Enhancing ASP with Constraints - The OrderLib

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Outline

Overview

Introduction

- combining ASP with any kind of theory
- SMT (SAT modulo Theories)
- LA, LIA, LRA, RA, Arrays, EUF, DL, Bitvectors, ...

A General Theory Language

Advantages

- no need to change the grounder gringo
- reuse of grounding capabilities to instantiate theory terms
- extensible to any theory
- basic syntax checking in the frontend
- AST and interface for writing your theory solver

A General Theory Language

Theory Atom

```
&name { theory terms : condition } <op> theory term.
```

syntax is similar to aggregates

A General Theory Language

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ASP modulo Acyclicity

```
1 { path(X,Y) : edge(X,Y) } 1 :- node(X).
1 { path(X,Y) : edge(X,Y) } 1 :- node(Y).
start(X) :- X = #min { Y : node(Y) }.
&edge { X,Y } :- path(X,Y), not start(Y).
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A General Theory Language

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A General Theory Language

ASP modulo Heuristics

```
&heuristic { atom(X,Y), [sign,0,0] : cond(X,Y) }.
```

A General Theory Language

ASP modulo Preferences

```
&preference(p1,subset) {
a(X) : gr(X);
b(X) : gr(X)
}.
&preference(p2,lexico) {
(1,X) :: name(X) : preference(X)
}.
&preference(p3,aso) {
a(X) > ~b(Y) || c(Z) & ~d(W) : dom(a,X;b,Y;c,Z;d,W)
}.
```

A General Theory Language

ASP modulo CSP

```
p(1..10).
q(X,1,10) :- p(X).
&dom {
f(X) :: {1..3, 5..7} : p(X);
g(X) :: {L..U} : q(X,L,U);
1 <= x <= 10
}.
&show { f/1 }.
a :- &sum{ X * f(X) + g(Y) : X=1..3 } >= 42, p(Y).
```

A General Theory Language

ASP modulo CSP

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```

A General Theory Language

Language Specification for ASPmCSP

```
#theory csp {
  linear_term {
  + : 1, unary;
  - : 1, unary;
  * : 2, binary, left;
  + : 3, binary, left;
  - : 3, binary, left
  };
  ...
```

A General Theory Language

Language Specification for ASPmCSP

