Optimizing a Structural Constraint Solver for Efficient Software Checking

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Introduction

- Constraint solving is an enabling technology for several static and dynamic analysis techniques.
- To analyze code that manipulates structurally complex data, the solver must support structural constraints
- Solving such constraints is expensive due to many aliasing possibilities.
- Our technique, called *focused generation*, reduces the number of test cases to be generated

Focused Generation

- Focused generation is bounded exhaustive testing where the exhaustive nature is focused on specific fields.
- Finds only one valid assignment for every focused field for a given assignment of other fields.
- Allows optimizing bounded exhaustive testing when objects to be tested contain previously tested objects.
- Focused Generation allows testing of subject classes assuming correctness of classes it depends on.
- It allows focusing tests to some aspect of a structure.
- Considering a red-black tree, we can focus test generation on ordering, coloring, or basic structure.
- The reduced state space for a binary search tree with testing focused on structure is shown below.
- As soon as a test case is found, focused generation backtracks over all not-focused fields.

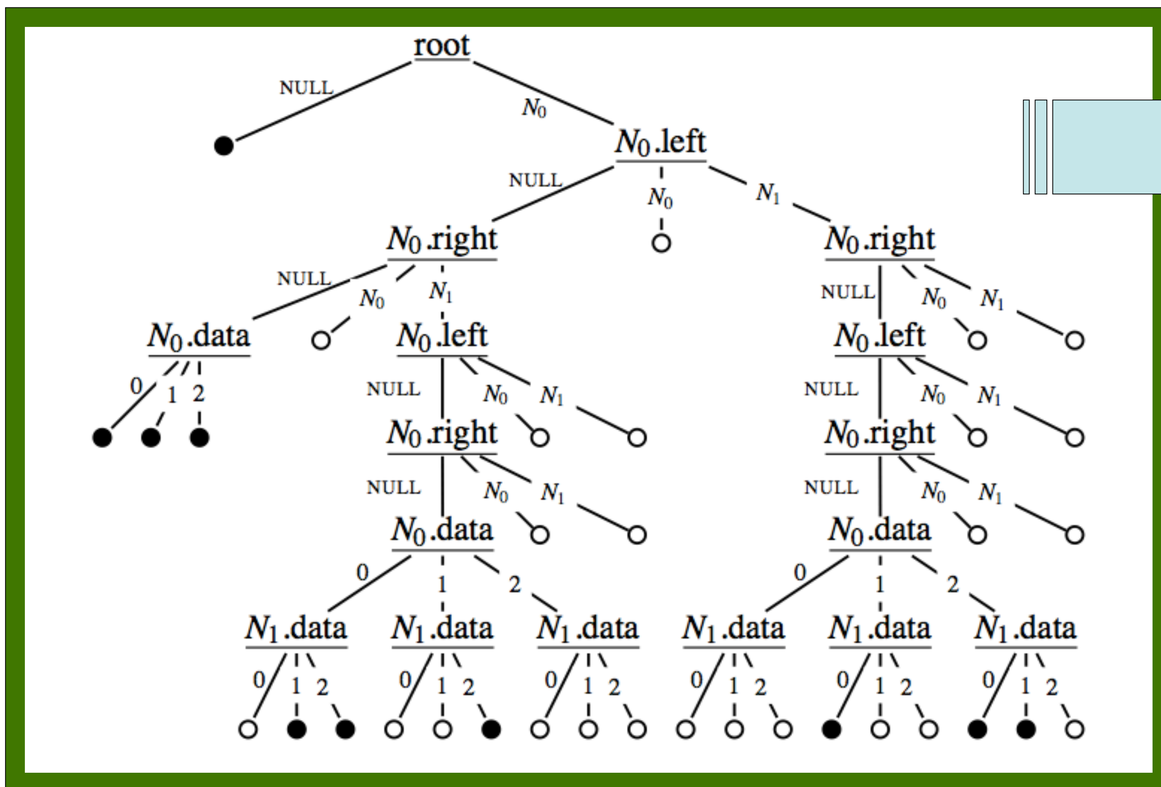
Contributions

- **Focused Generation**: A way to allow some constraints solved exhaustively while others for a single solution
- **Implementation**: We implemented focused generation on top of the Korat constraint solver.
- **Evaluation**: We compared number of tests generated and performance for Korat with and without focused generation.

