Oxiflex - A Constraint Programming Solver for MiniZinc written in Rust

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Constraint Network

Constraint Network

- Variables
  - Values to choose from
- Constraints
  - Rules for choosing values

Simple Example

Variables:

$$w = \{1, 2, 3, 4\}$$
$$y = \{1, 2, 3, 4\}$$
$$x = \{1, 2, 3\}$$
$$z = \{1, 2, 3\}$$

Constraints:

$$w = 2 \cdot x$$
$$w < z$$
$$y > z$$

Constraint Programming

var 1..4: w;
var 1..4: y;
var 1..3: x;
var 1..3: z;

constraint $w = 2 \cdot x$;
constraint $w < z$;
constraint $y > z$;

Constraint Programming

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$\rightarrow$ MiniZinc!

MiniZinc

compilation

$\rightarrow$

FlatZinc

```
array [1..2] of int: x_introduced_2_ = [1,-2];
array [1..2] of int: x_introduced_3_ = [1,-1];
array [1..2] of int: x_introduced_4_ = [-1,1];

var 2..4: w:: output_var;
var 1..4: y:: output_var;
var 1..3: x:: output_var;
var 1..3: z:: output_var;

constraint int_lin_eq(x_introduced_2_,[w,x],0);
constraint int_lin_le(x_introduced_3_,[w,z],-1);
constraint int_lin_le(x_introduced_4_,[y,z],-1);

solve satisfy;
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FlatZinc

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FlatZinc constraint example

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predicate int_lin_eq(array [int] of int: as,
                     array [int] of var int: bs,
                     int: c)