```
  domain_term {
  <= : 1, binary, left;
  >= : 1, binary, left;
  > : 1, binary, left;
  < : 1, binary, left;
  = : 1, binary, left;
  != : 1, binary, left;
  :: : 1, binary, left };
  show_term { / : 1, binary, left};
  &dom/0 : domain_term, directive;
  &show/0 : show_term, directive;
  &sum/0 : linear_term, { <=, >=, <, >, =, != },
           linear_term, any
}.
```

Overview

Techniques

- early approach
- lazy approach
- online approach
  - incremental (lazy clause generation)
  - theory propagation
  - lazy variable creation

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orderLib

Overview

Translation Methods

Direct Encoding

Order Encoding

$x, y \in \{2..6\}$

Variables:

x=2, x=3, x=4, x=5, x=6

Translation Methods

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At least one:

x=2 $\vee$ x=3 $\vee$ x=4 $\vee$ x=5 $\vee$
x=6

Translation Methods

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Order Encoding

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At least one:

x=2 $\vee$ x=3 $\vee$ x=4 $\vee$ x=5 $\vee$
x=6

At most one:

$\neg$x=2 $\vee$ $\neg$x=3, $\neg$x=2 $\vee$ $\neg$x=4,
$\neg$x=2 $\vee$ $\neg$x=5, $\neg$x=2 $\vee$ $\neg$x=6,
$\neg$x=3 $\vee$ $\neg$x=4, $\neg$x=3 $\vee$ $\neg$x=5,
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Translation Methods

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At most one:

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$\neg$x=5 $\vee$ $\neg$x=6

Order Encoding

Variables:

$x \leq 2$, $x \leq 3$, $x \leq 4$,
$x \leq 5$, $x \leq 6$

Translation Methods

$x, y \in \{2..6\}$

Direct Encoding

Variables:

x=2, x=3, x=4, x=5, x=6

At least one:

x=2 $\vee$ x=3 $\vee$ x=4 $\vee$ x=5 $\vee$
x=6

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Order Encoding

Variables:

$x \leq 2$, $x \leq 3$, $x \leq 4$,
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Translation Methods

$x, y \in \{2..6\}$

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x=2, x=3, x=4, x=5, x=6

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Order Encoding

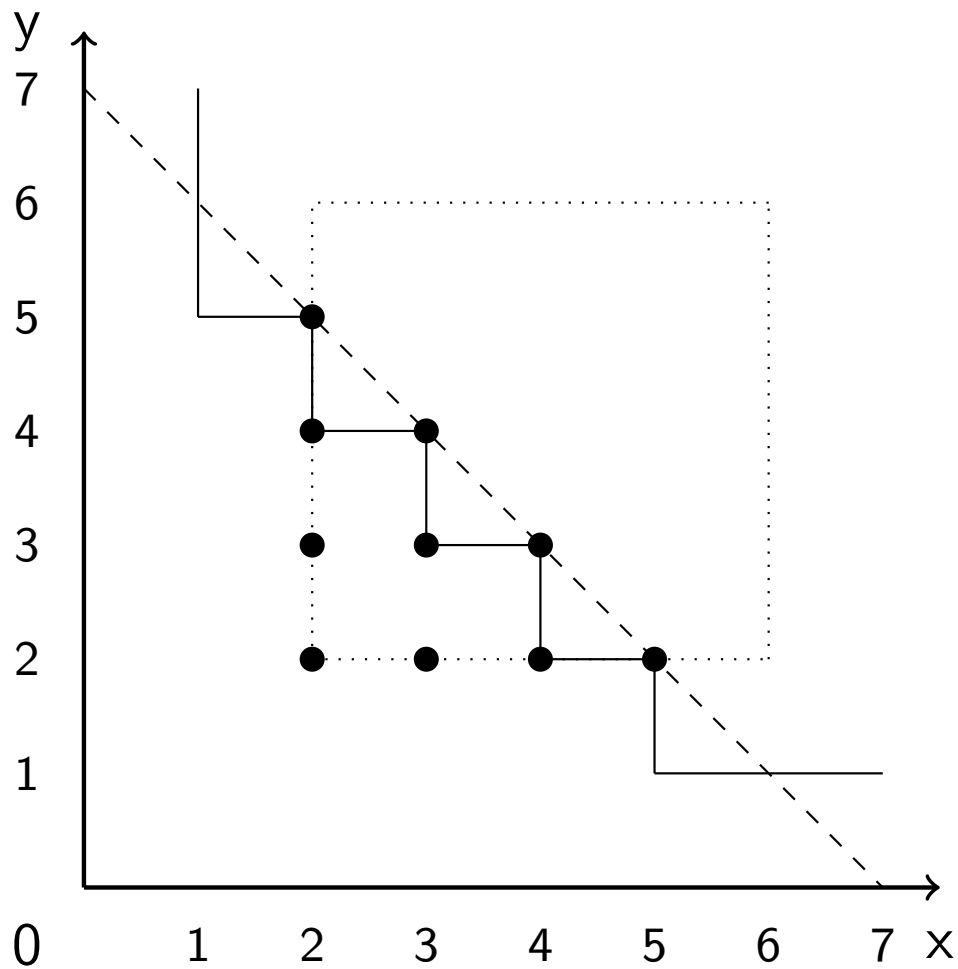
