MiniZinc Linter

Tool for Static Model Analysis

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Outline

Outline

- MiniZinc
- Linter
- Rules
- Implementation
- Summary

MiniZinc, Tool for Solving Problems

What it is

Toolchain for modelling combinatorial optimisation problems

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Travelling Salesman Problem

Find an order to visit $n \in \mathbb{N}^+$ cities in to minimise the total distance travelled.

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- etc.

Many statements can't be proven!

Have to introduce limitations and approximations.

Linter Rules

Rule

A linter performs several checks, also called rules. Each rule can be disabled or enabled individually.

Demo

```
$ lzn nsp_1.mzn
```

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```
/home/erik/Documents/minizinc-benchmarks/nsp/nsp_1.mzn:67.1-67.55: possibly non-functionally defined variable not in search hint [non-func-hint(9)]
    |     array [period, shifts] of var int:           coverage;
    |     ^~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
/home/erik/Documents/minizinc-benchmarks/nsp/nsp_1.mzn:66.1-66.62: possibly non-functionally defined variable not in search hint [non-func-hint(9)]
    |     array [nurses, period] of var shifts_and_off:  nurses_schedule;
    |     ^~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
/home/erik/Documents/minizinc-benchmarks/nsp/nsp_1.mzn:67.1-67.55: no explicit domain on variable declaration [unbounded-variable(13)]
    |     array [period, shifts] of var int:           coverage;
    |     ^~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
/home/erik/Documents/minizinc-benchmarks/nsp/nsp_1.mzn:68.1-68.60: no explicit domain on variable declaration [unbounded-variable(13)]
    |     array [shifts] of var int:                   shifts_values;
    |     ^~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
/home/erik/Documents/minizinc-benchmarks/nsp/nsp_1.mzn:68.1-68.60: is only constrained to par values, shouldn't be var [constant-variable(4)]
    |     array [shifts] of var int:                   shifts_values;
    |     ^~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
/home/erik/Documents/minizinc-benchmarks/nsp/nsp_1.mzn:88.13-88.28: constrained here
    ^     shifts_values[j] = j
    |     ^~~~~~~~~~~~~~~
```

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Rule: Unused Variables and Functions

Motivation

Unused variables and functions don't contribute to the model and should be removed.

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Example

```
int: K = 69;
var 1..K: a;        % uses K
var int: b;         % unused
constraint a > 2; % uses a, and indirectly K
solve satisfy;
```

Rule: Unused Variables and Functions Cont.

Steps

1. Find all variables and functions **2.** Calculate dependencies **3.** Find all uses and recursively mark nodes as used

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```
int: K = 1;
int: N = 1;
int: M = let {int: J = 5} in J+N;
var 0..K: x;
function var int: f() = x+N;
solve minimize f();
```

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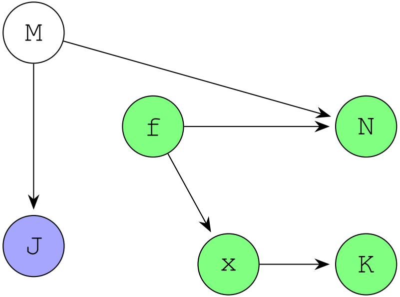

Rule: Unused Variables and Functions Cont.

Steps

1. Find all variables and functions **2.** Calculate dependencies **3.** Find all uses and recursively mark nodes as used **4.** Simplify output

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int: K = 1;
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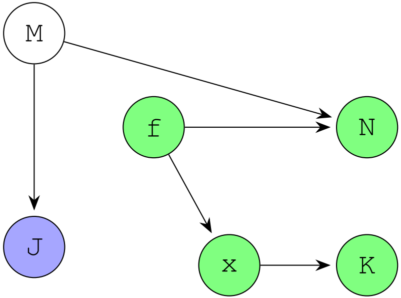

Rule: Missing Domain on Decision Variables

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Decision variables should always have tight domain to limit the amount of potential values.