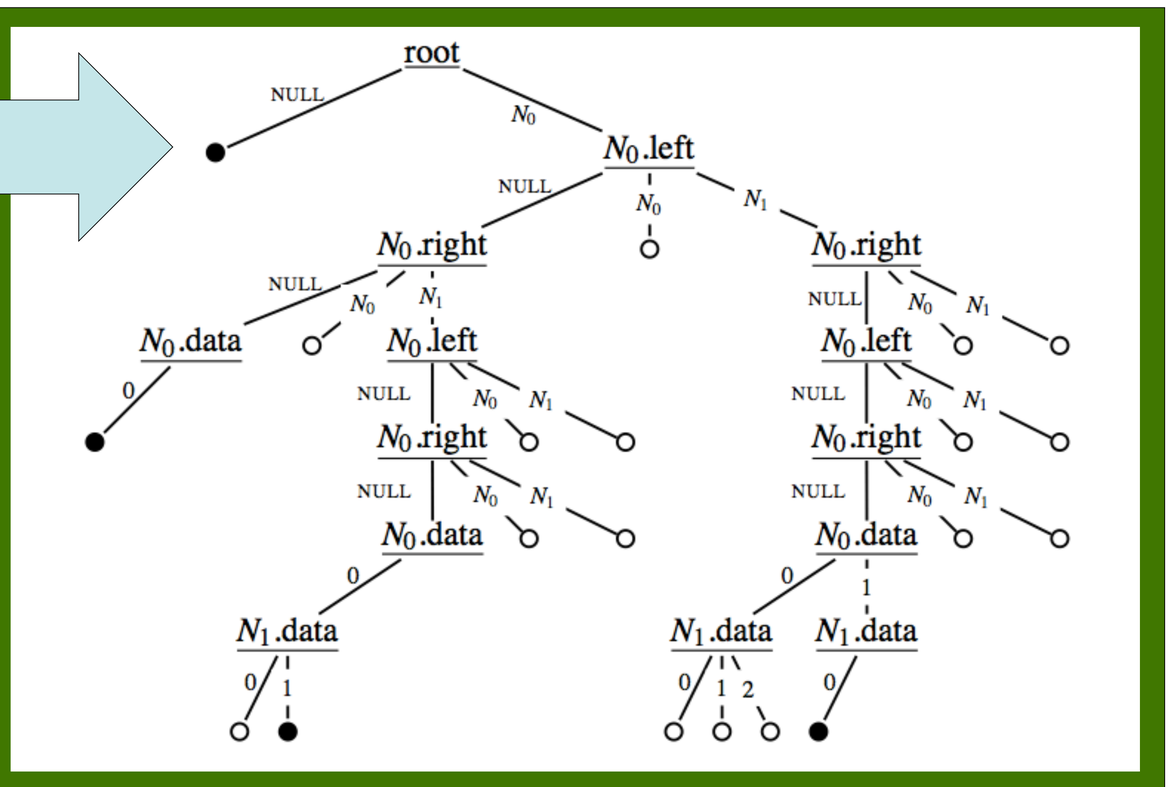
Experiment

- We compared baseline Korat and Korat with focused generation.
- With a 10 minute timeout we compared different sized sorted singly linked lists and red-black trees.
- The results show that Focused generation significantly reduces test cases generated.
- This also enables more pruning of search space and reduced test generation time.
- Test execution time decreases as a consequence of reduced number of tests.

Subject	Size	Baseline		Focused	
		Tests	Time	Tests	Time
Sorted Singly Linked List focused on structure	20	1 M	478s	20	0.00s
	25	N/A	> 600s	25	0.01s
	100	N/A	> 600s	100	2s
	200	N/A	> 600s	200	32s
Red-black tree focused on structure and coloring	10	5 M	26s	377	9s
	11	20 M	110s	707	36s
	12	85 M	478s	1395	142s
	13	N/A	> 600s	2835	563s



Binary Search Tree Exploration by Baseline Korat



Binary Search Tree Exploration with Focused Generation

- For a given structure, only one assignment of data fields is found with focused generation.