Variables:

$x \leq 2$, $x \leq 3$, $x \leq 4$,
$x \leq 5$, ~~$x \leq 6$~~

At most one:

$\neg x \leq 2 \vee x \leq 3$,
$\neg x \leq 3 \vee x \leq 4$,
$\neg x \leq 4 \vee x \leq 5$

Translating $x + y \leq 7$

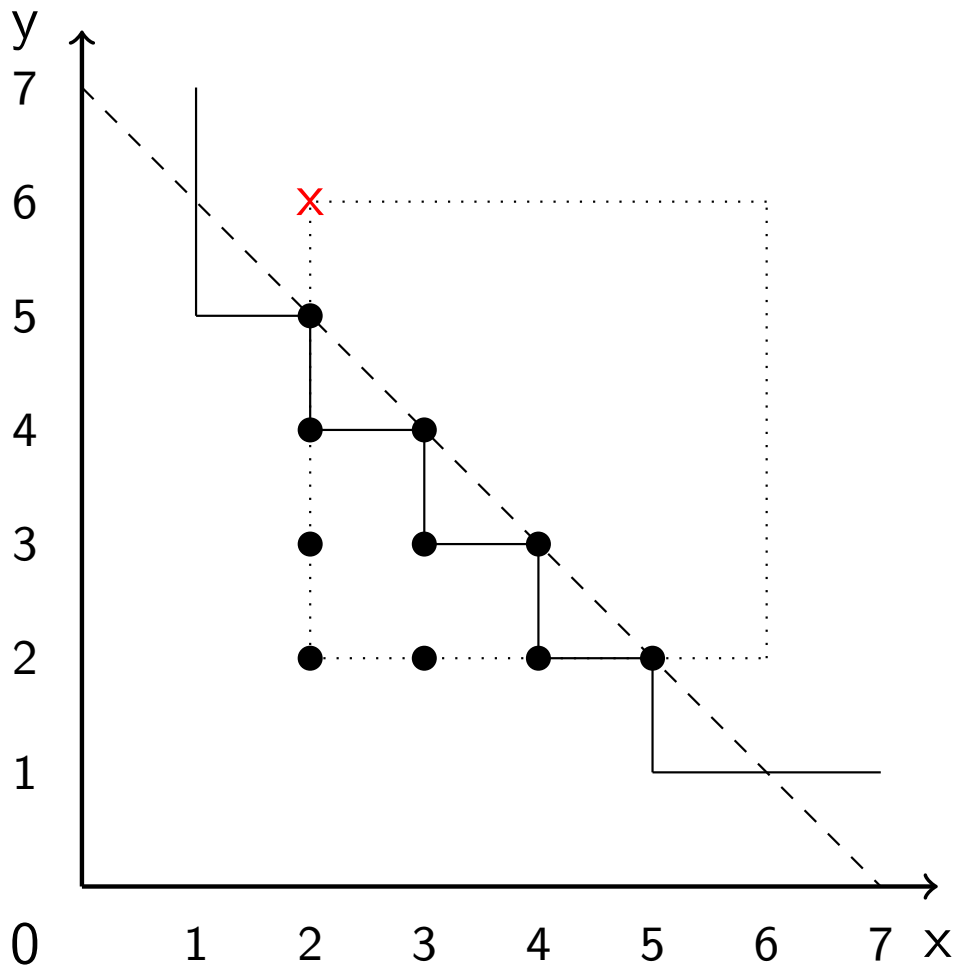


Direct Encoding

$x \neq 2 \vee y \neq 6$

Translating $x + y \leq 7$

Order Encoding



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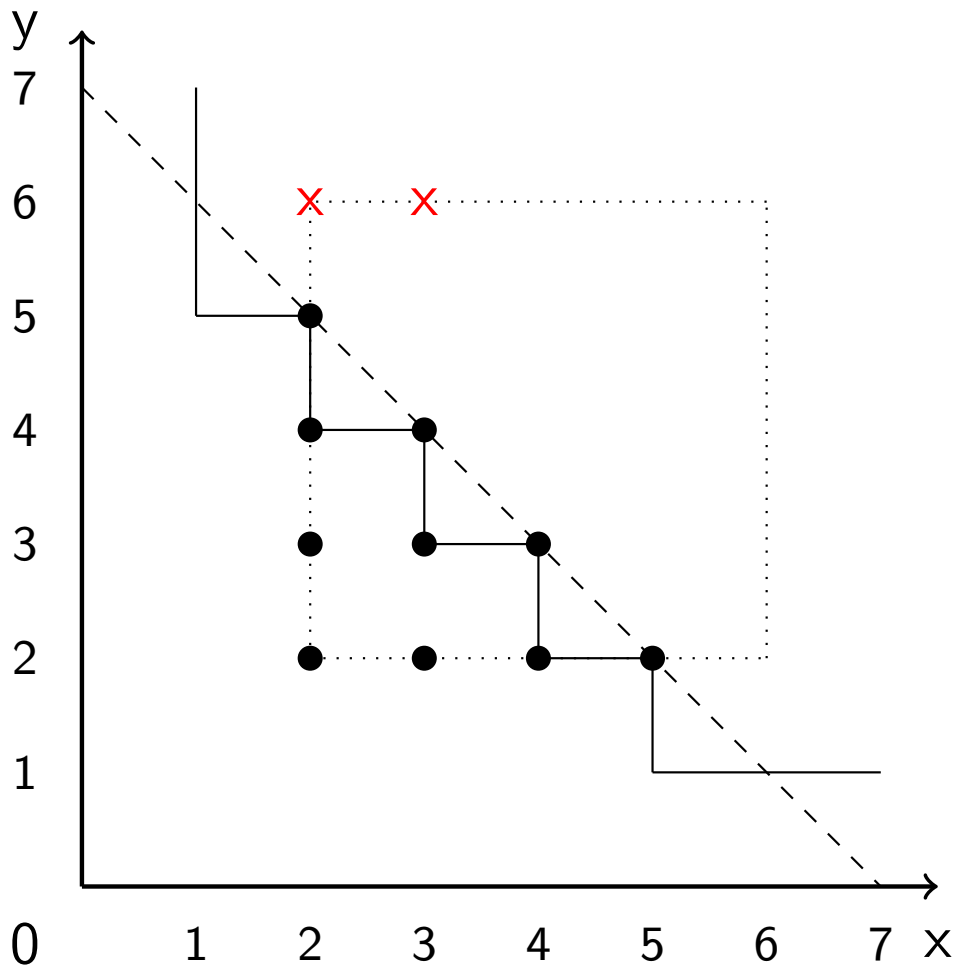

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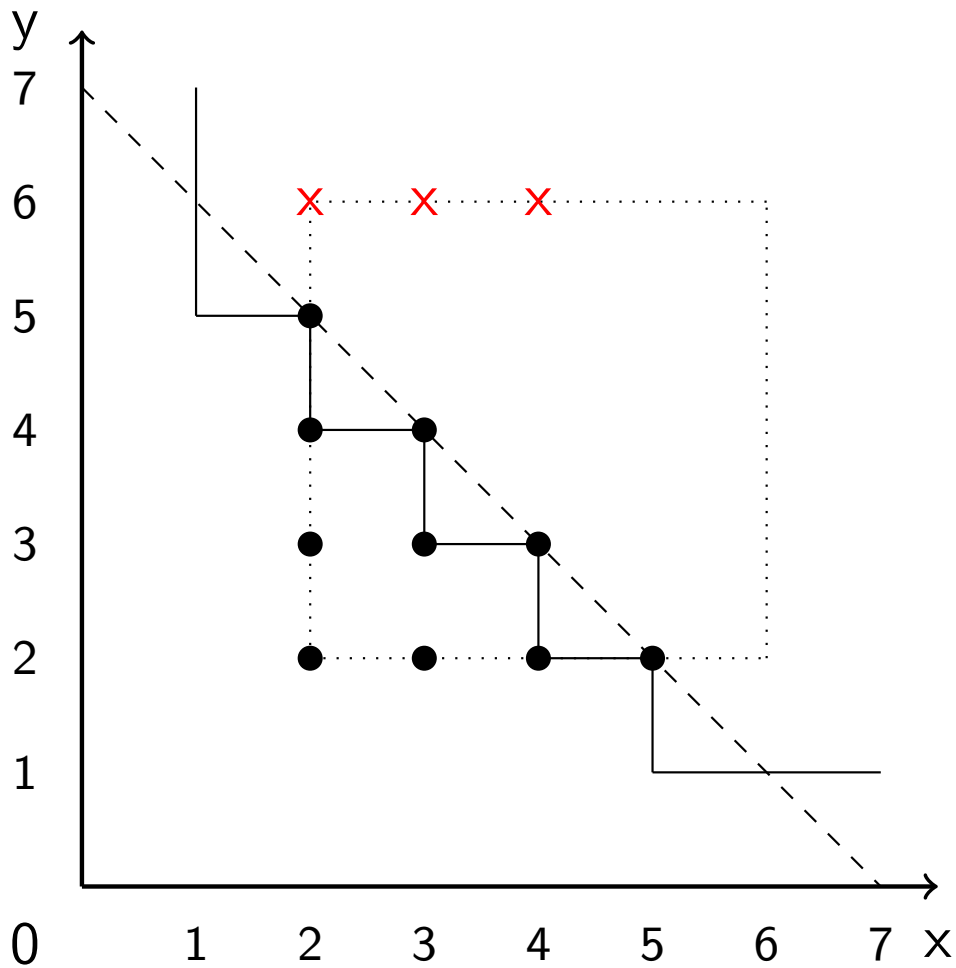

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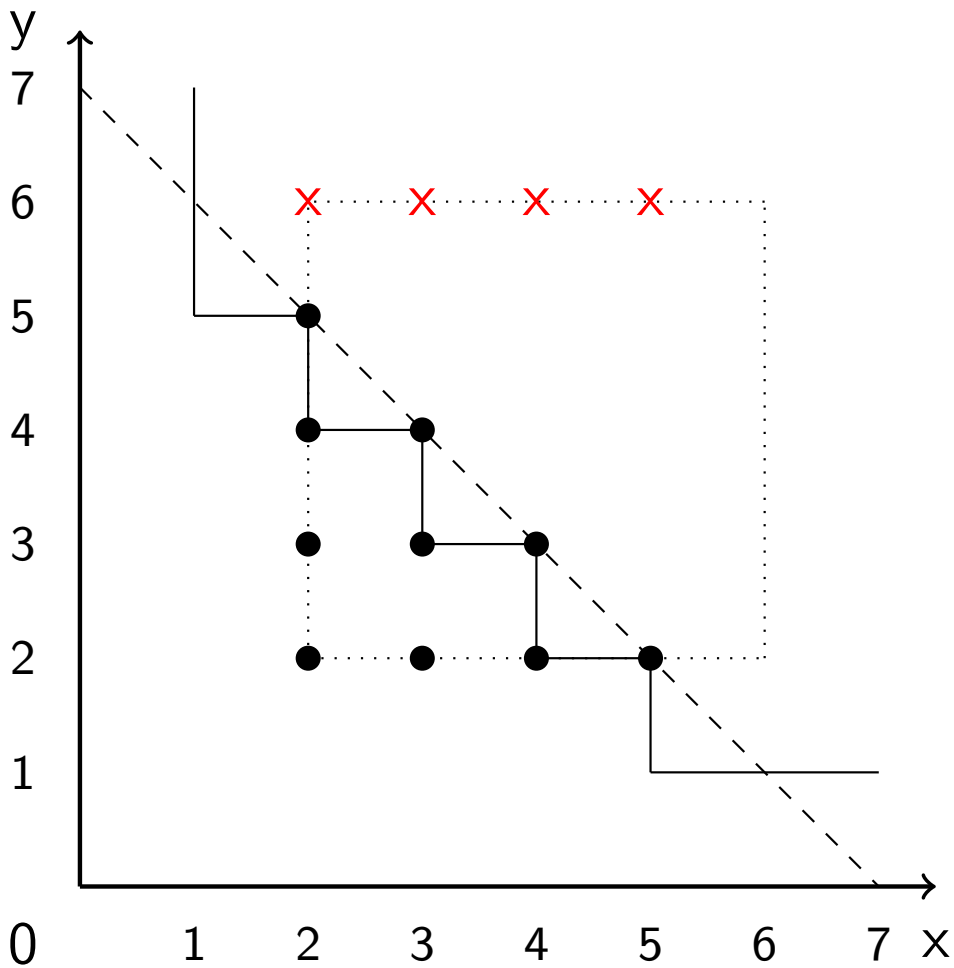

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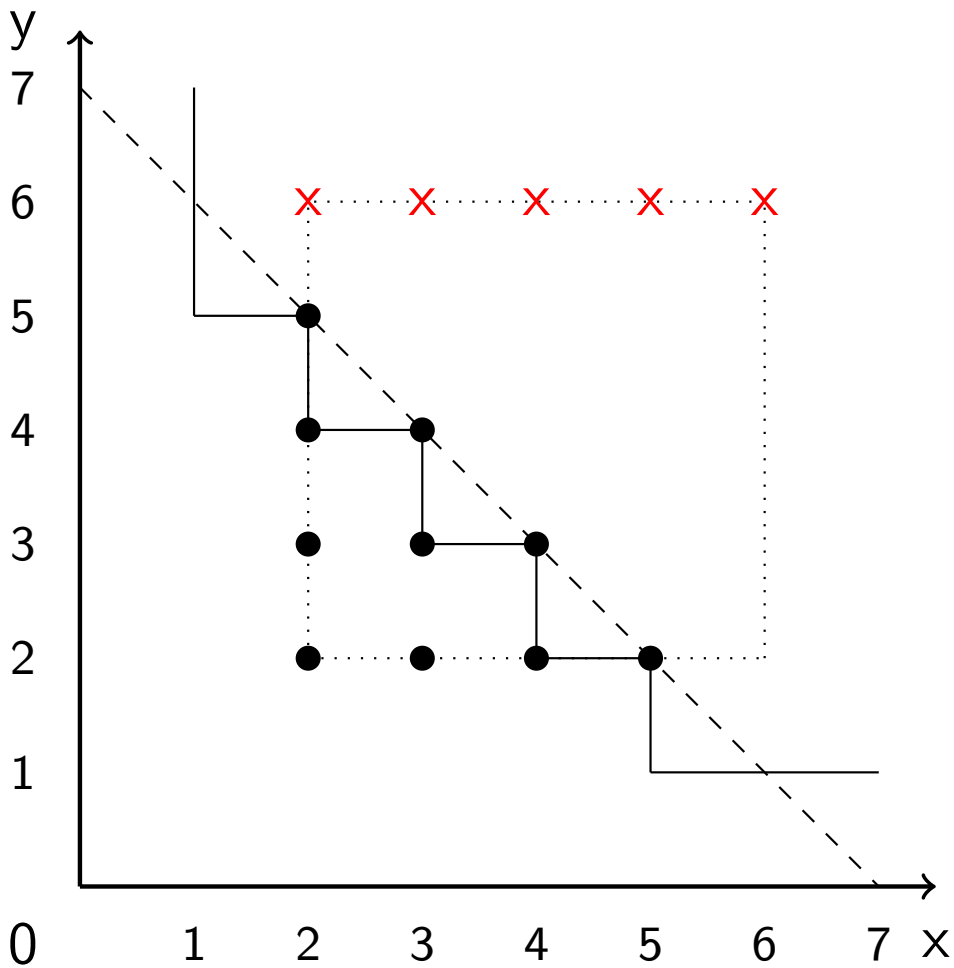

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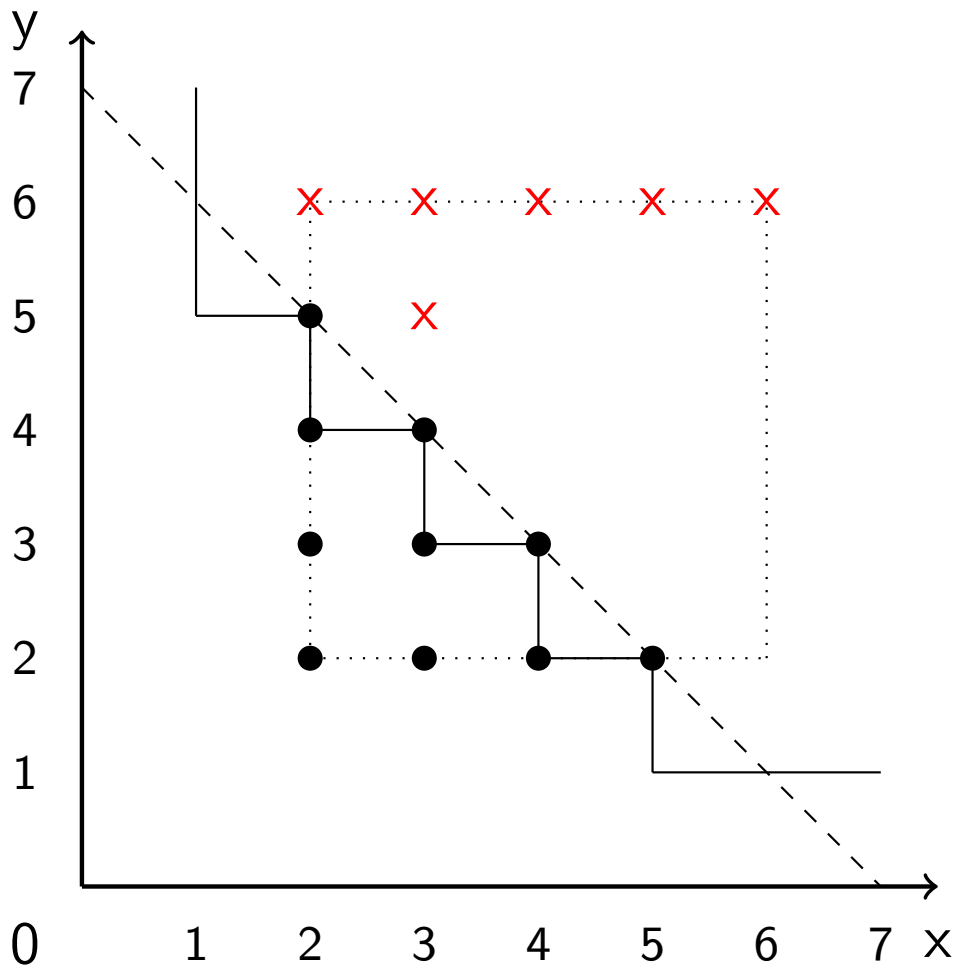

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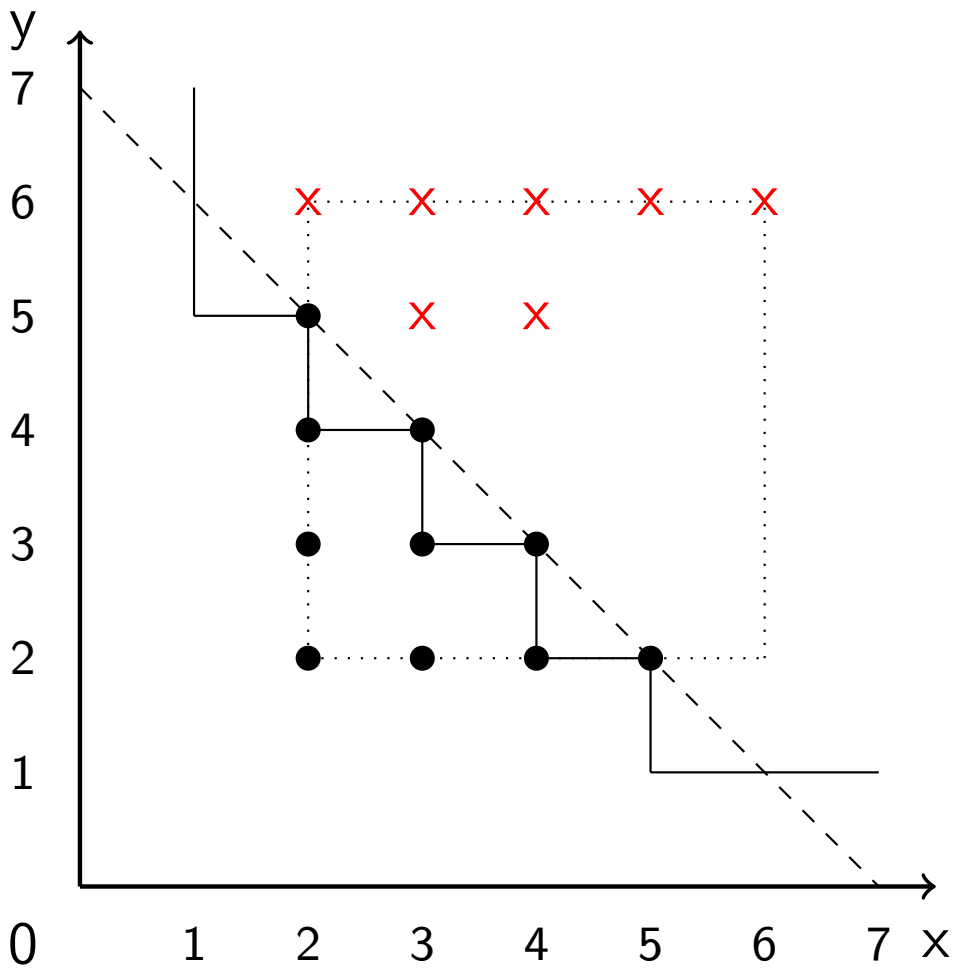

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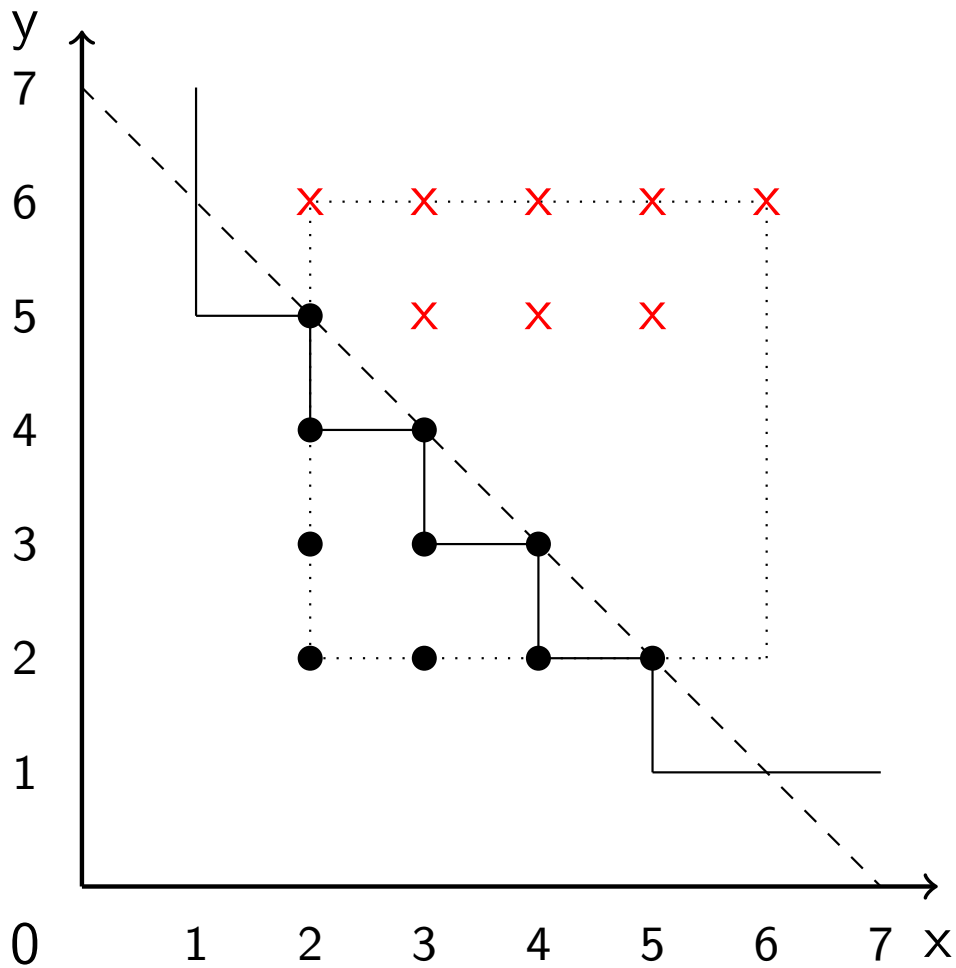

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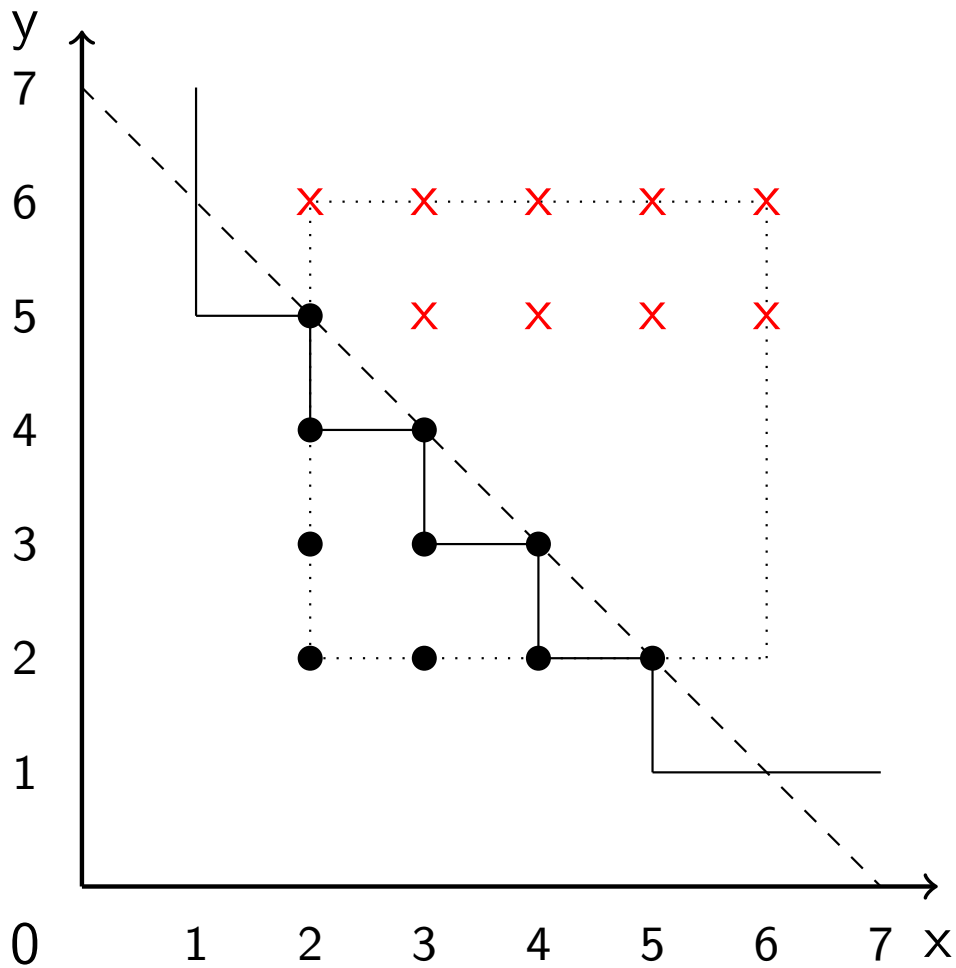