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var int: a;
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Good

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var int: b = a+1;
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```
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```
var 1..5: a;
var int: b = a+1;
constraint b = a+1;
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Will *not* always constrain `a`

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constraint ... -> a=2;
constraint a=2 \/ ...;
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constraint ... -> a=2;
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Will always constrain `a`

```
constraint a=2;
constraint a=2 /\ ...;
constraint forall([a=2]);
```

General Limitations

Obfuscate the model

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constraint a=2 \/ false;
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constraint a=2 \/ false; % linter won't find
constraint true /\ a=2;
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Not feasible to account for all cases

They are too many ways to obfuscate! Maybe add rules to remove some obfuscation?

General Limitations Cont.

No reliance on instance variables (par)

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Determine whether all individual elements have been accessed in an array

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int: A = 5;
array[1..A] of var int: xs;
constraint forall(i in 1..5)(xs[i] = ...);
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General Limitations Cont.

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The index sets have to be exactly the same.

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Reads text and structures it into a data structure that can be processed, AST is a common one.

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- Easier to maintain one than two
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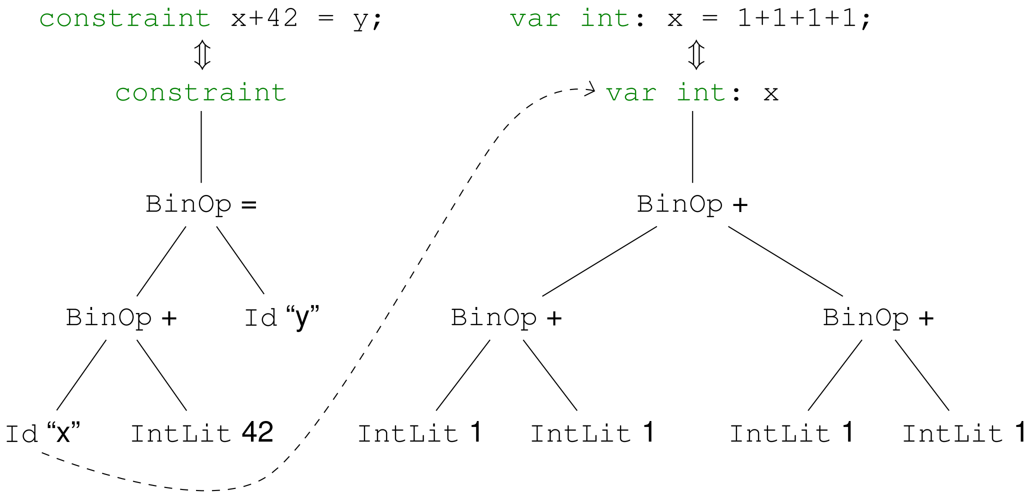
MiniZinc AST



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Find locations of interest in an AST from a path specification (regex-like).

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- `+ >> int`

- Find an addition node
- Find an addition node with an integer under it

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Find locations of interest in an AST from a path specification (regex-like).

- `+`
- `+ >> int`
- `= > id`

- Find an addition node
- Find an addition node with an integer under it
- Find id directly under equals node

