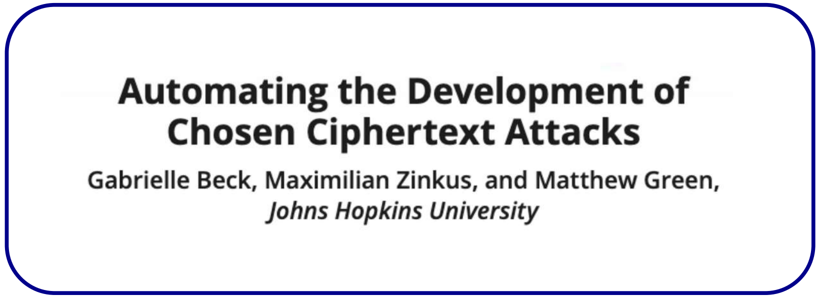
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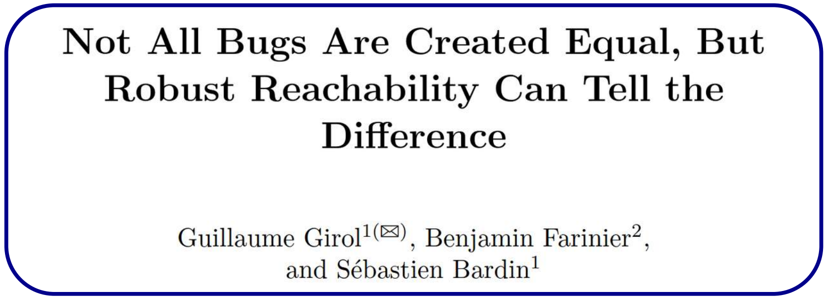
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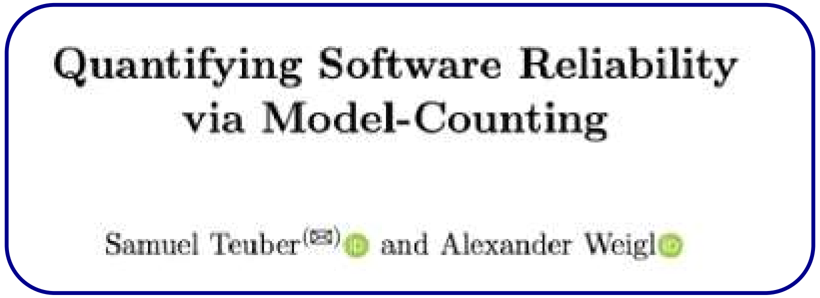
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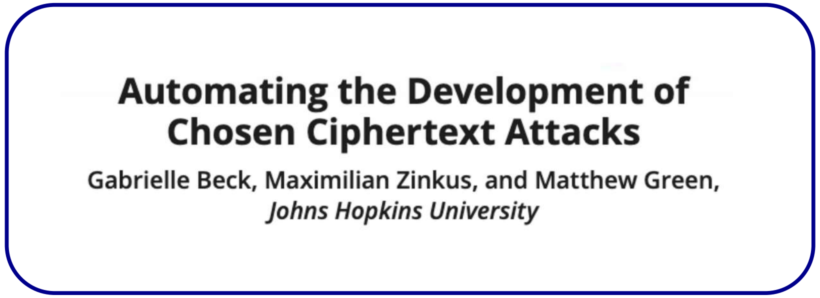
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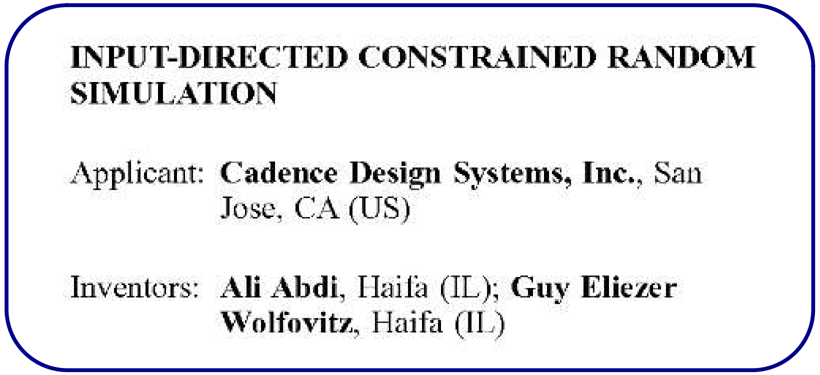
INPUT-DIRECTED CONSTRAINED RANDOM SIMULATION