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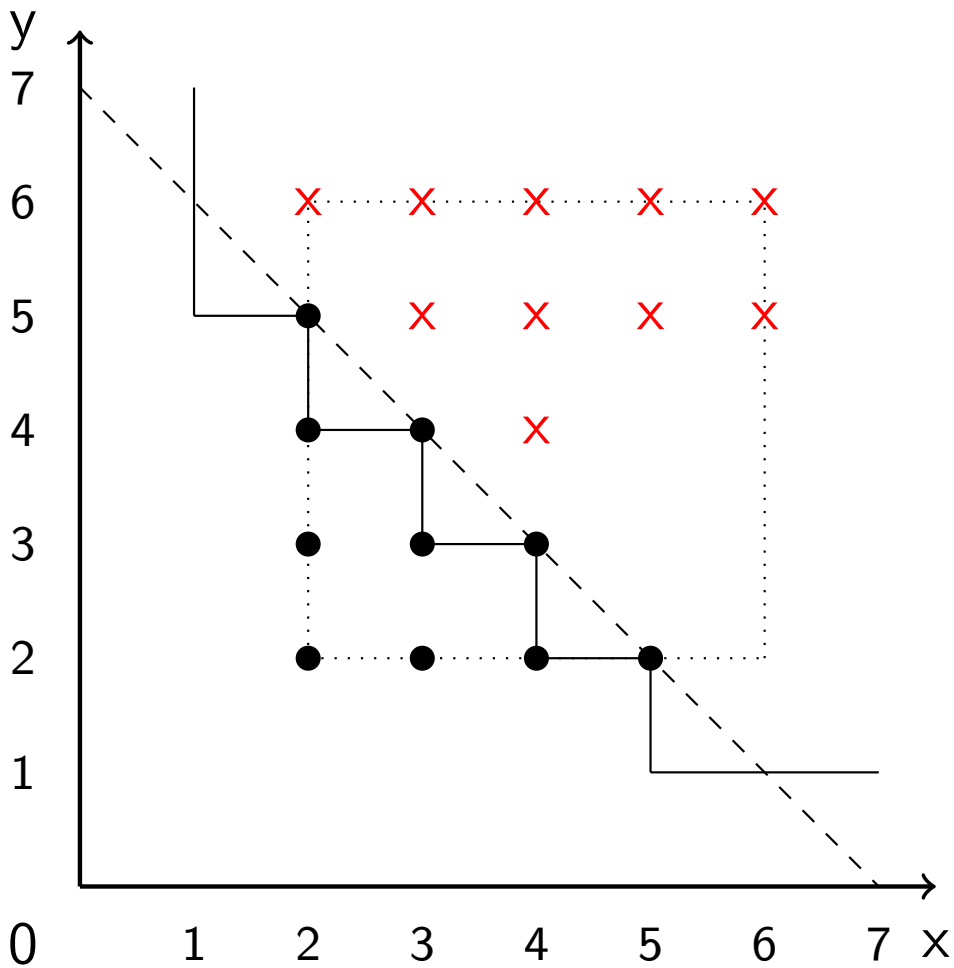

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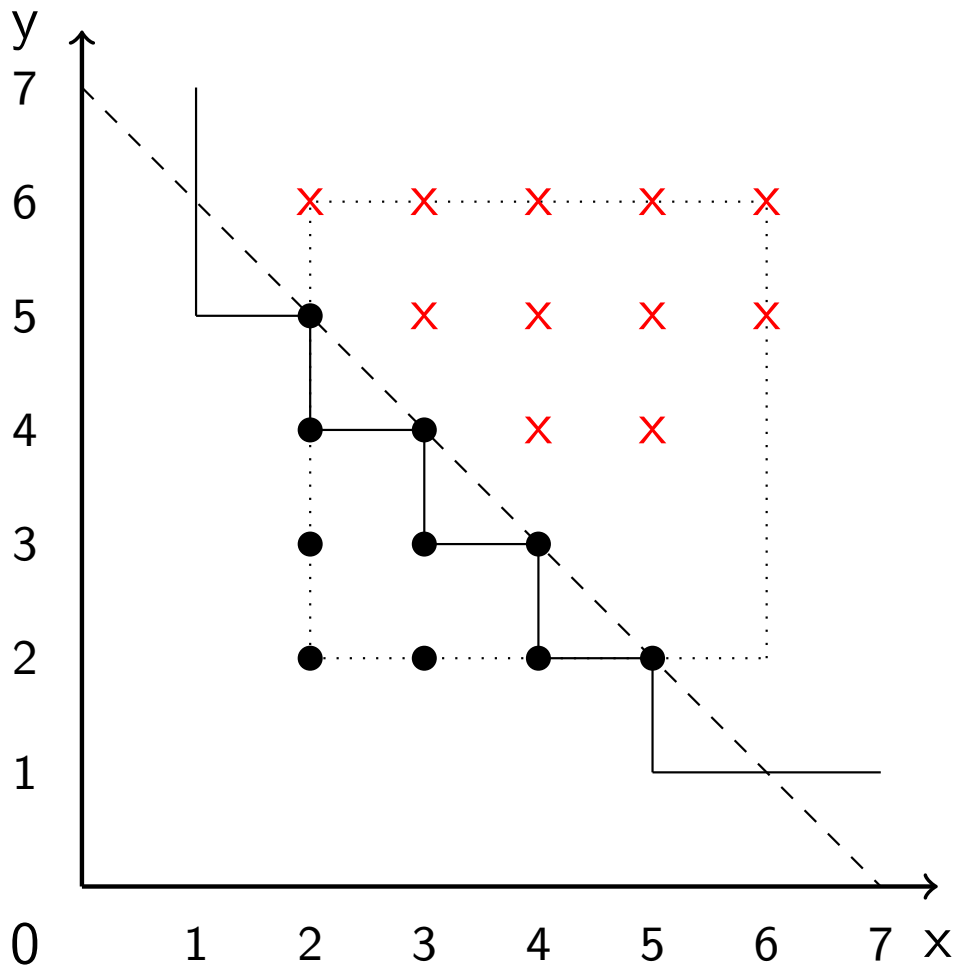

Translating $x + y \leq 7$

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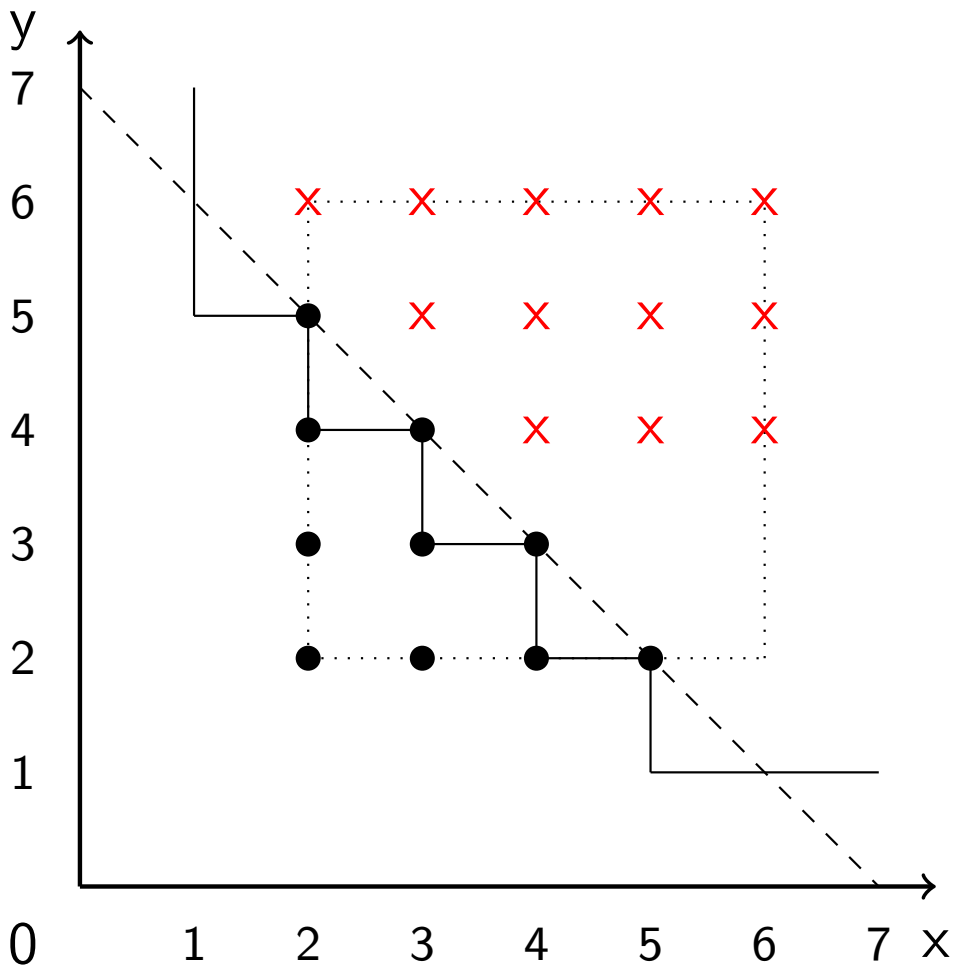

Order Encoding

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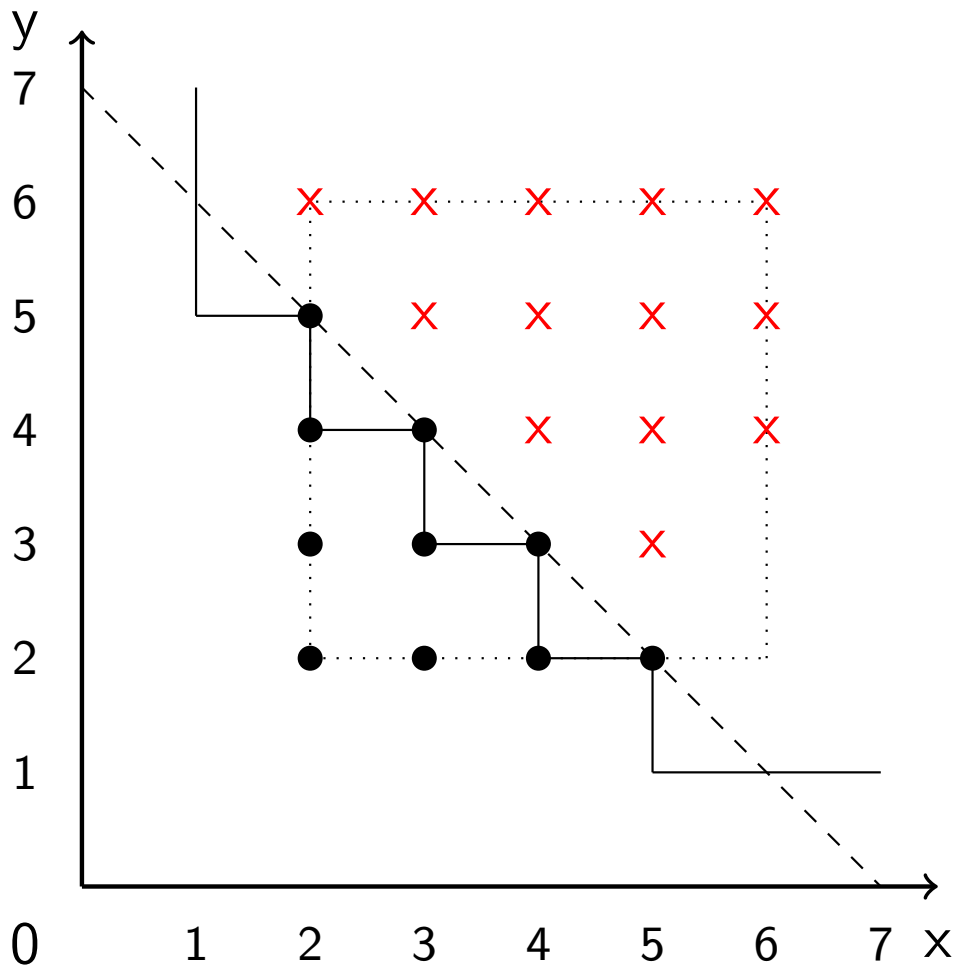
Translating $x + y \leq 7$

Order Encoding



Translating $x + y \leq 7$

Direct Encoding

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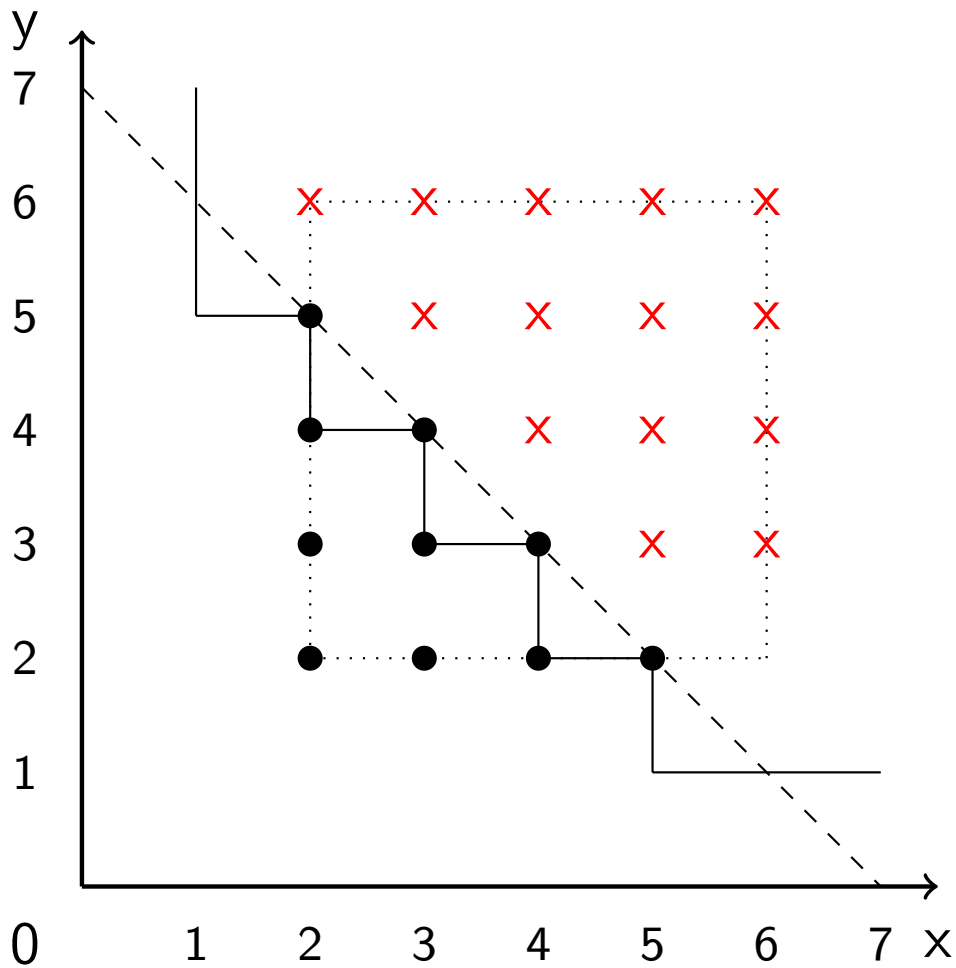

Order Encoding

Direct Encoding

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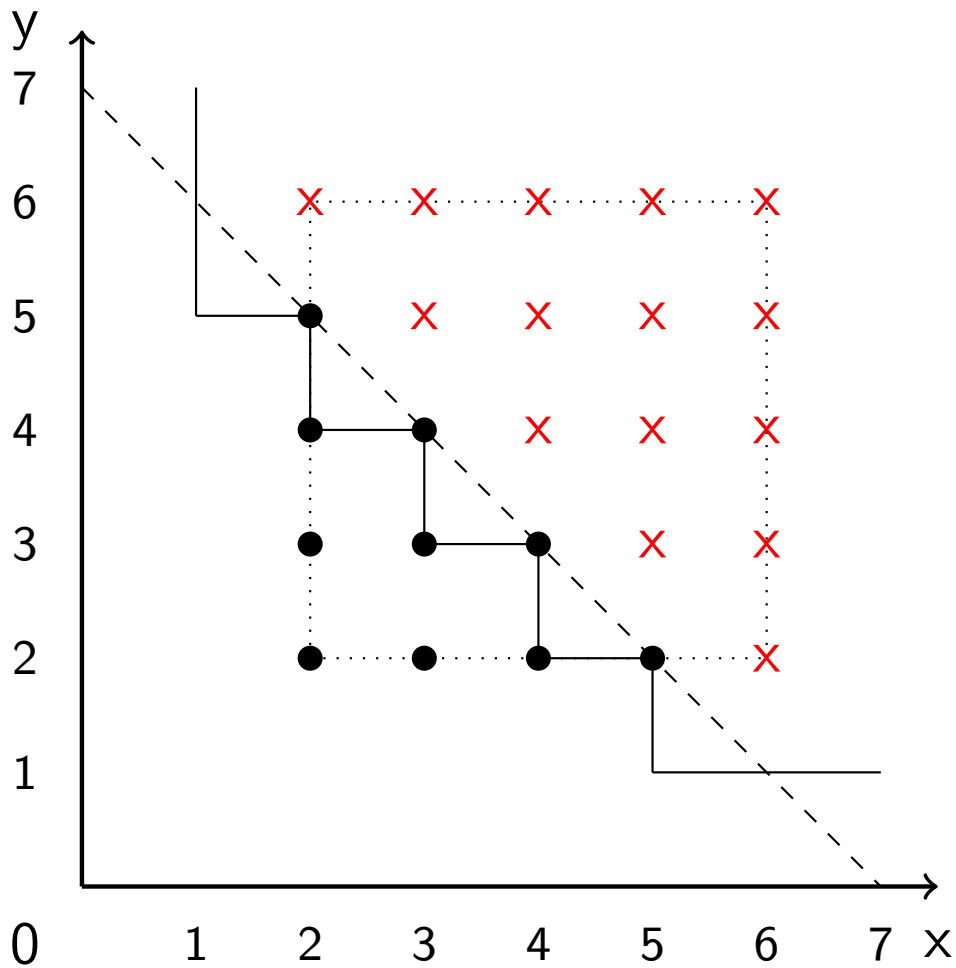
Translating $x + y \leq 7$

Order Encoding



Translating $x + y \leq 7$

Direct Encoding

$x \neq 2 \vee y \neq 6$
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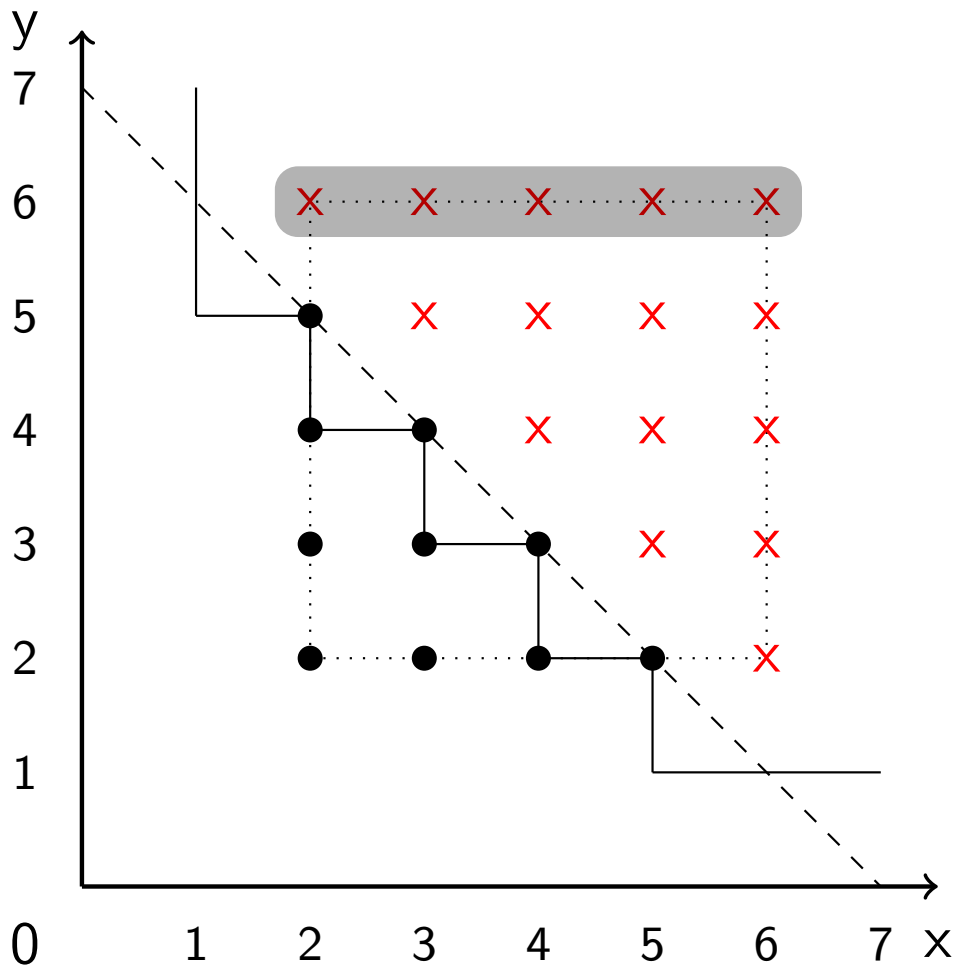

Order Encoding

$x \leq 1 \vee y \leq 5$

Translating $x + y \leq 7$

Direct Encoding