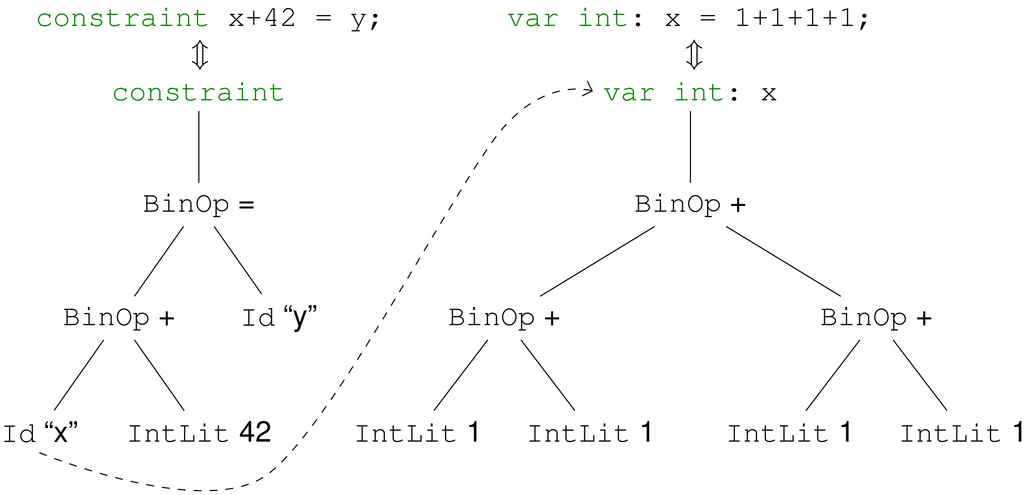
AST Searcher

How to Search

Find locations of interest in an AST from a path specification (regex-like).

- `+` — Find an addition node
- `+ >> int` — Find an addition node with an integer under it
- `= > id` — Find id directly under equals node
- `let > = >> + > id` — Can be arbitrarily long

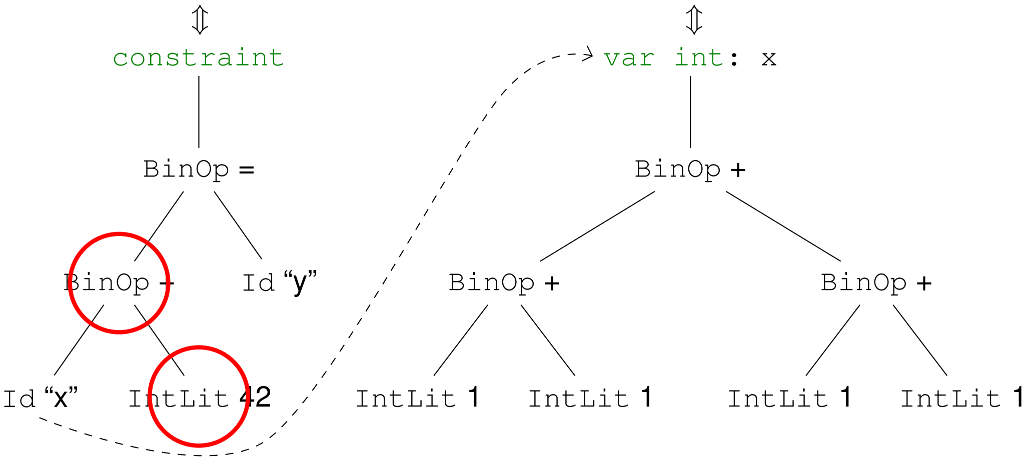
MiniZinc AST



MiniZinc AST

```
constraint x+42 = y;
```

```
var int: x = 1+1+1+1;
```



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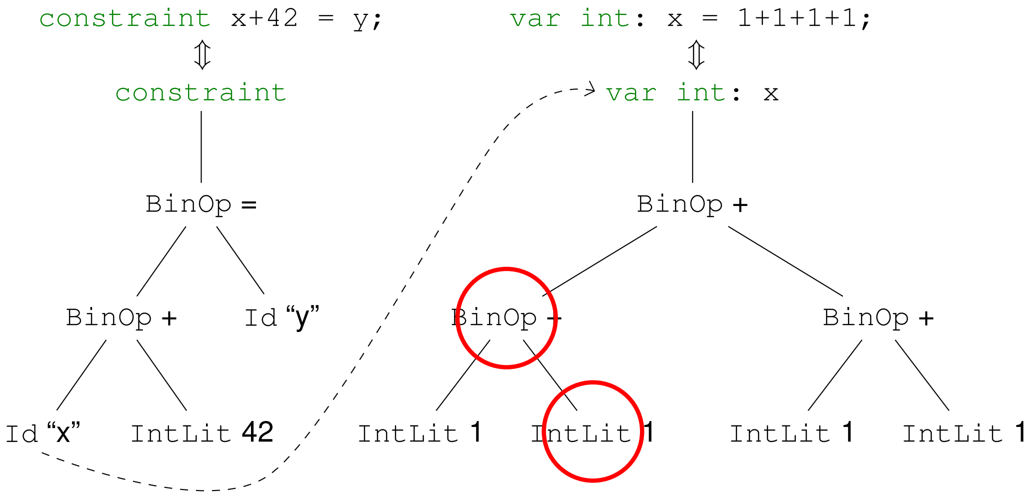