Applicant: **Cadence Design Systems, Inc.**, San Jose, CA (US)

Inventors: **Ali Abdi**, Haifa (IL); **Guy Eliezer Wolfovitz**, Haifa (IL)

## Current state of the art

### Counting

- SMTApproxMC [CMMV '16]
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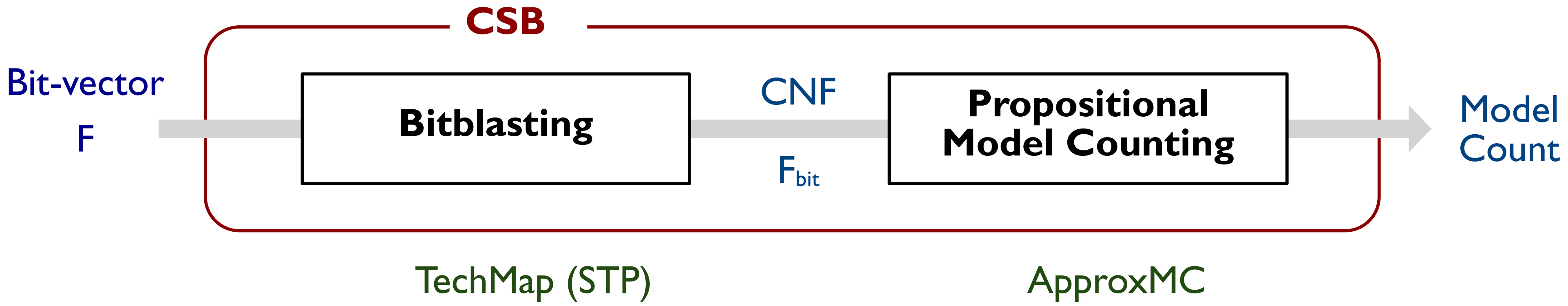
## This work

- Significant recent improvement on CNF counting and sampling
  - Can the improvement be translated to bit-vector counting directly?

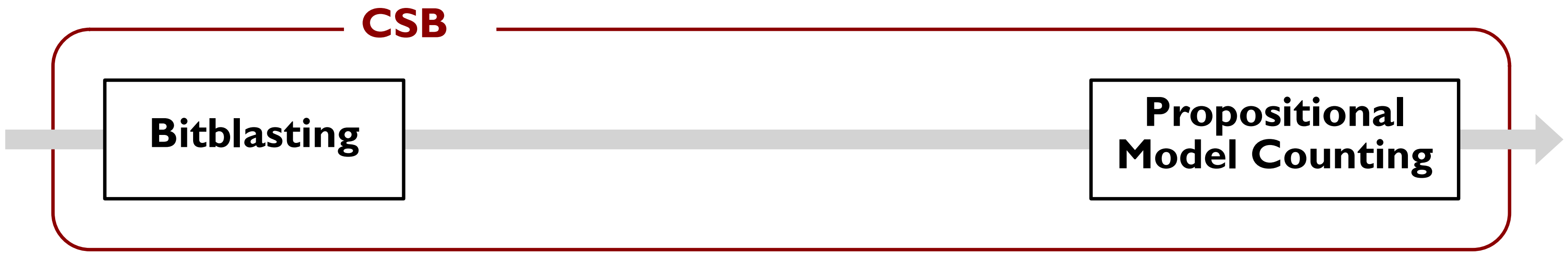
## Framework for Counting



### Implementation

- Built on top of SMT solver **STP**
- Turned off simplifications and rewrites
- Added ApproxMC in place of SAT solver backend