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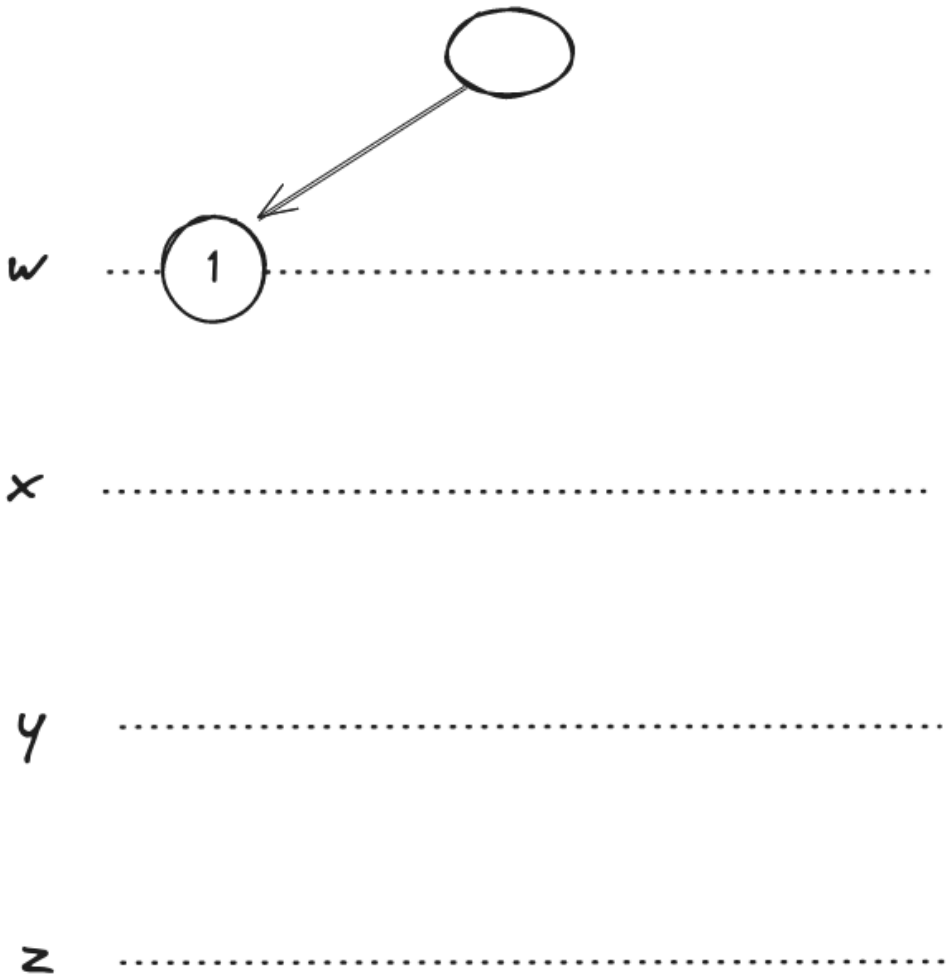
Backtracking

Backtracking Example



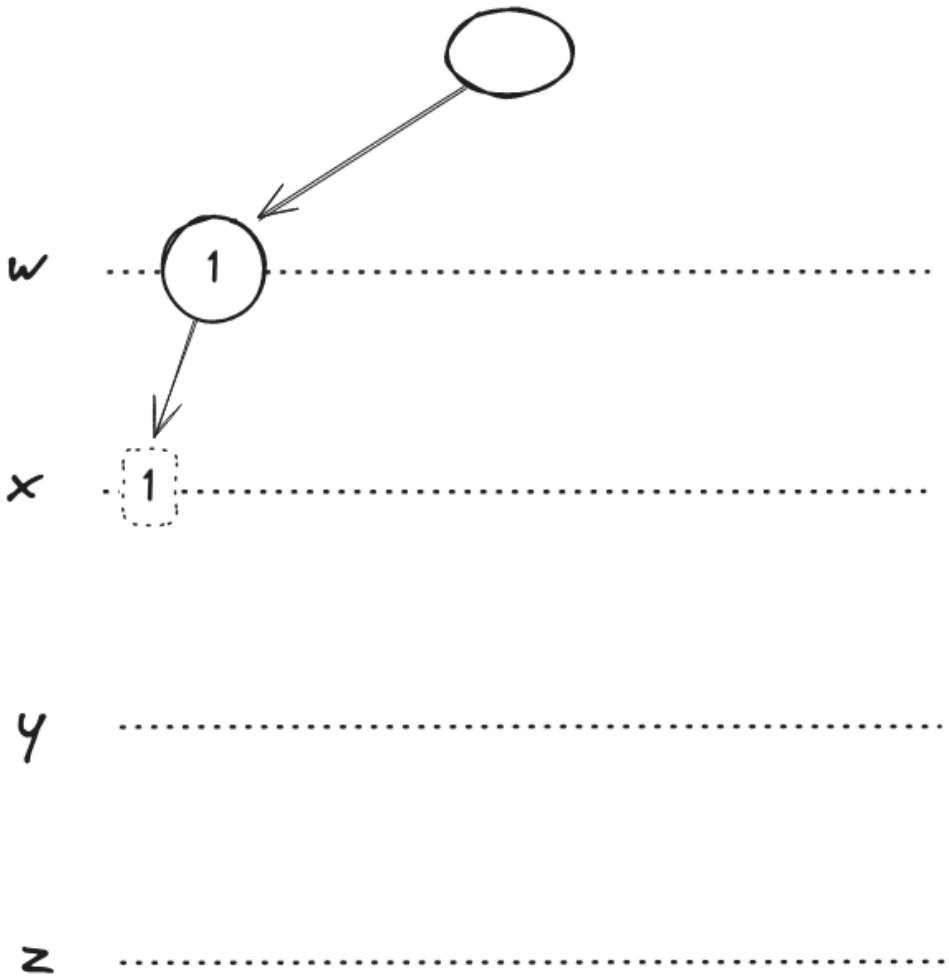
Constraints:

w = 2 * x

w < z

y > z

Backtracking Example



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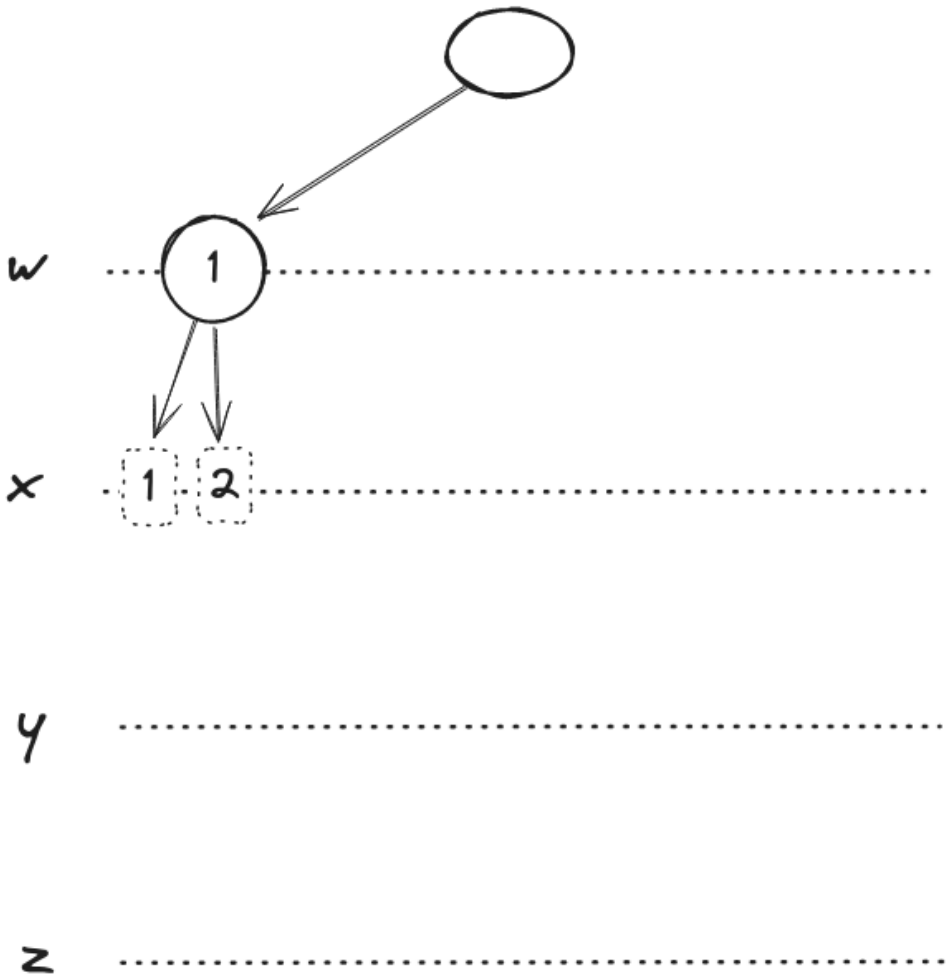

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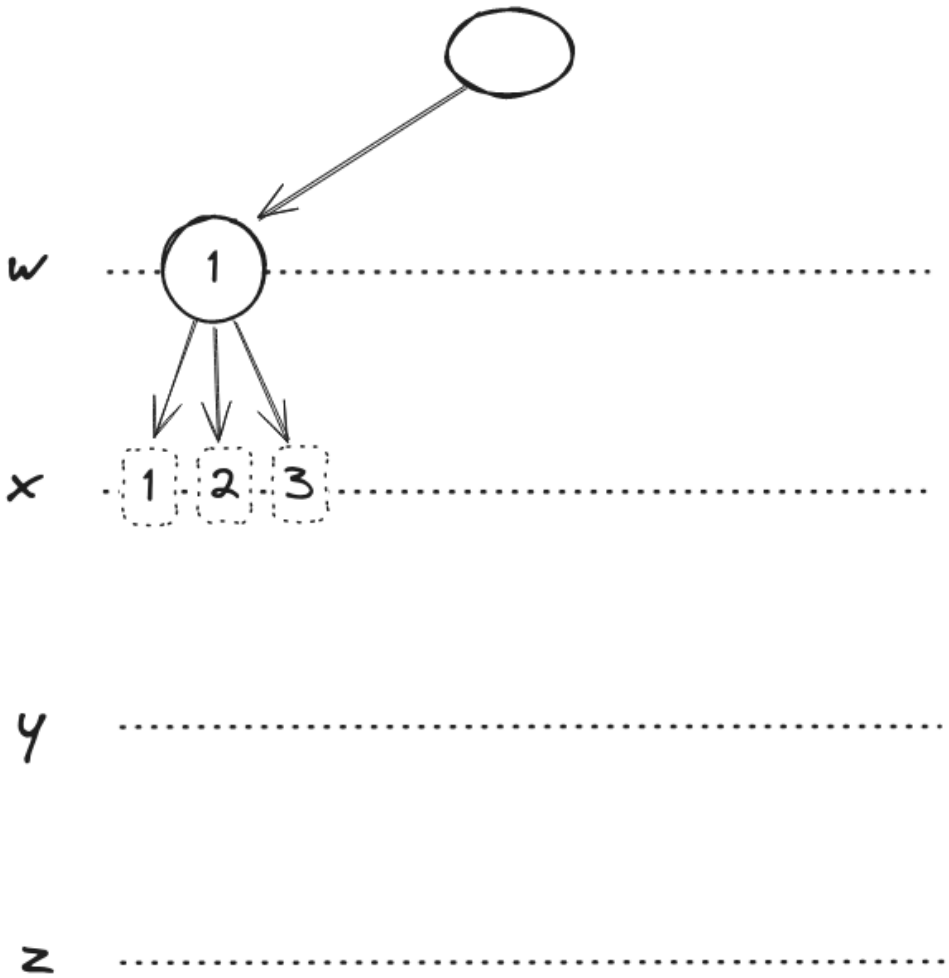

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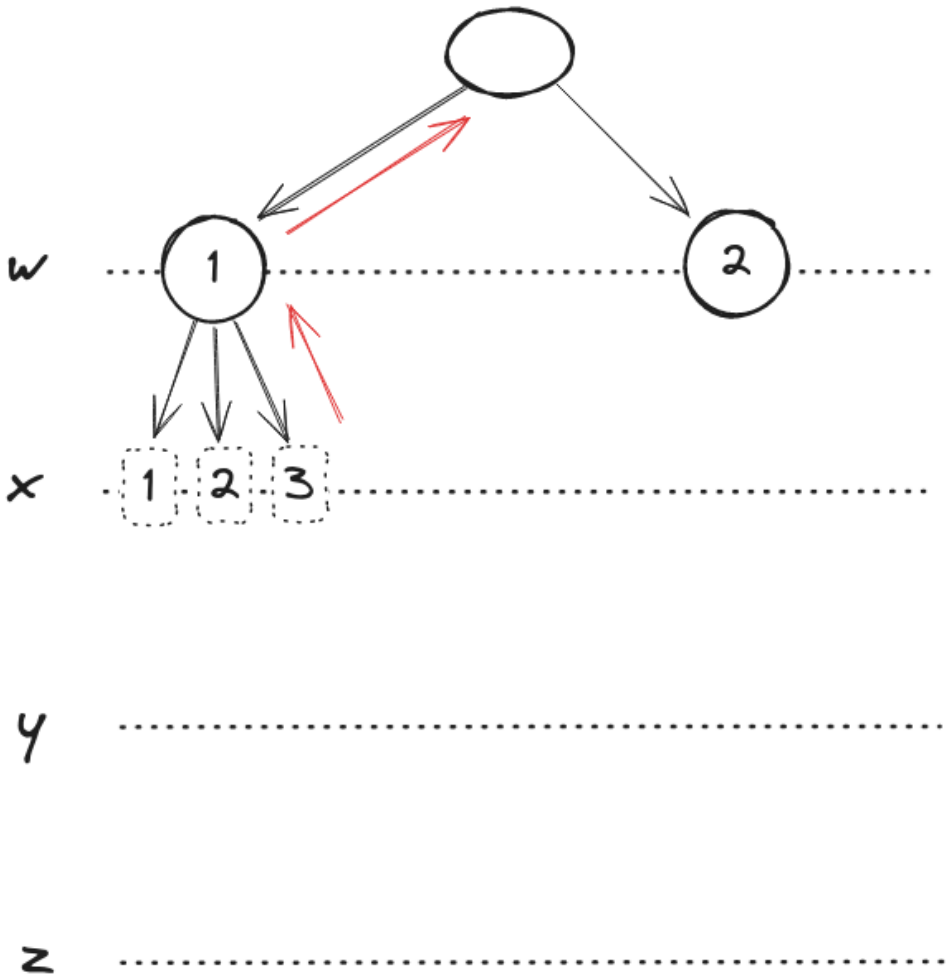

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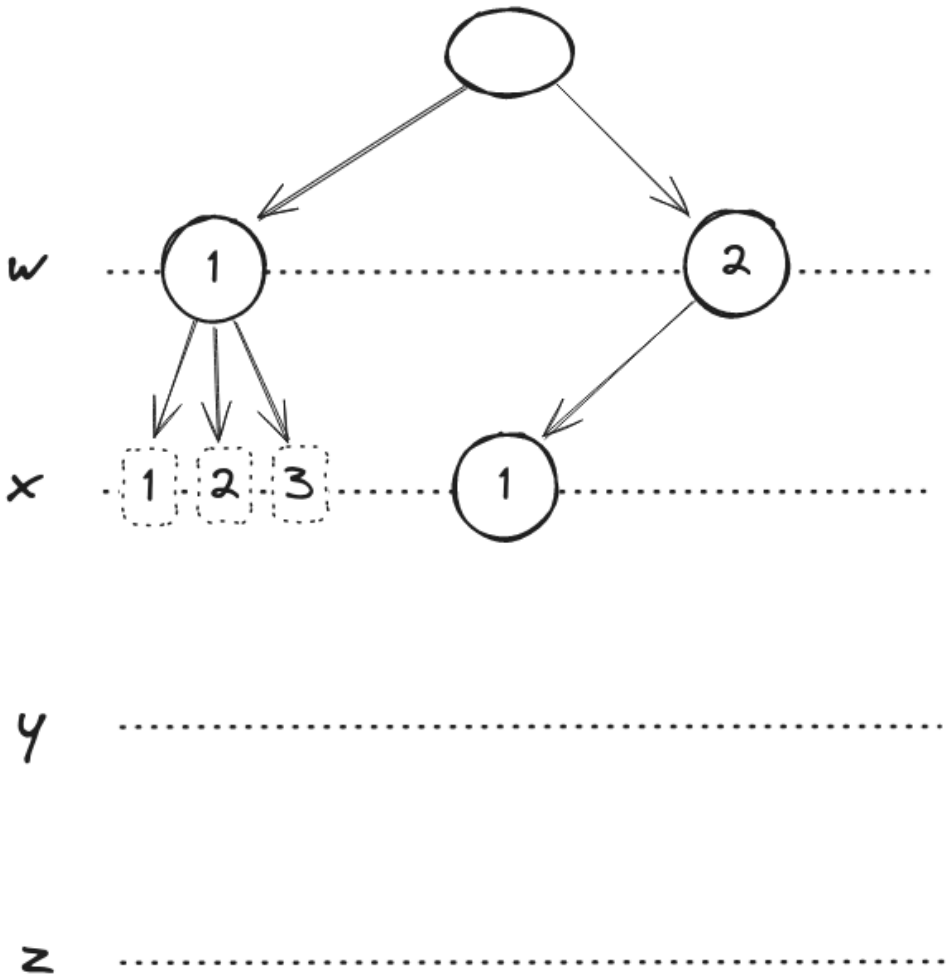

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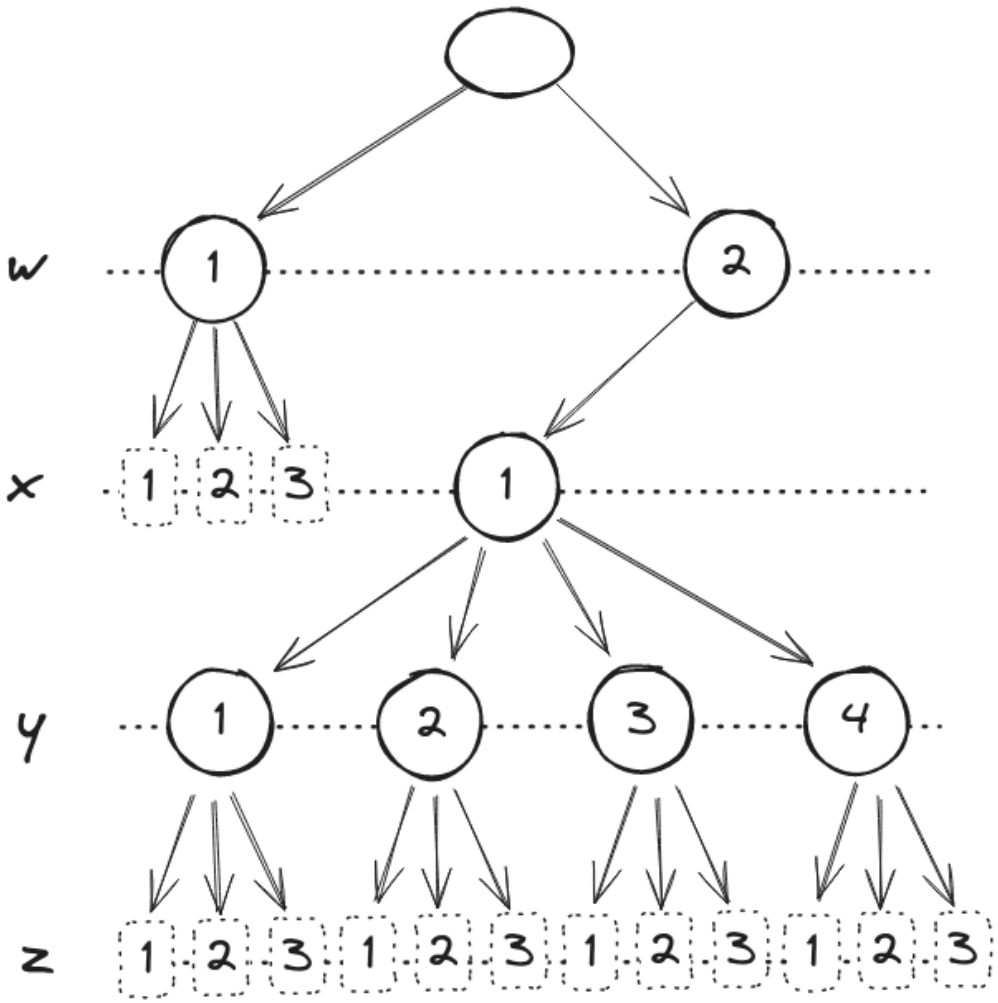