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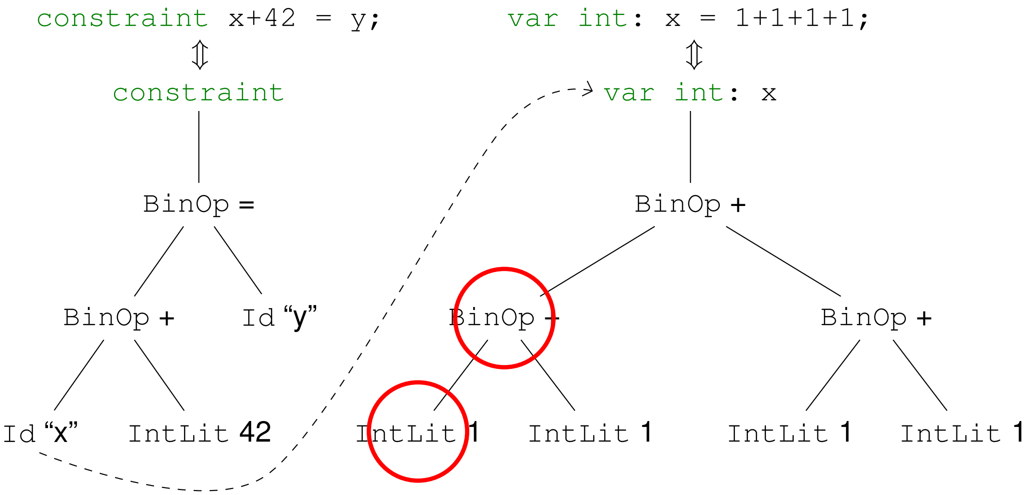

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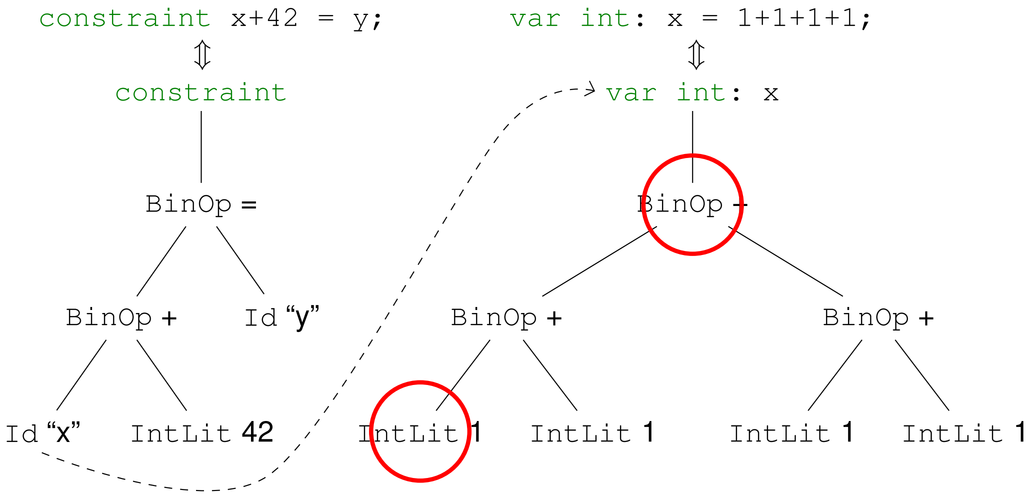