## Trying different possibilites



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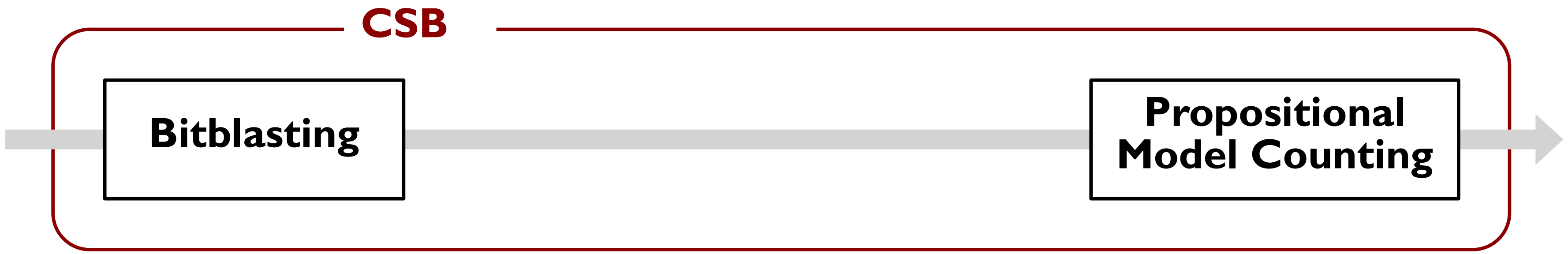

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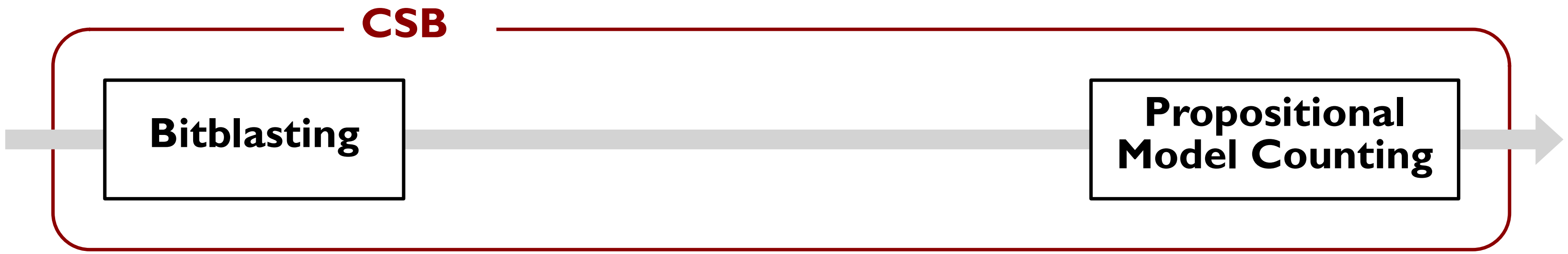

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Approximate Counter:
- ApproxMC
  - Hashing-based counter

Exact counter:
- ADDMC
- ExactMC
- SharpSAT-TD
- Ganak

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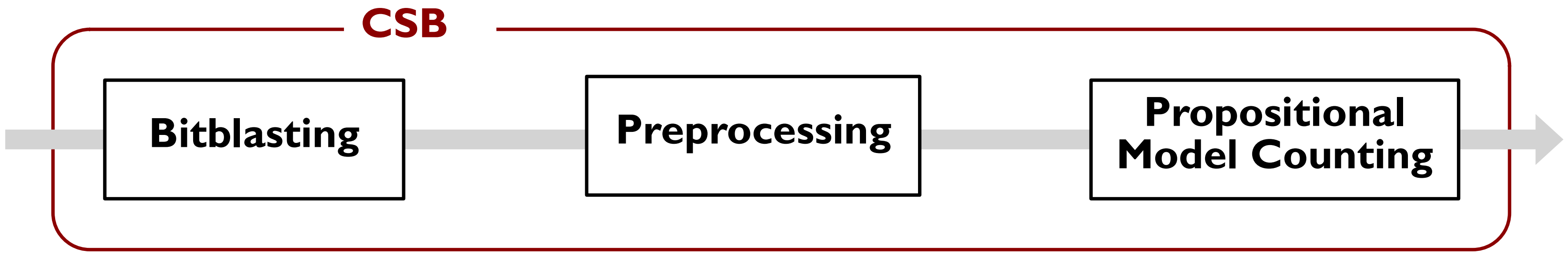