$x \neq 2 \vee y \neq 6$
$x \neq 3 \vee y \neq 6$
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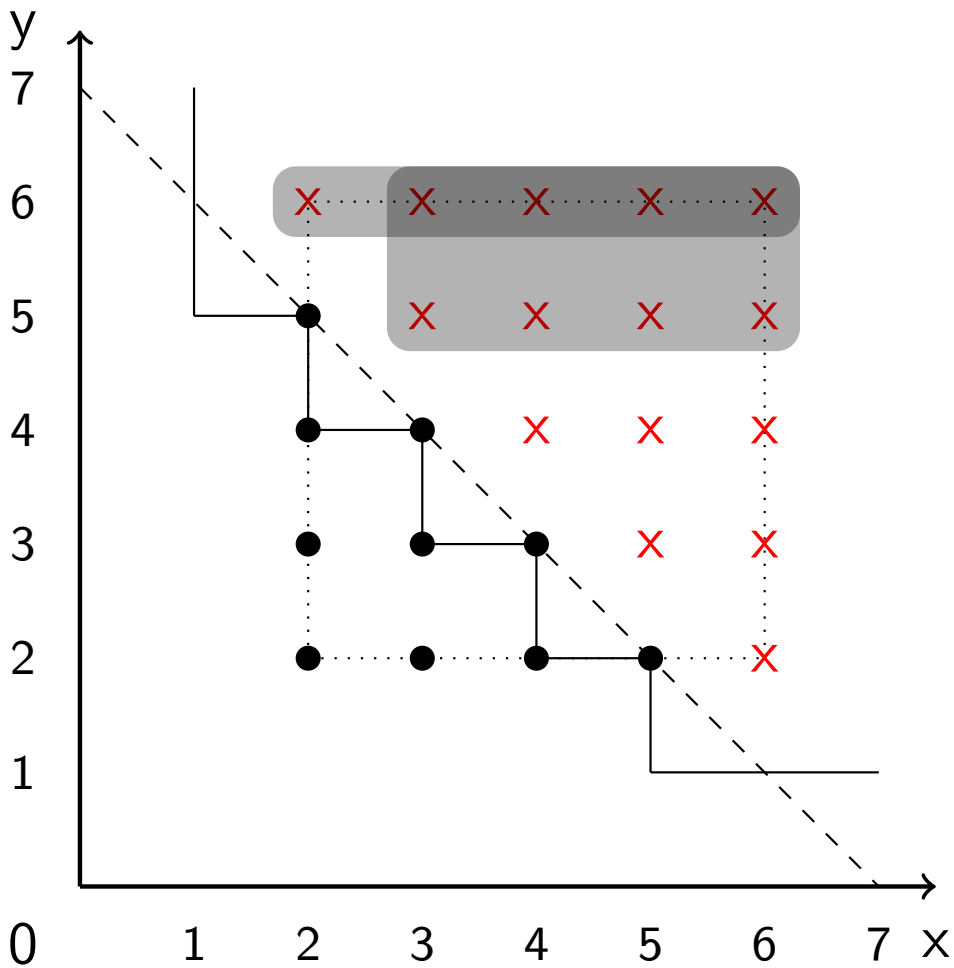

Order Encoding

$x \leq 1 \vee y \leq 5$
$x \leq 2 \vee y \leq 4$

Direct Encoding

$x \neq 2 \vee y \neq 6$
$x \neq 3 \vee y \neq 6$
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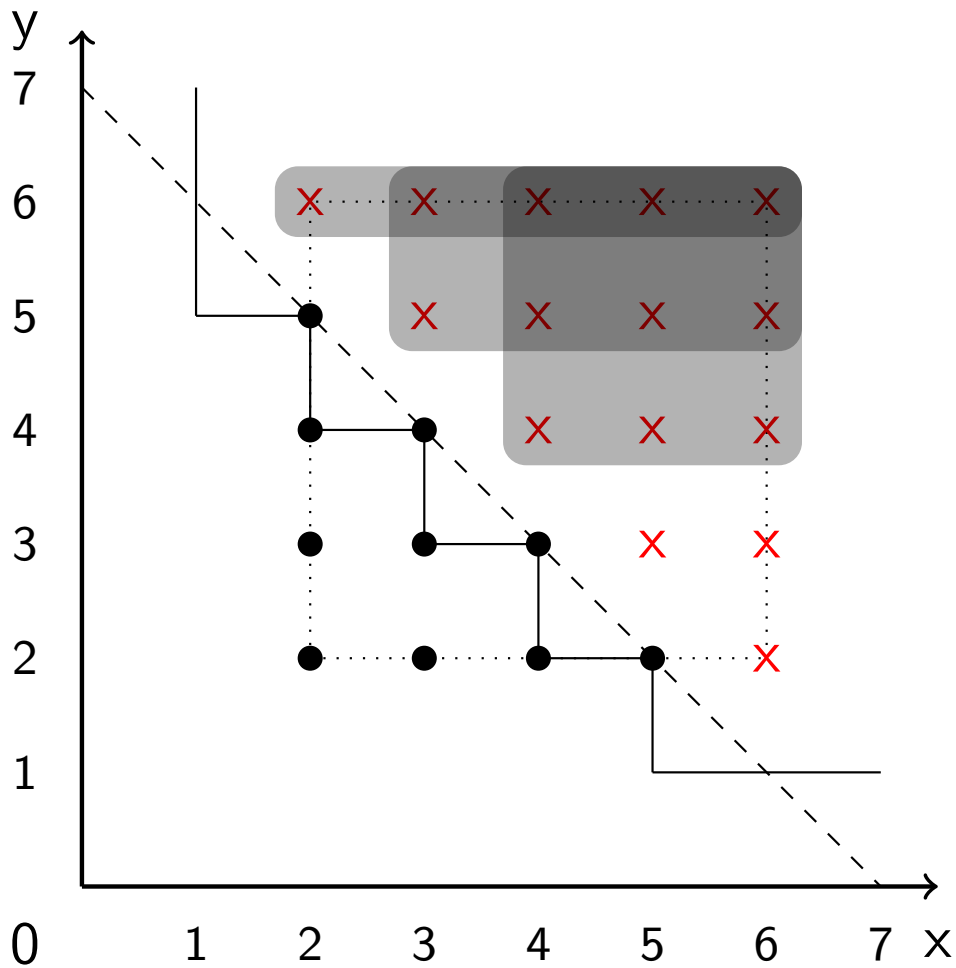
Translating $x + y \leq 7$



Order Encoding

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$x \leq 2 \vee y \leq 4$
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Translating $x + y \leq 7$

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$x \neq 3 \vee y \neq 6$
$x \neq 4 \vee y \neq 6$
$x \neq 5 \vee y \neq 6$
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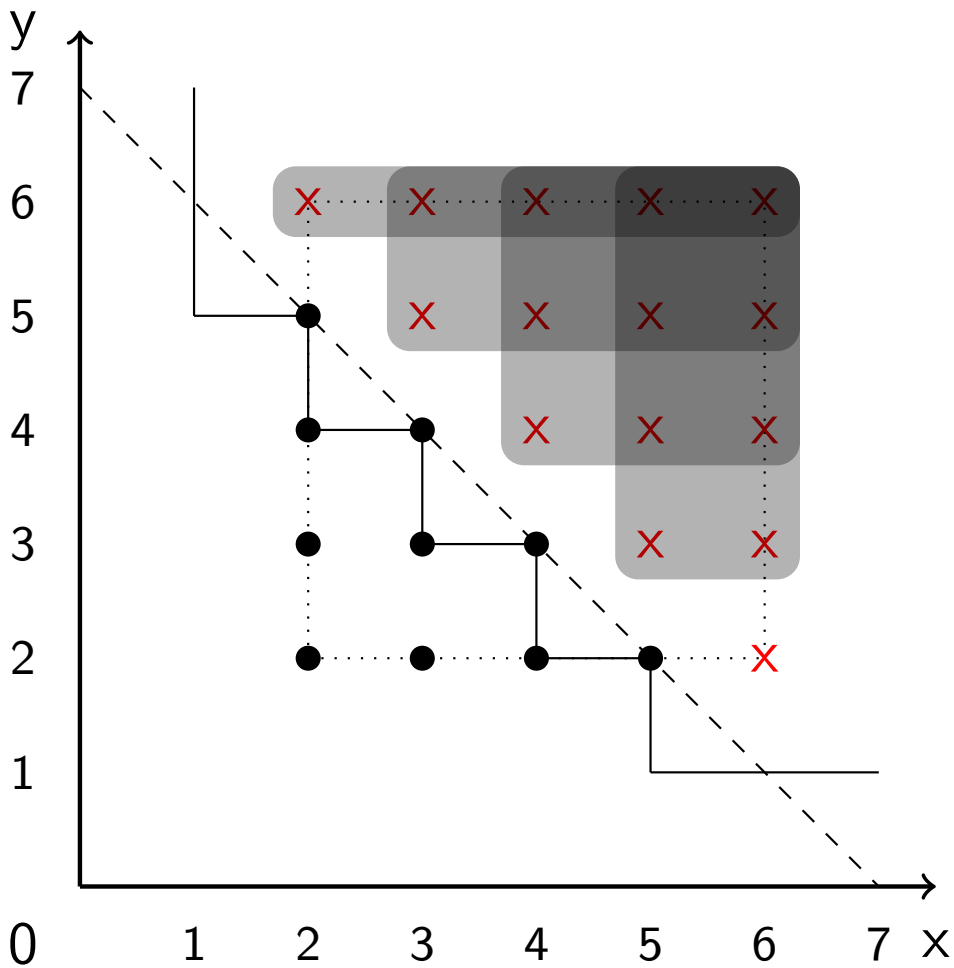
$x \neq 5 \vee y \neq 3$
$x \neq 6 \vee y \neq 3$
$x \neq 6 \vee y \neq 2$



Order Encoding

$x \leq 1 \vee y \leq 5$
$x \leq 2 \vee y \leq 4$
$x \leq 3 \vee y \leq 3$
$x \leq 4 \vee y \leq 2$

Translating $x + y \leq 7$

Direct Encoding