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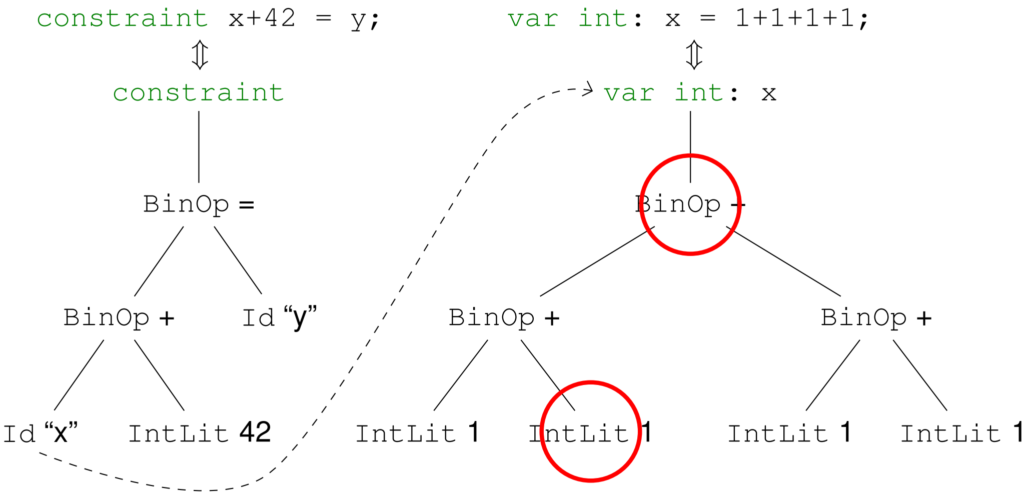

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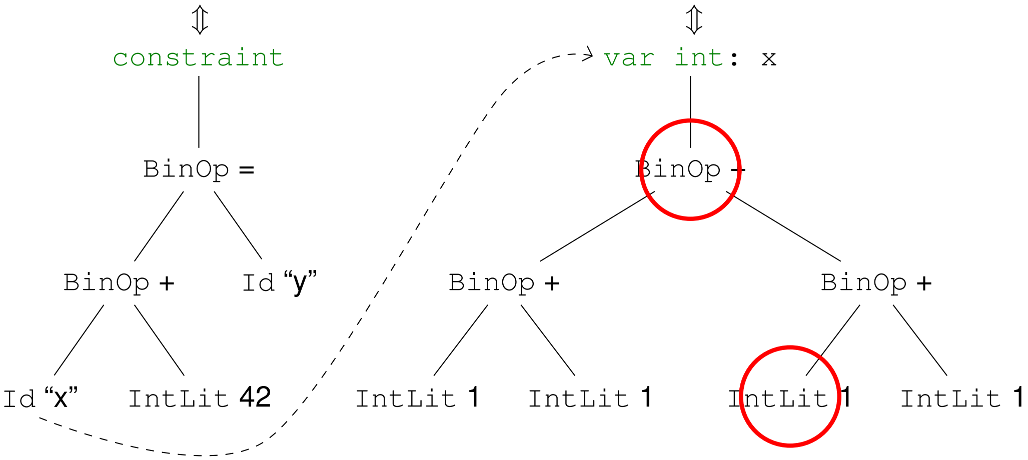

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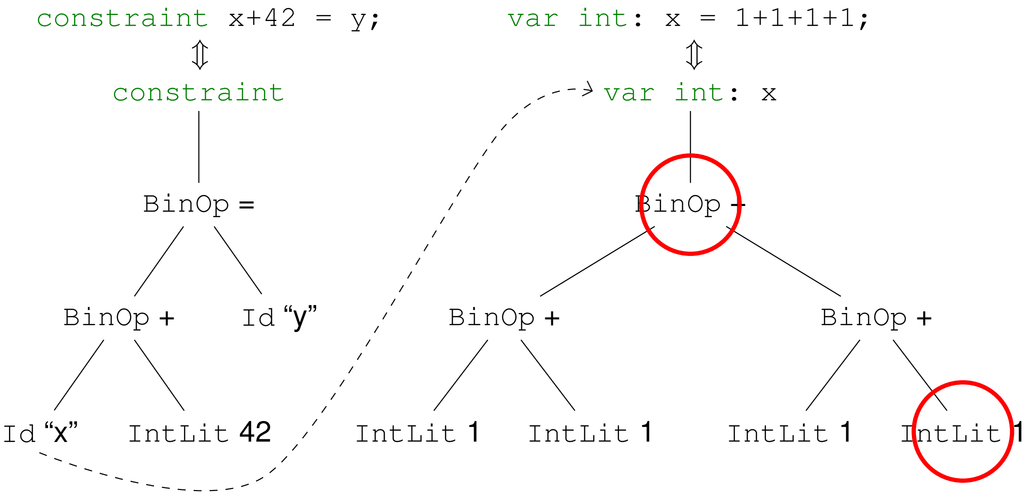