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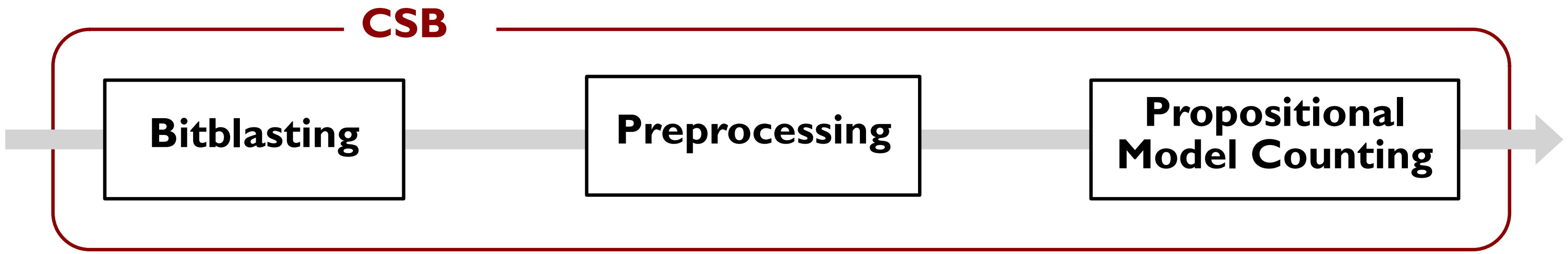

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- Arjun
- B + E

  - Input-output bipartition

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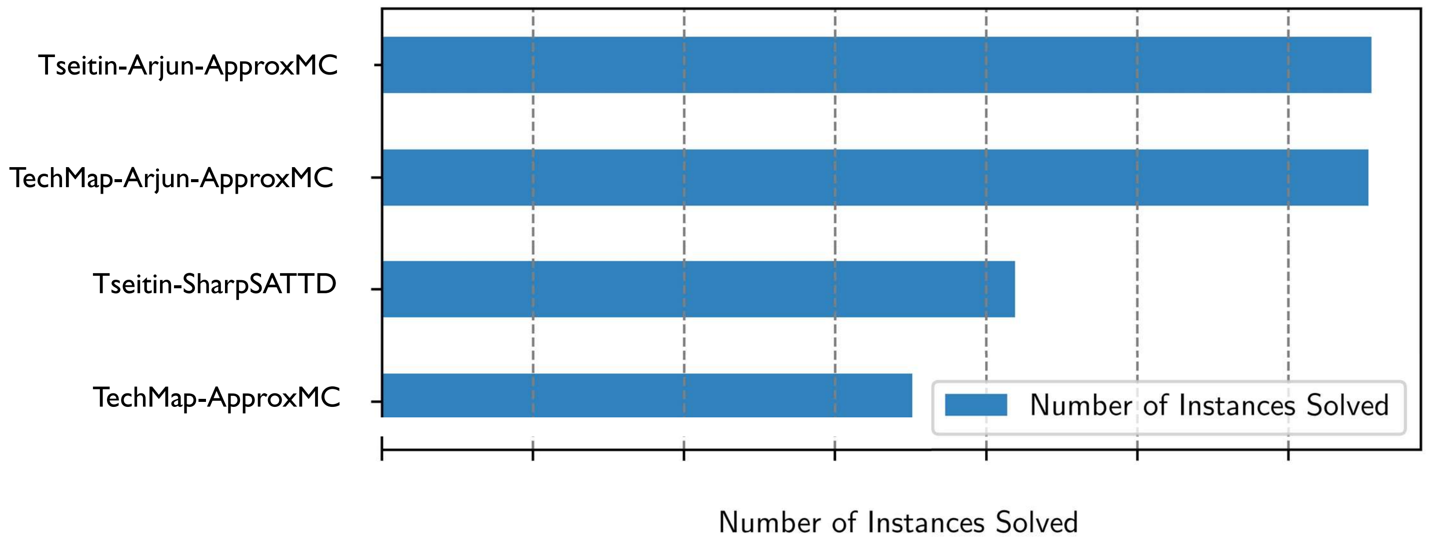
## Best Performing Settings