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$x \neq 3 \vee y \neq 6$
$x \neq 4 \vee y \neq 6$
$x \neq 5 \vee y \neq 6$
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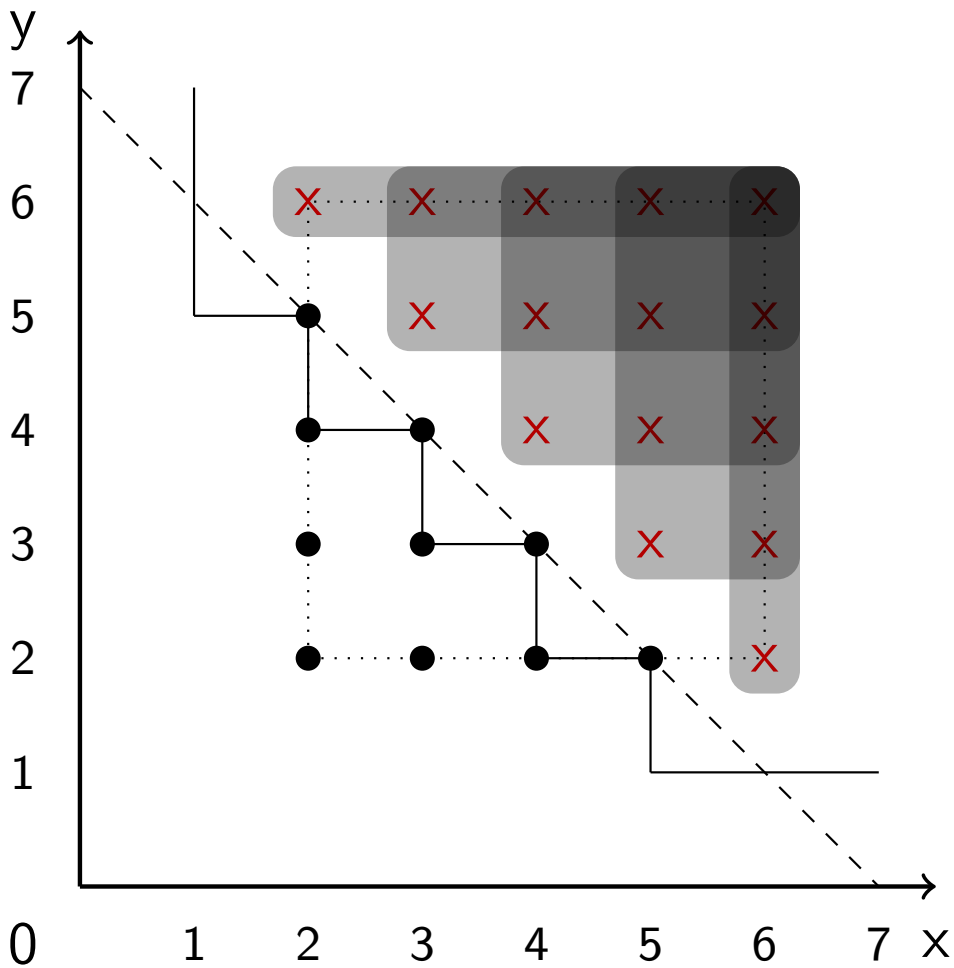

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$x \leq 5 \vee y \leq 1$

OrderLib

Tasks

- storing constraints and variables
- preprocessing
- propagation w/wo reasoning
- translation

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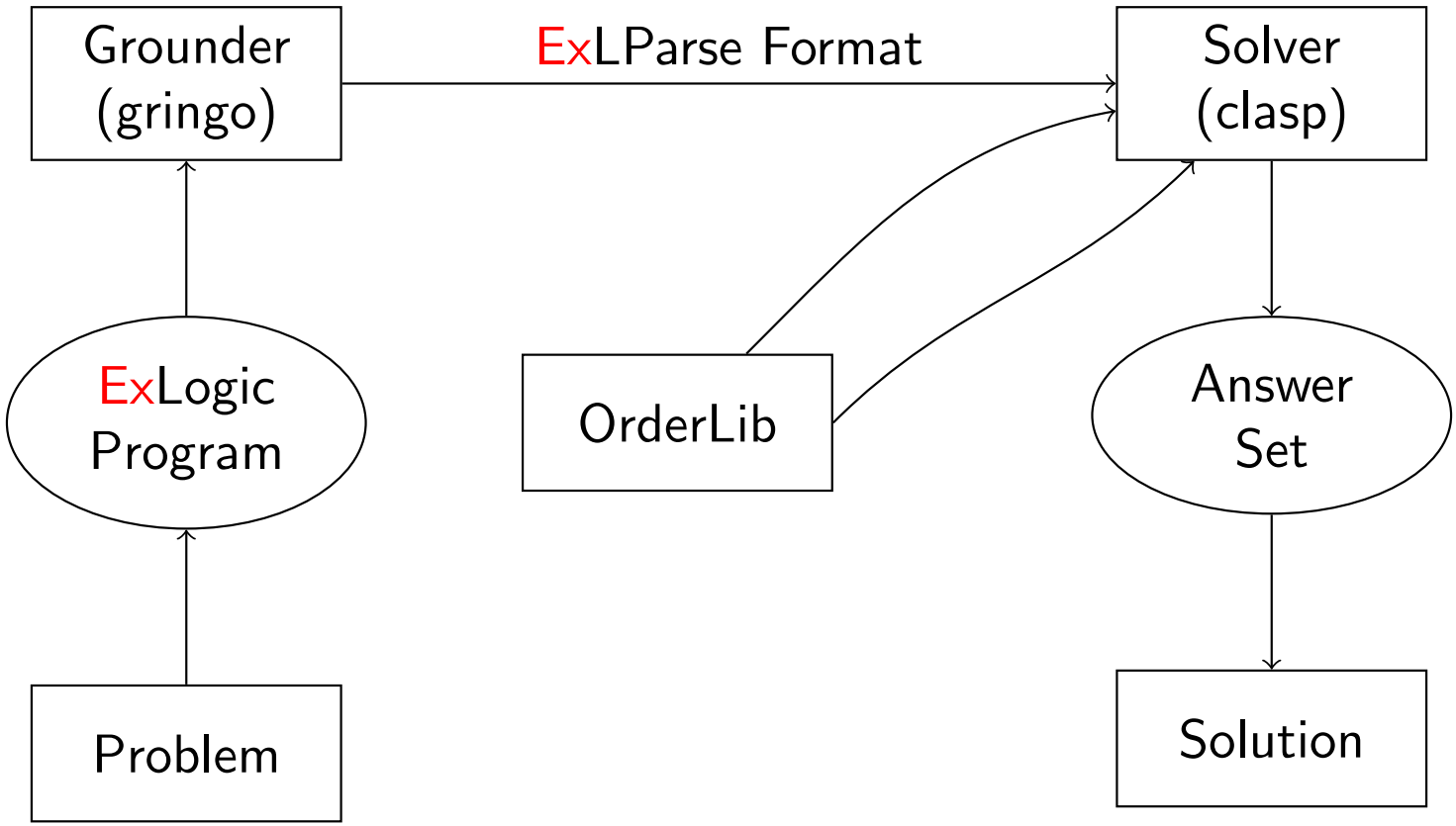
What to do with it?



Features

Make it nice!

- order variables + direct variables on demand
- equality processing
- domain constraints
- disjoint constraints
- alldifferent constraints
  - simple pairwise equality
  - scaleable hall intervals (exponential, better propagation)
  - pidgeon hole optimization

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More Features

Make it nicer!

- splitting
- heuristic domain propagation
- symmetry breaking
  - using projection ?
  - computing only 1 model
- redundant clause check

Splitting

Exponential Translation