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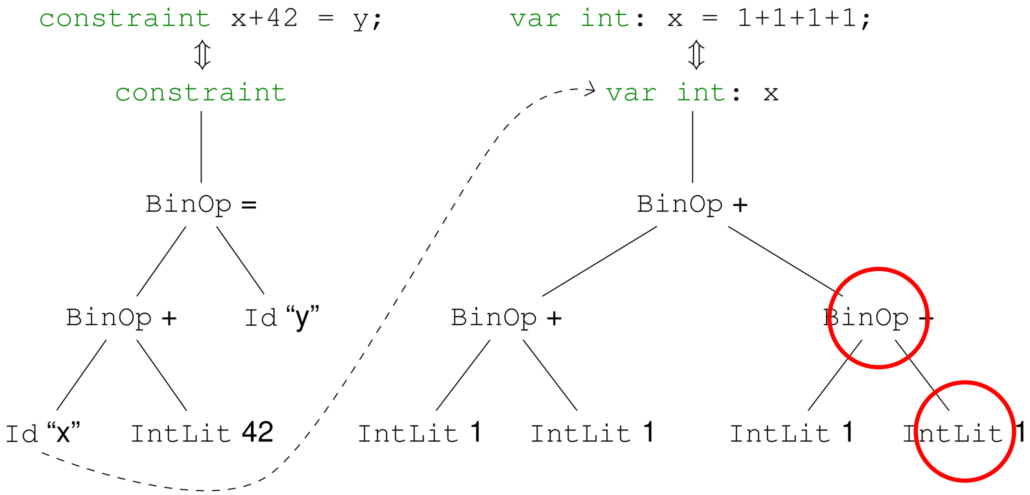

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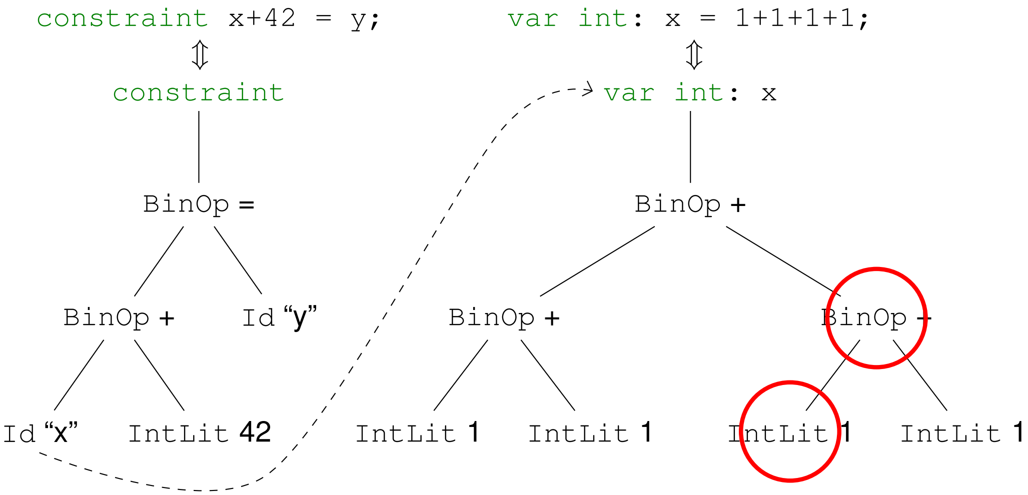
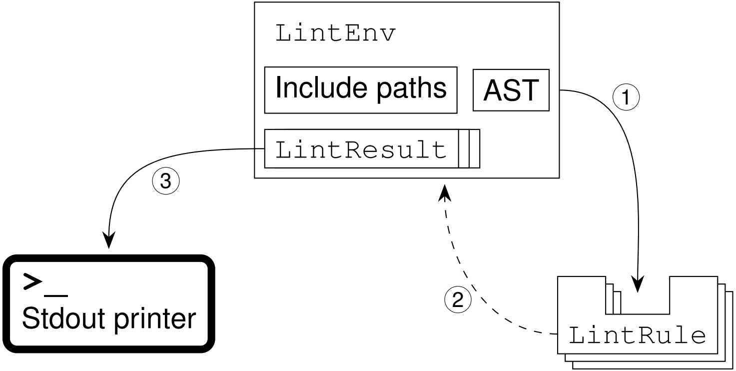