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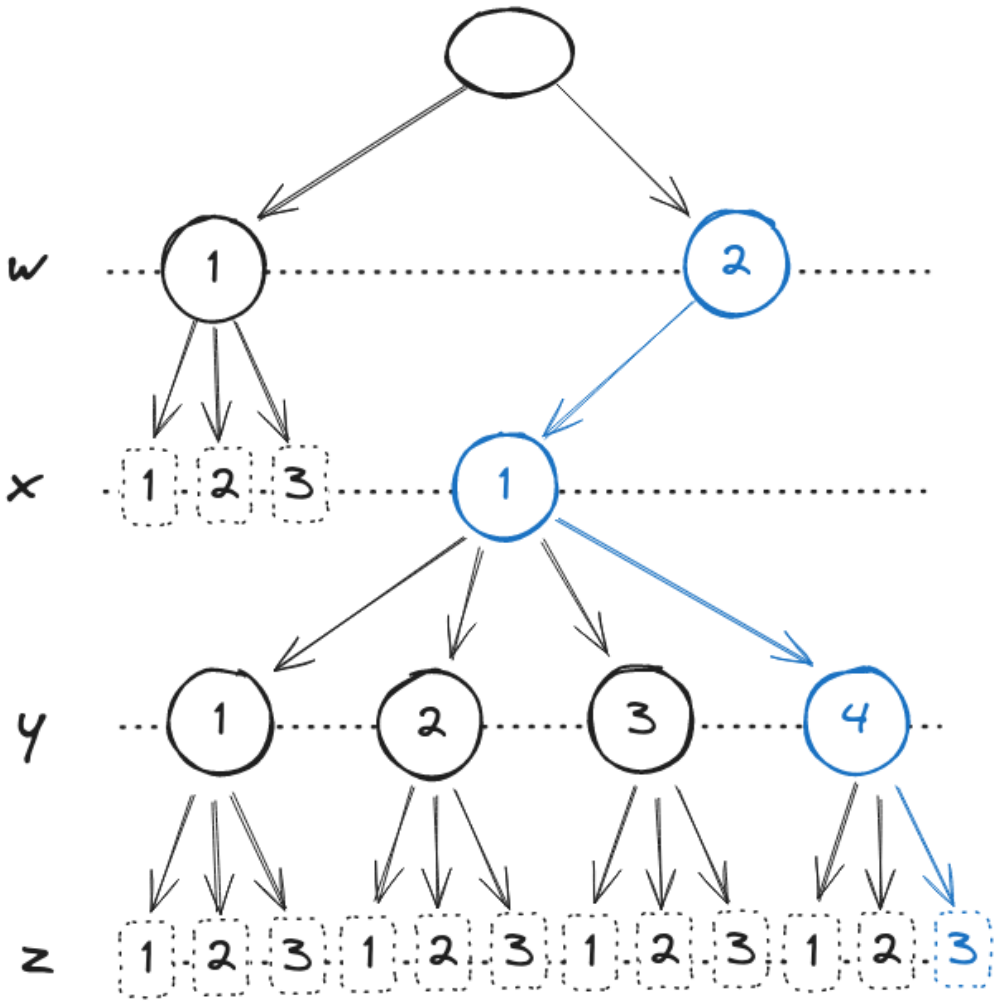


Constraints:

$w = 2 * x$

$w < z$

$y > z$

Solution:

$w = 2$

$x = 1$

$y = 4$

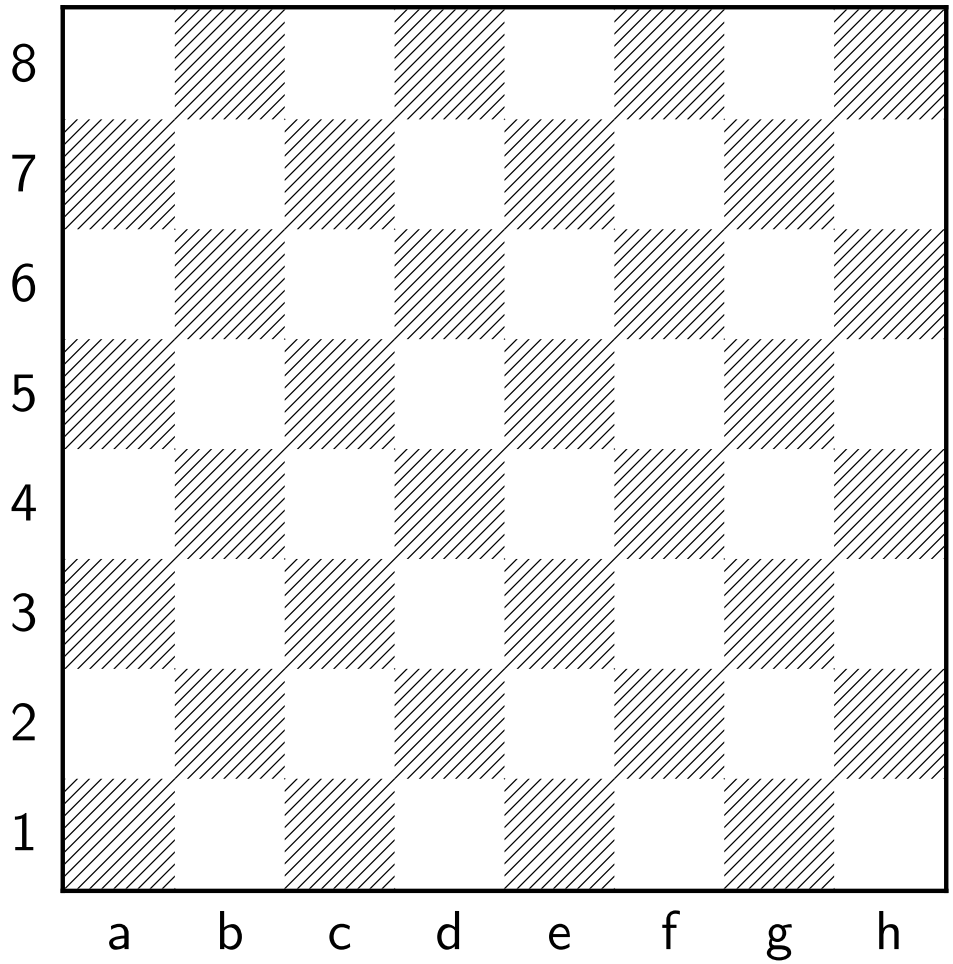
$z = 3$

Kinda like search...

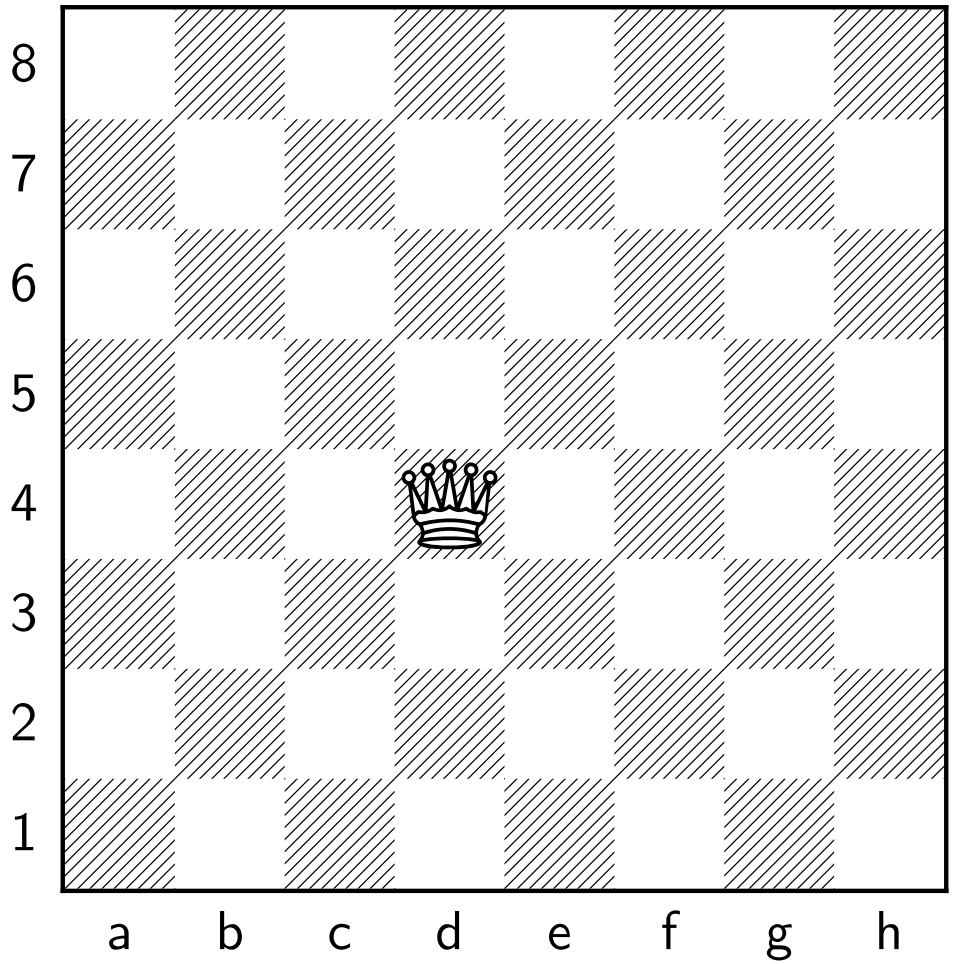
Can we do better?

8-Queens Problem

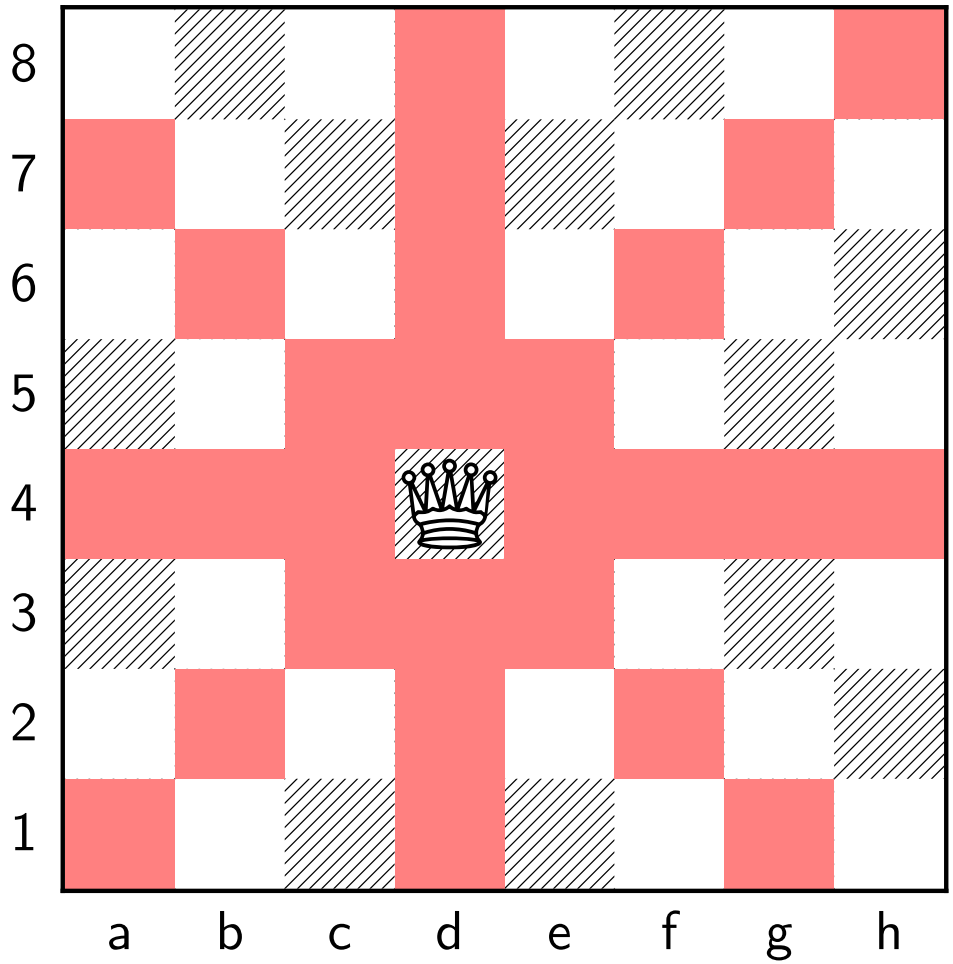
Chessboard



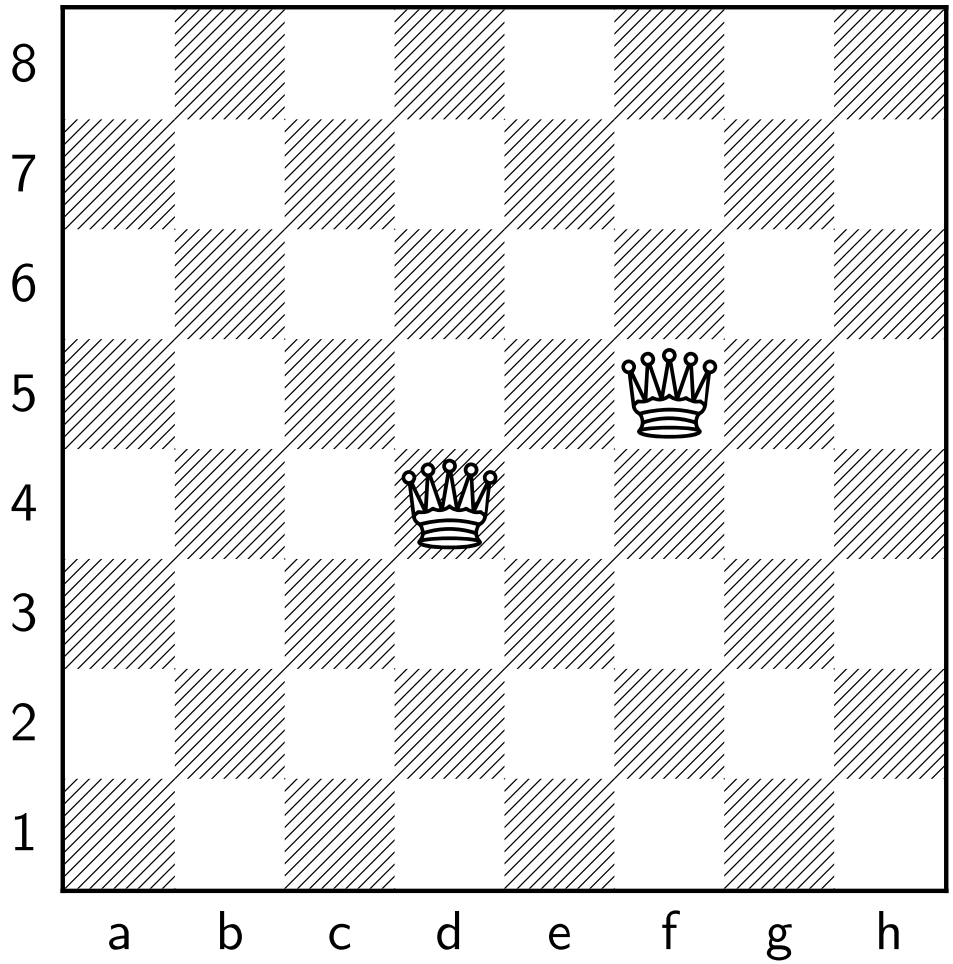
One Queen



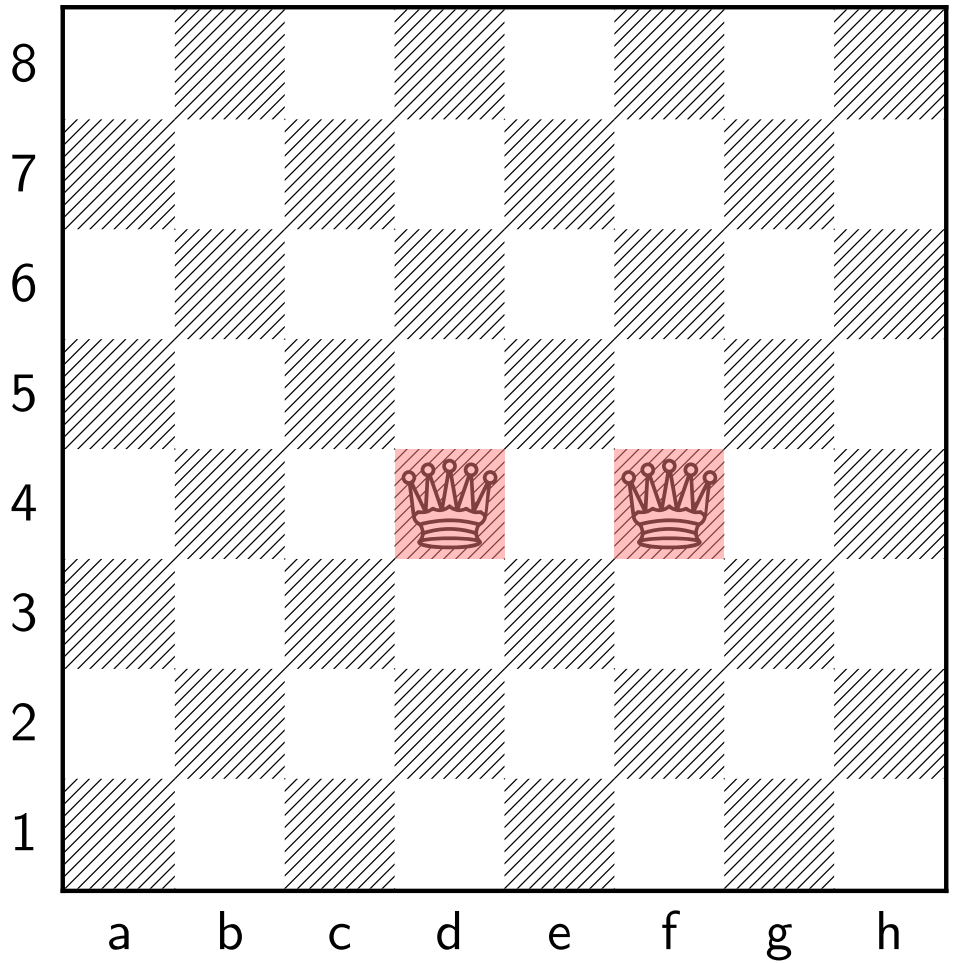
One Queen



Two Queens



Two Queens



N-Queens Problem

- Scalable

N-Queens Problem

- Scalable
  - 8-Queens $\rightarrow$ N-Queens

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  - $n \times n$ chessboard

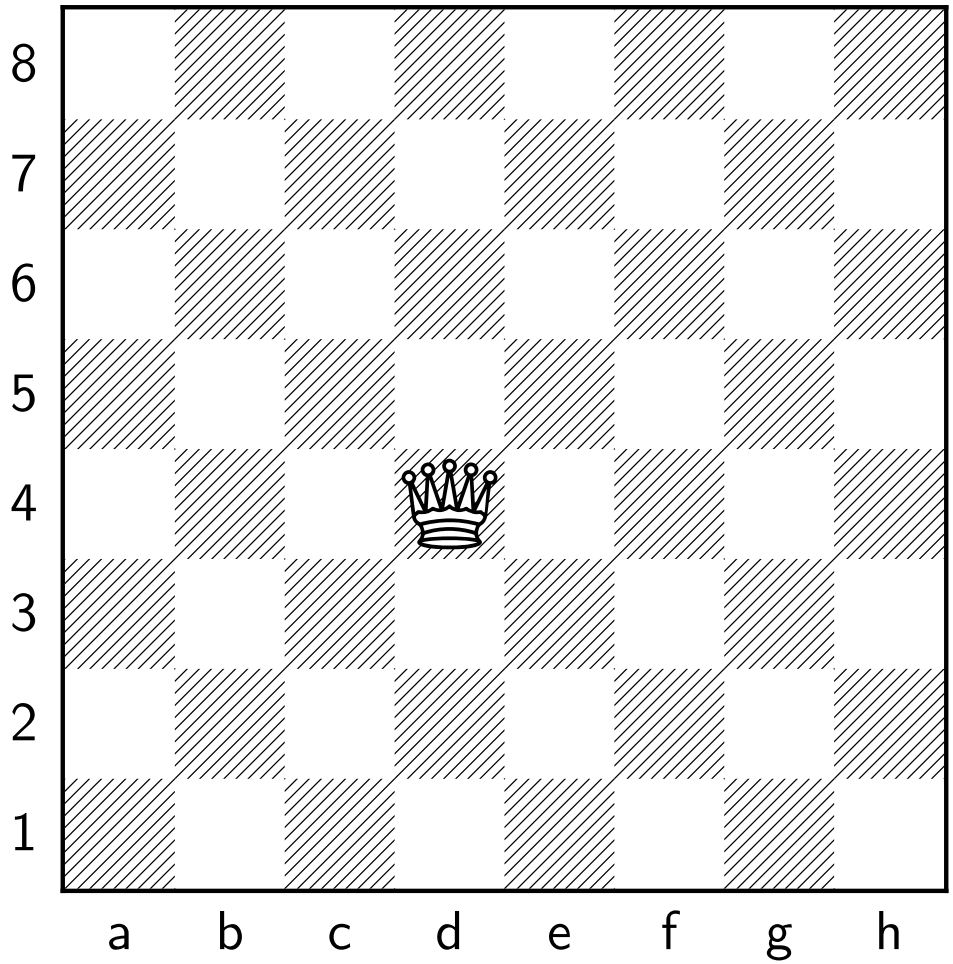
N-Queens Problem