### Bitblasting + Preprocessing + Model Counting



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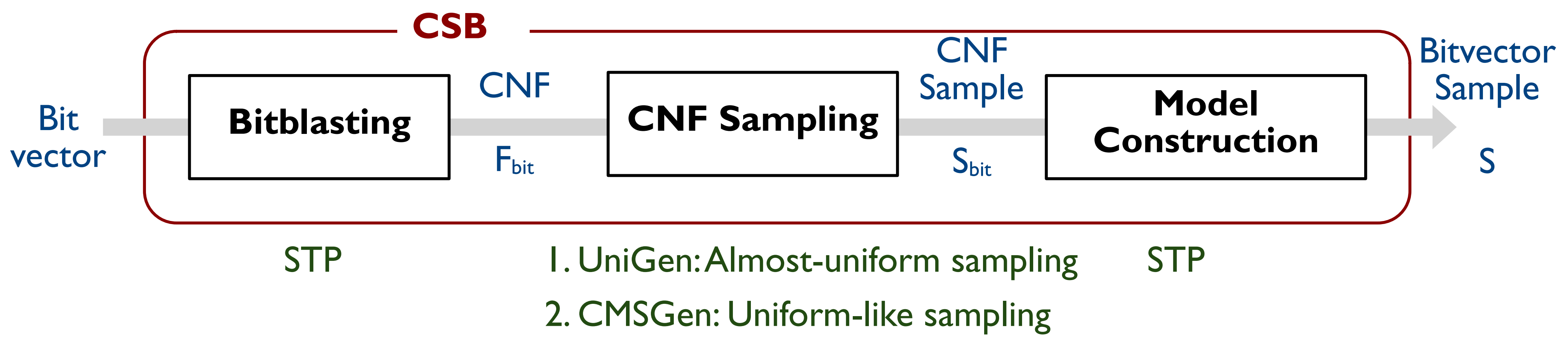

### Implementation

- Built on top of SMT solver **STP**
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- Added UniGen and CMSGen in place of SAT solver backend

## Two modes of Sampling

- **Almost-uniform** sampling (UniGen)
  - Sampling with theoretical guarantees. Hashing-based approach.
- **Uniform-like** sampling (CMSGen)
  - No theoretical guarantee, but passes distribution testing based criterions
  - CMSGen is made by using random heursitics in CryptoMiniSat

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**Uniform-like sampling is much faster in practice**