Execution Overview



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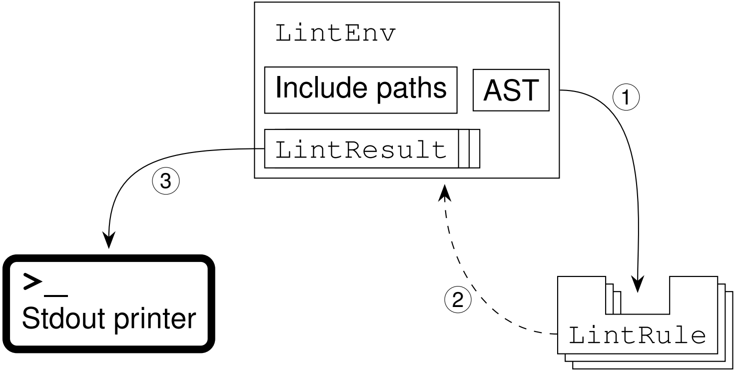

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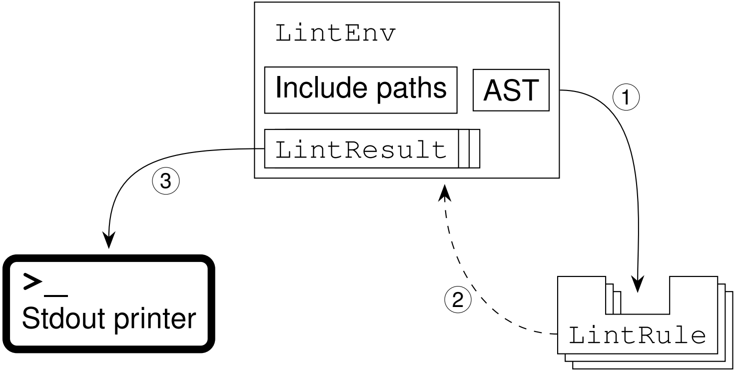

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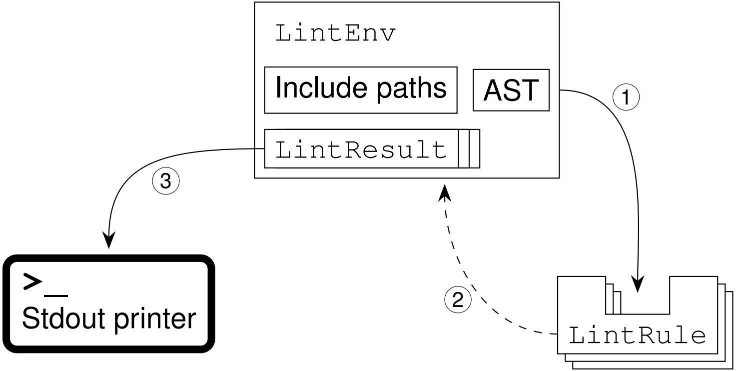

1. Each rule reads the AST from the environment
2. They write back results
3. The results are displayed in some way

Outline

Summary

- MiniZinc is a modelling language that supports several different solvers.
- Decision variables are unknows and constraints constrain them.
- A linter for static analysis of models was created.
- Some things are impossible to deduce.
- Written in C++.
- The MiniZinc parser was reused.
- An AST searcher searches for locations of interest in models.