- Scalable
  - 8-Queens $\rightarrow$ N-Queens
  - $n \times n$ chessboard
  - n Queens

Inference

Forward Checking

Forward Checking Example



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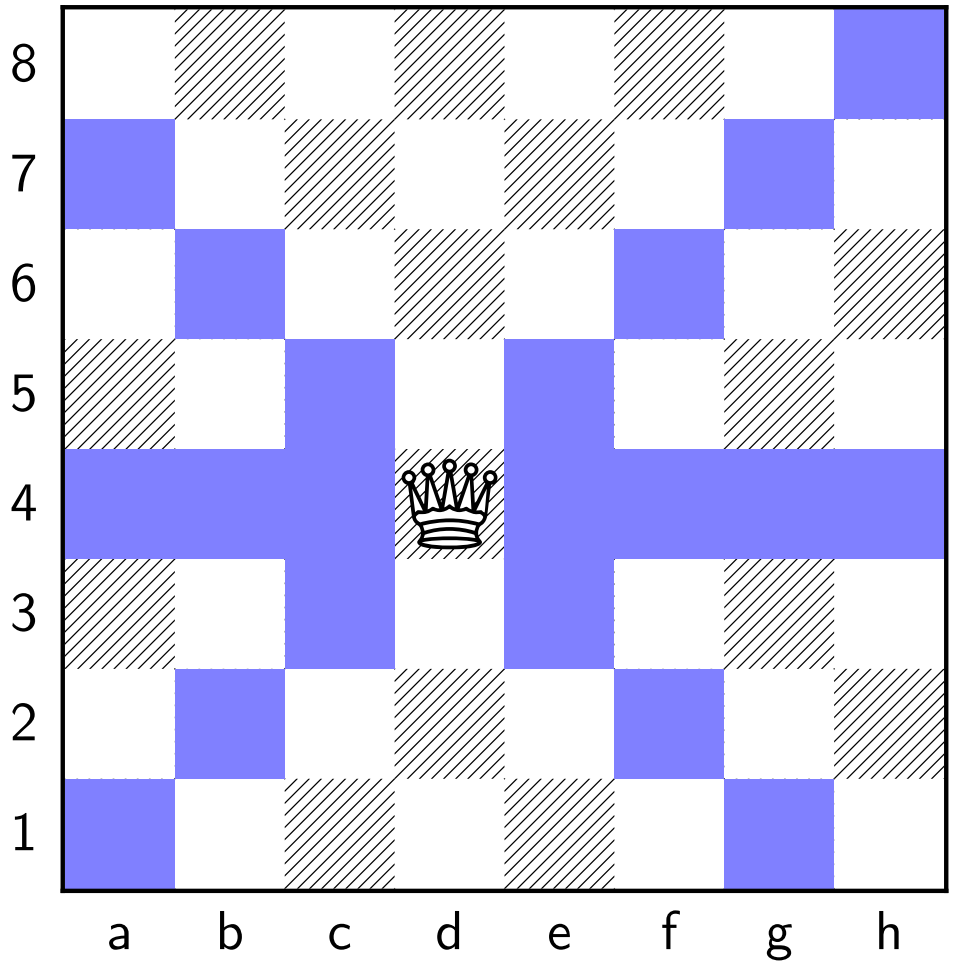
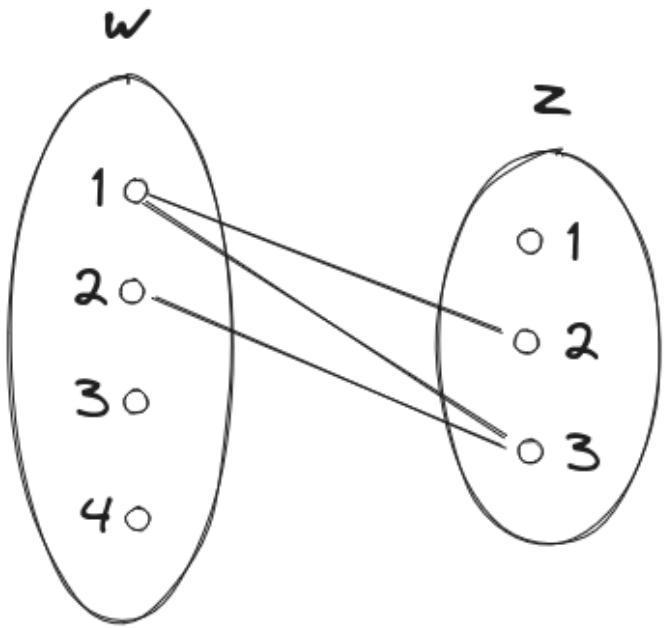


Arc Consistency

Arc Consistency Example



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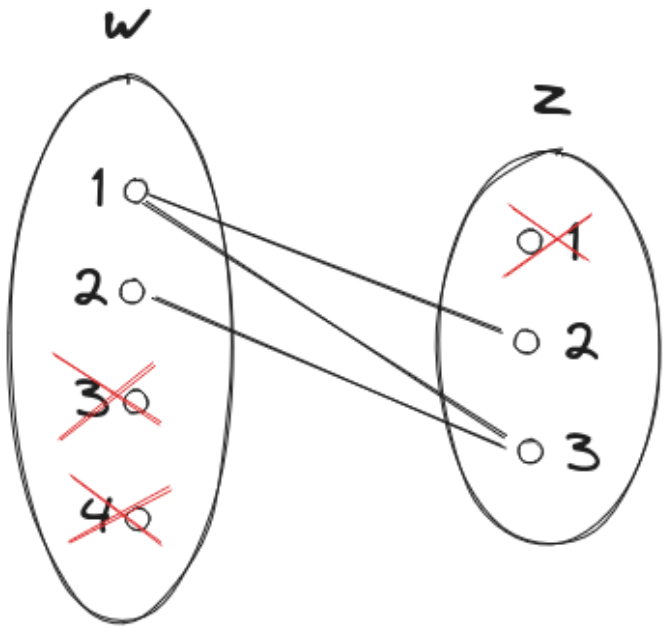

Improvements

- Inference

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- Inference
  - Forward Checking

Improvements

- Inference
  - Forward Checking
  - Arc consistency

Improvements

- Inference
  - Forward Checking
  - Arc consistency
    - AC-1

Improvements

- Inference
  - Forward Checking