```
x_1 + x_2 + x_3 + ... + x_22 <= 13864
```

Quadratic Translation

```
x_1 + x_2 = v_1
x_3 + x_4 = v_2
...
v_1 + v_2 = w_1
...
w_1 + w_2 <= 13864
```

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Heuristic Domain Propagation

Bound Propagation

```
0 <= x <= 1
0 <= y <= 1
42*x + 1337*y = v
```

```
0 <= v <= 1379
```

Domain Propagation

v={0,42,1337,1379}

Heuristic Domain Propagation

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Symmetry Breaking

Splitting

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Project away additional solutions

More Features

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More Features

Make it perfect!

- propagator for order literals
- lazy clause generation
- lazy variable creation
- difference logic propagator
- ...

Overview

SendMoreMoney

```
          1000s + 100e + 10n + 1d +
          1000m + 100o + 10r + 1e =
10000m + 1000o + 100n + 10e + 1y.

alldistinct{s,e,n,d,m,o,r,y}.
```

- Ol' gringo: timeout/memout
- newgringo: 4500 vars, 1000 constraints, 0 seconds
- (hopefully) compareable to state of the art CSP systems

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Large Domains

```
1440a + 6b - 3c = 136164
```

- a,b,c $= \{0..2^{30}\}$
- lazy clause and variable generation
- starting search with 0 constraints/variables
- generates 80 variables on the fly

Thanks for your attention

CSP Competition

549 instances from global category

- OrderLib: 85(23) timeouts, 177.000s
- OldGringo: 267(172) timeouts, 497.000s
- Clingcon: 209(0) timeouts, 411.000s
- Sugar: 70(11) timeouts, 137.000s

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