## Experiments: Efficiency in Counting

**Compiled a set of 668 benchmarks**
- quantitave model checking
- cryptography
- old literature

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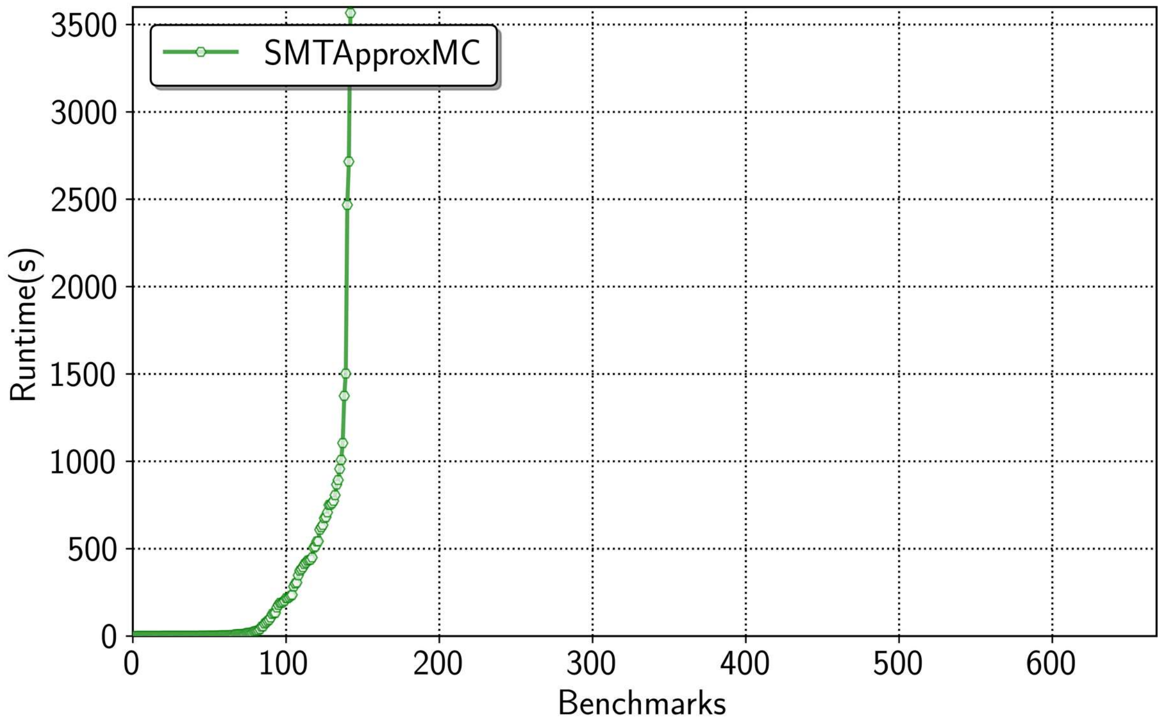
| SMTApproxMC | 143 |



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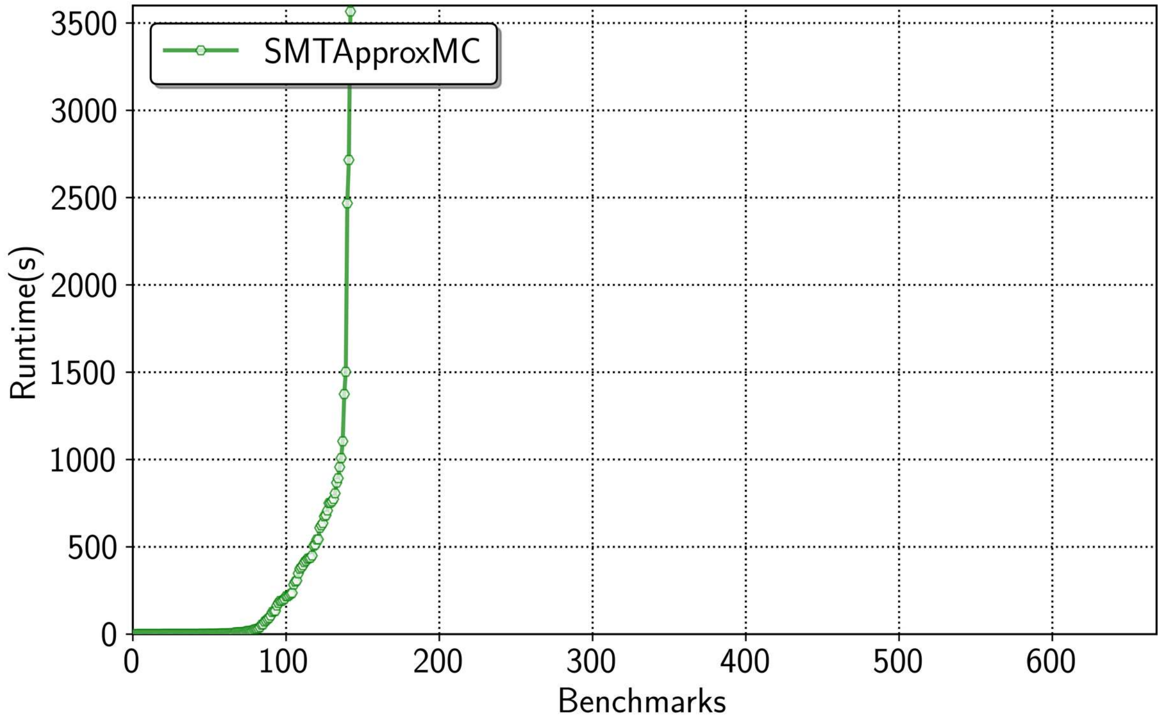