  - Arc consistency
    - AC-1
    - AC-3

Improvements

- Inference
  - Forward Checking
  - Arc consistency
    - AC-1
    - AC-3
- Variable Ordering: fail early

Oxiflex

Demo

Limitations

- FlatZinc builtins

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- FlatZinc builtins
  - IntLinEq
  - IntLinLe
  - IntLinNe

Limitations

- FlatZinc builtins
  - IntLinEq
  - IntLinLe
  - IntLinNe
- No floating points

Limitations

- FlatZinc builtins
  - IntLinEq
  - IntLinLe
  - IntLinNe
- No floating points
  - No minimize / maximize

Constraint Programming Solver for MiniZinc

written in Rust

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Solver Language

- Performance

Solver Language

- Performance
  - fast

Solver Language

- Performance
  - fast
  - like real fast

Solver Language

- Performance
  - fast
  - like real fast
- $\rightarrow$ no abstractions, no garbage collector, no JIT

Possible Language

Assembly

Possible Language

Assembly

or

Solver

- Performance
  - fast
  - like real fast

Solver

- Performance
  - fast
  - like real fast
- Correctness
  - Prevent bugs

Rust

Rust

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  - fast
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  - Functional

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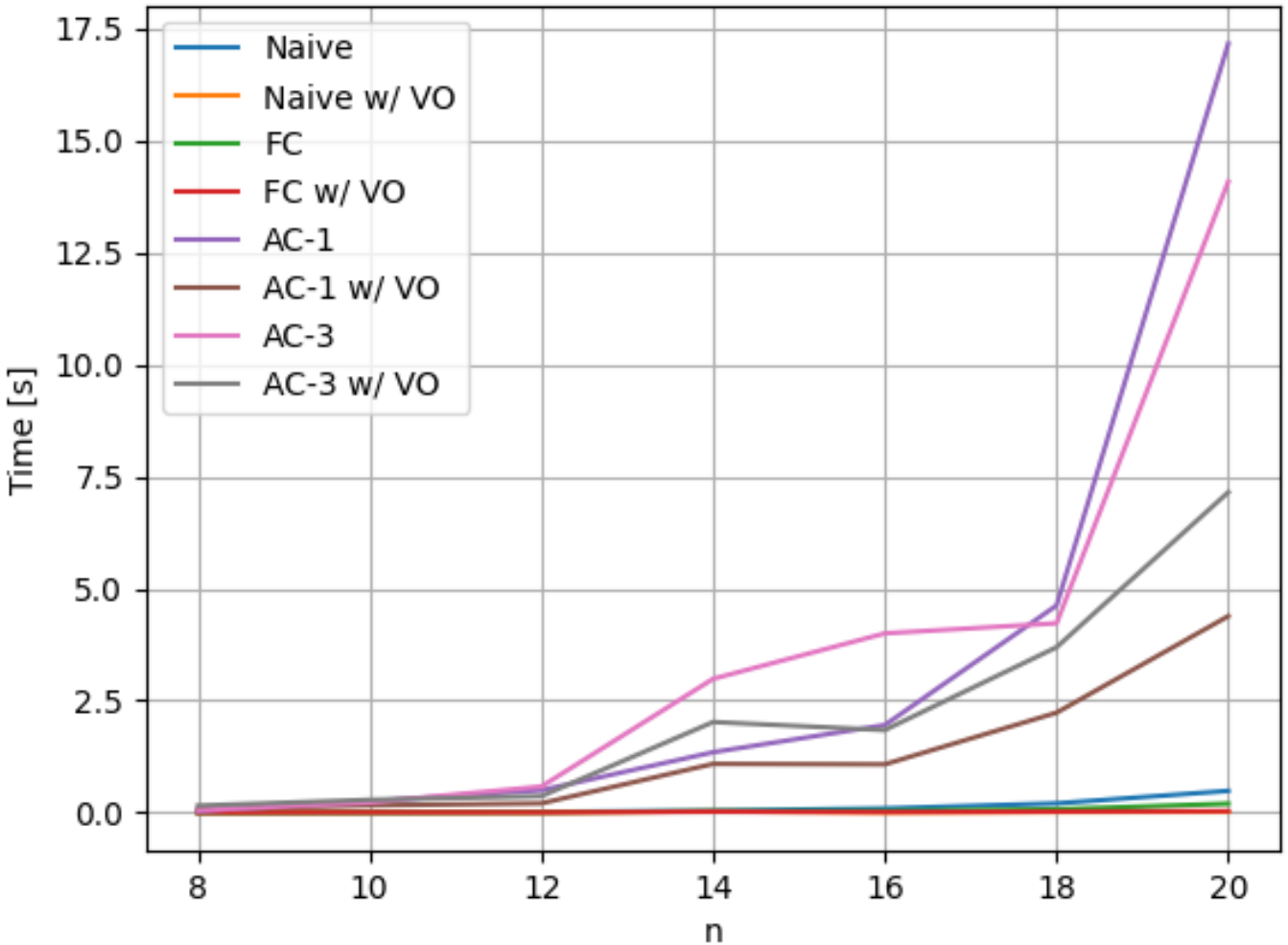
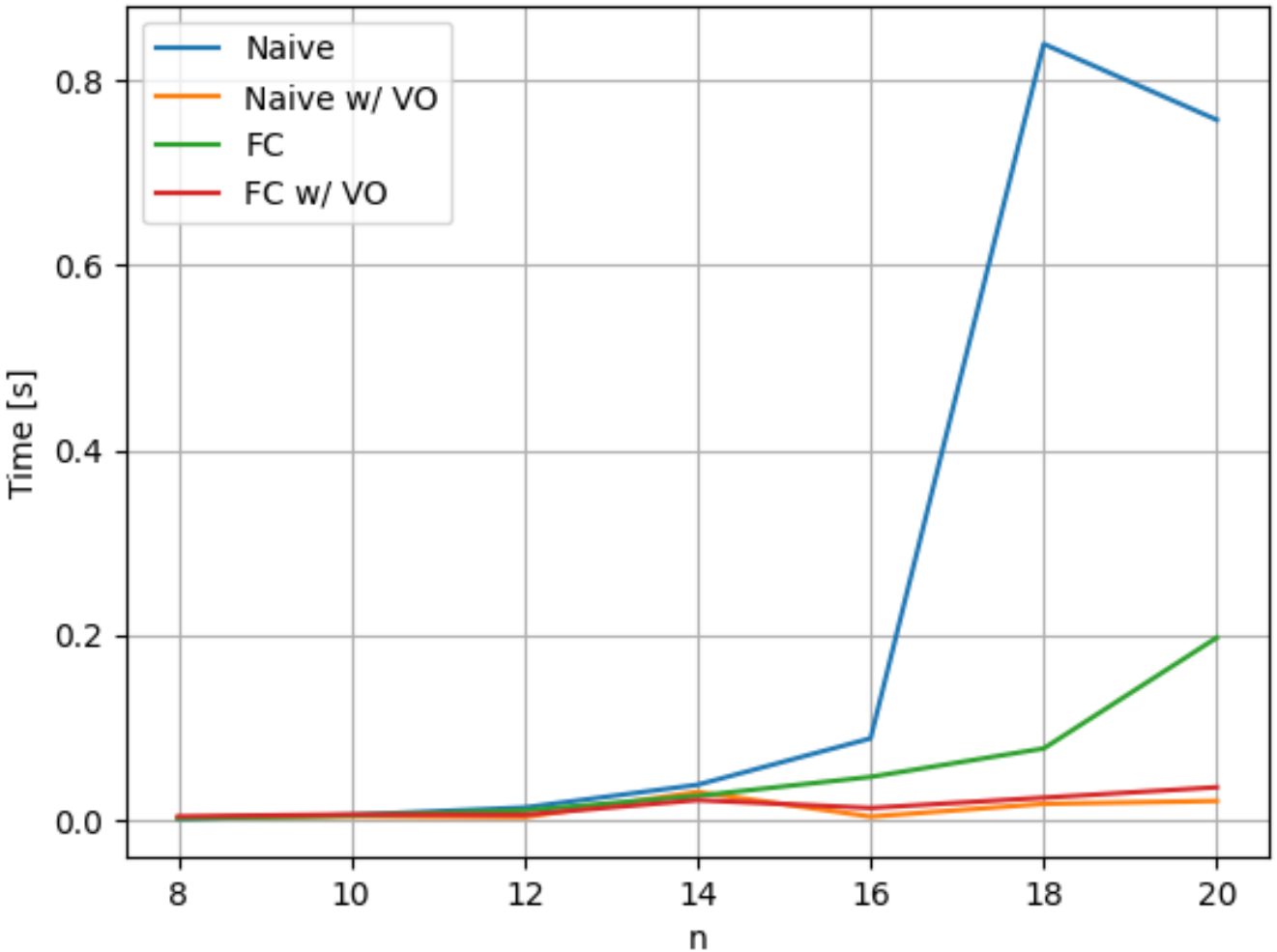
Benchmarks

N-Queens Problem

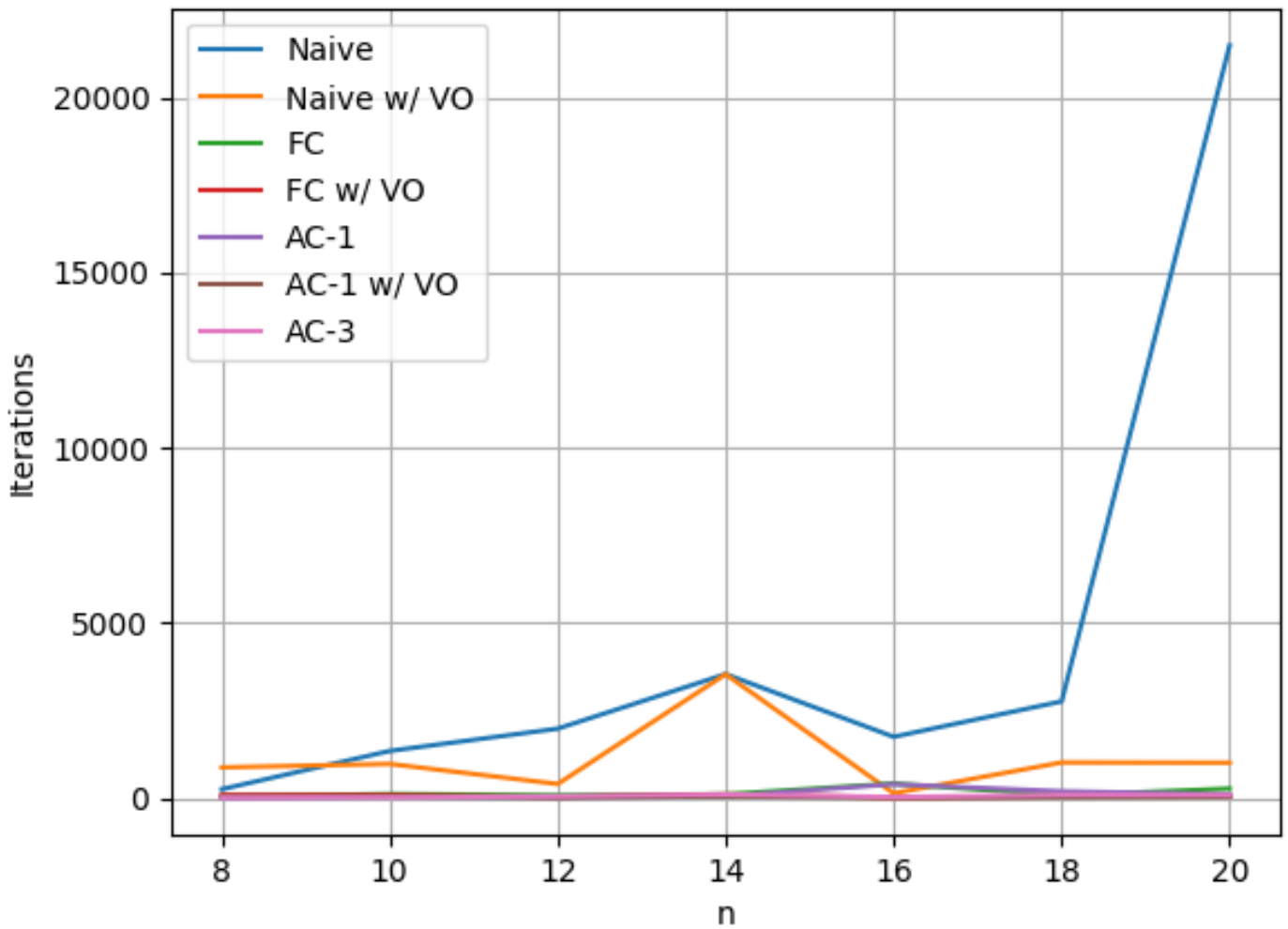
Queens Time


Naive
Naive w/ VO
FC
FC w/ VO
AC-1
AC-1 w/ VO
AC-3
AC-3 w/ VO
Time [s]
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
8
10
12
14
16
18
20
n

Queens Time



Queens Iterations



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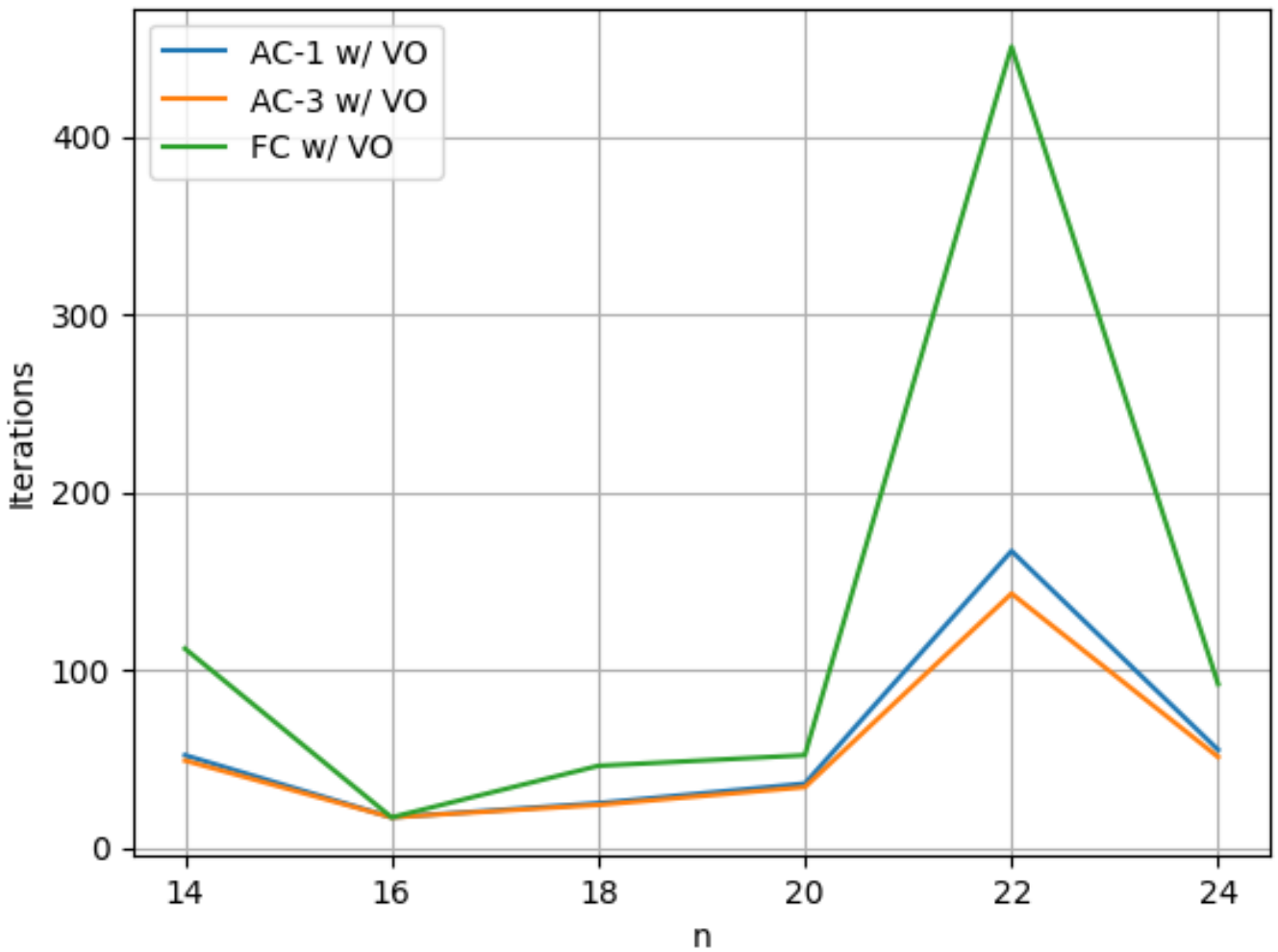
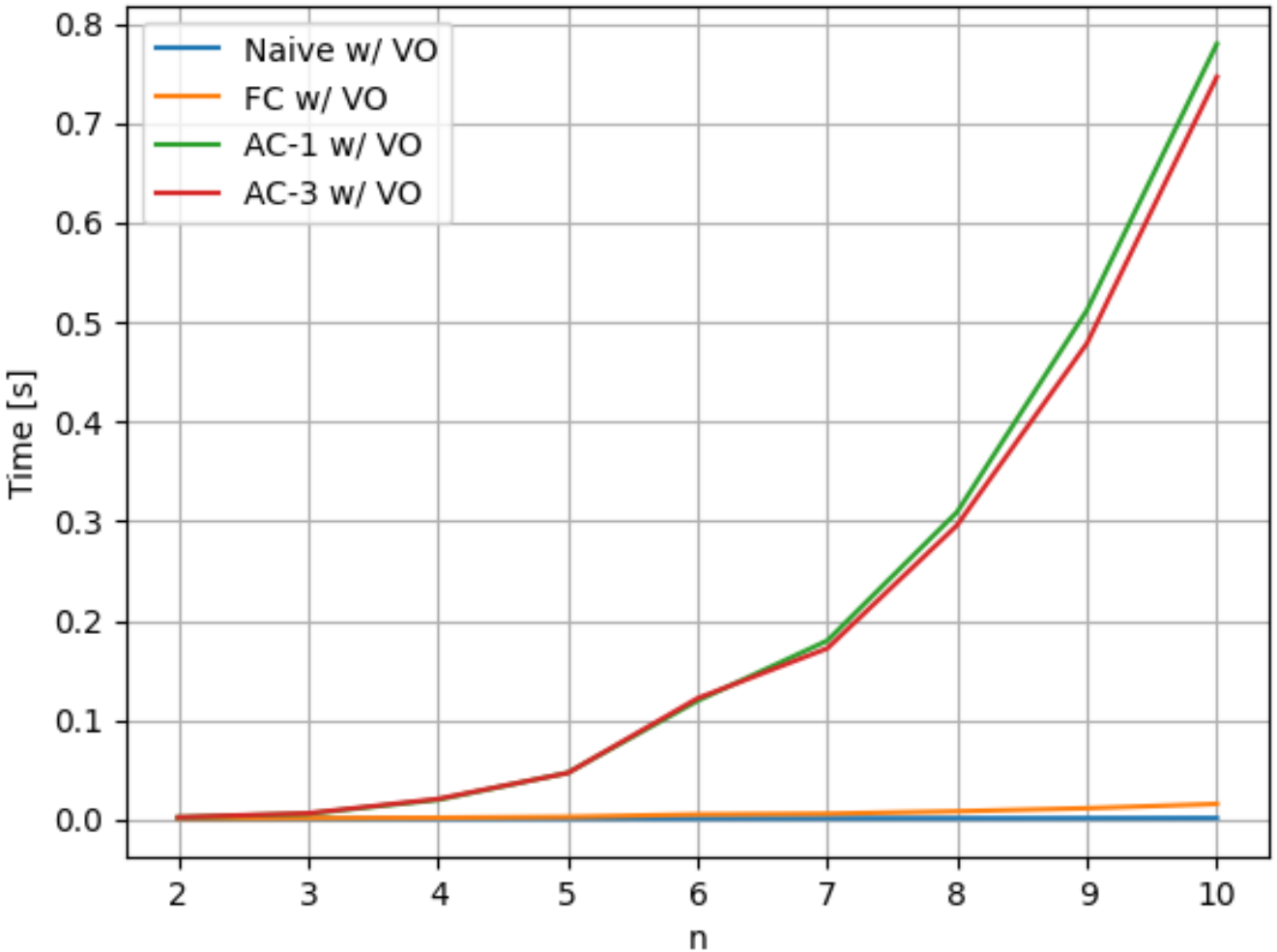


Slow Convergence

Slow Convergence for small n



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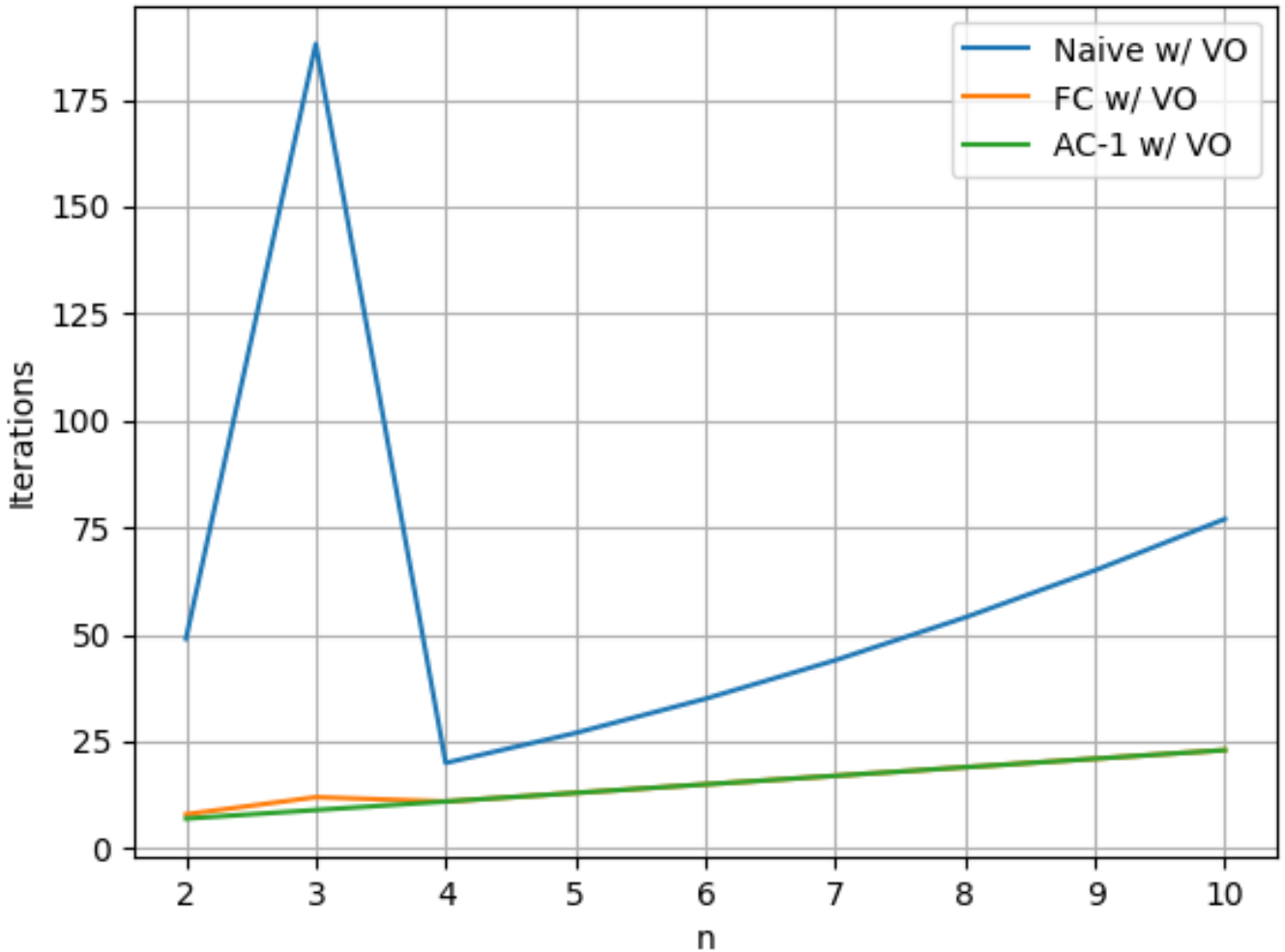
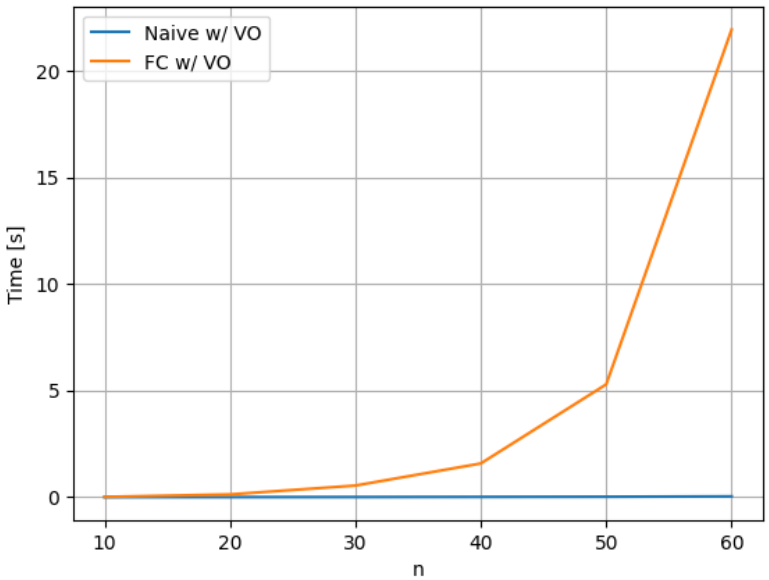
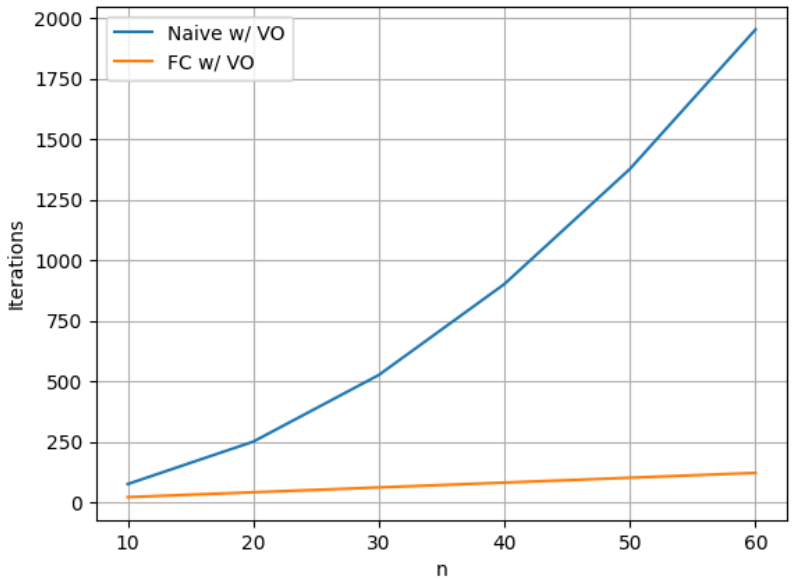
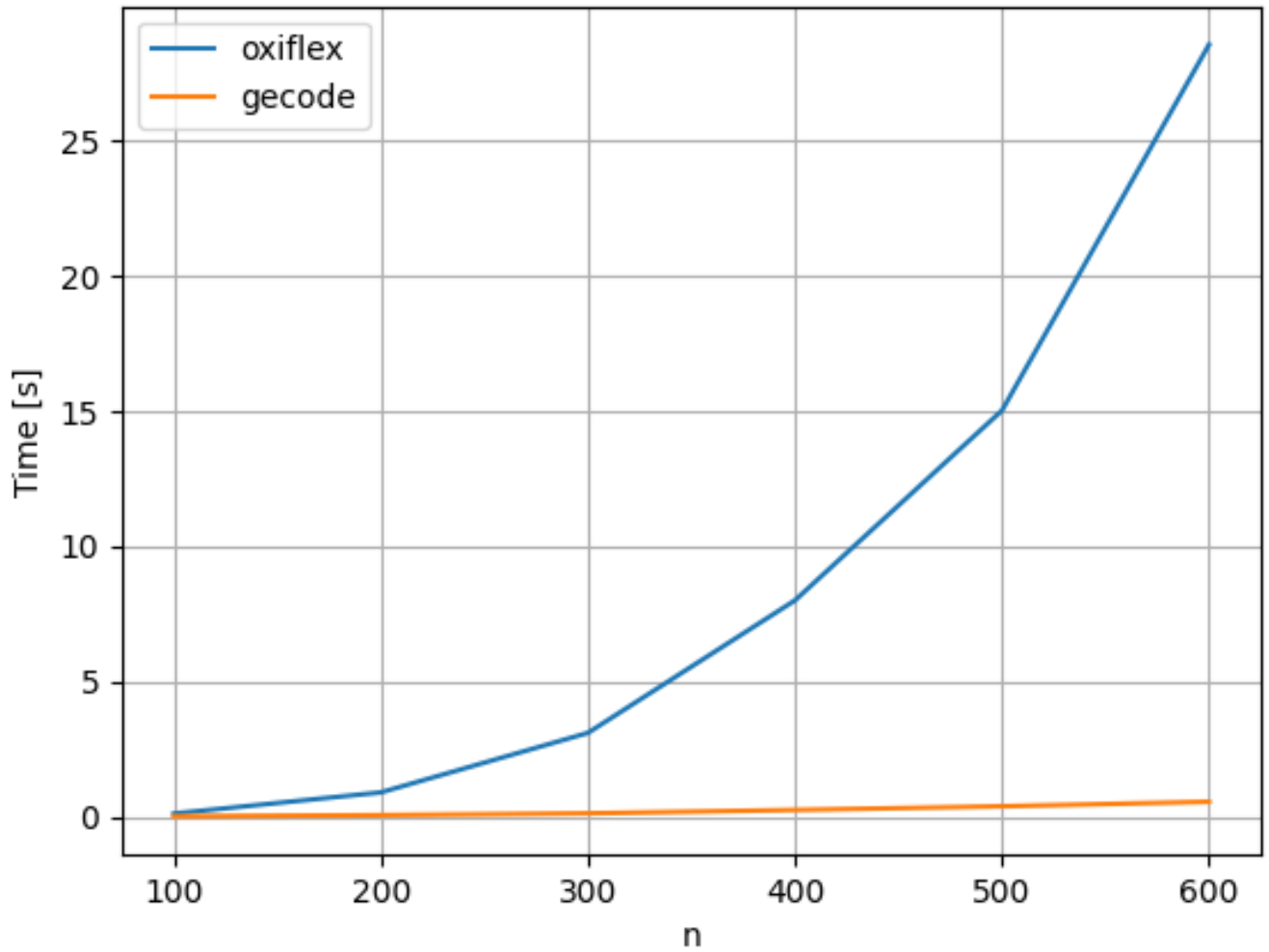


Slow Convergence Comparison






oxiflex
gecode
Time [s]
0
5
10
15
20
25
100
200
300
400
500
600
n

Conclusion

The end