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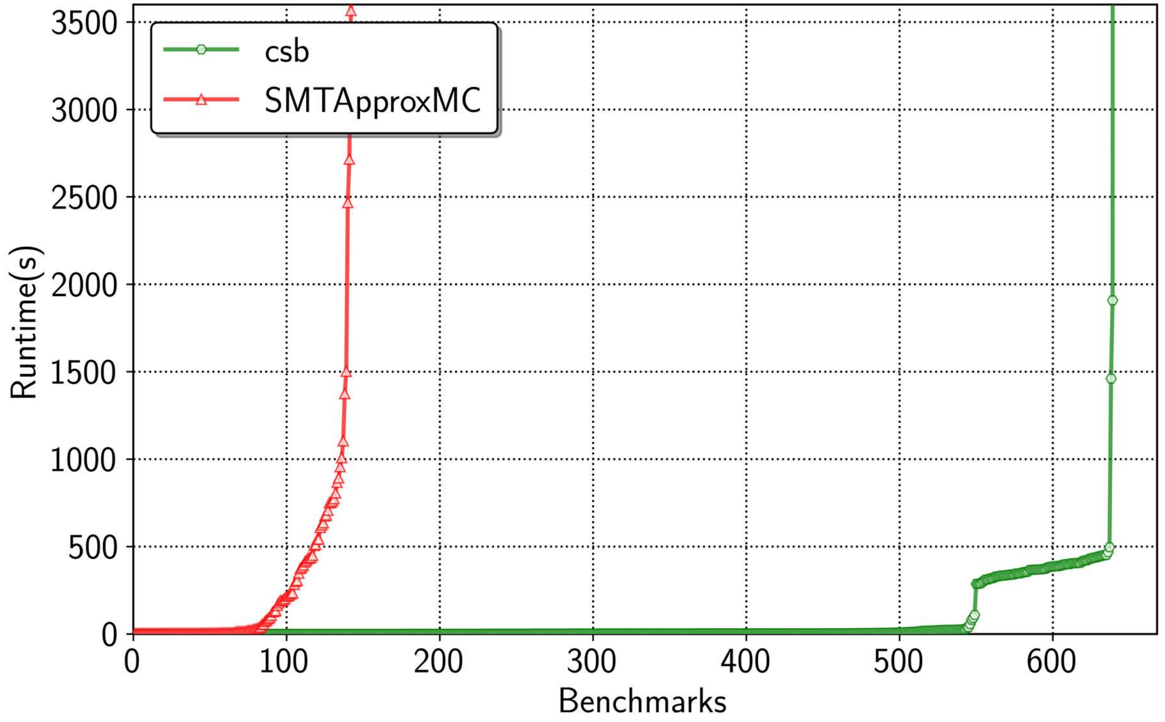

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## Efficiency in Sampling

| Sampling Mode | Median Runtime (s) | Instances solved |
|---|---|---|
| Almost-uniform *(with guarantees)* | 74.6 | 641 |
| Uniform-like *(without theoretical guarantees)* | 1.24 | 662 |

**Sampling 500 samples in 1 hour / 668 instances**

## Conclusion

- A very efficient tool for bitvector counting
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github.com/meelgroup/csb/

**Thank You!**