Pocket calculators for hard combinatorial search and optimization problems

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University of Potsdam

Potassco

Outline

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Characteristics of good pocket calculators

0. handy
1. easy to use
2. lots of operations
3. computes effectively

Claim

Answer Set Programming (ASP) offers good pocket calculators for hard combinatorial search and optimization problems

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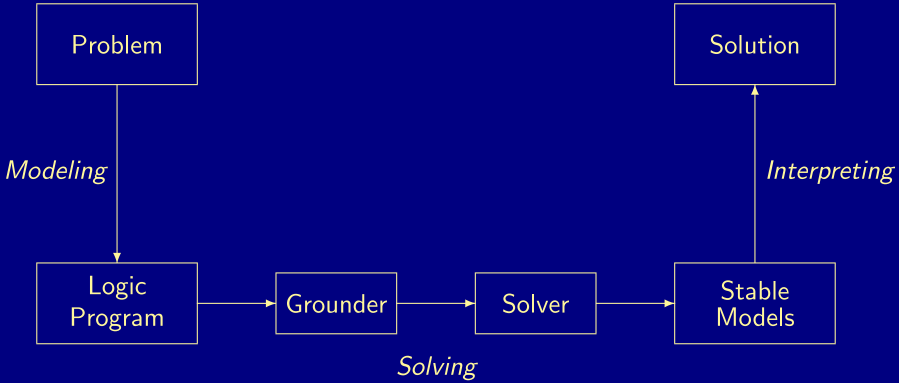
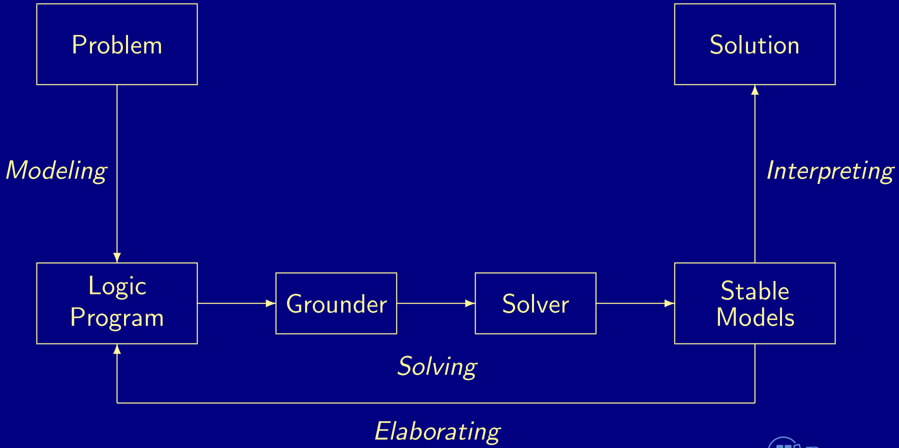
ASP solving


Problem
Solution
Modeling
Interpreting
Logic Program
Grounder
Solver
Stable Models
Solving

ASP solving


Problem
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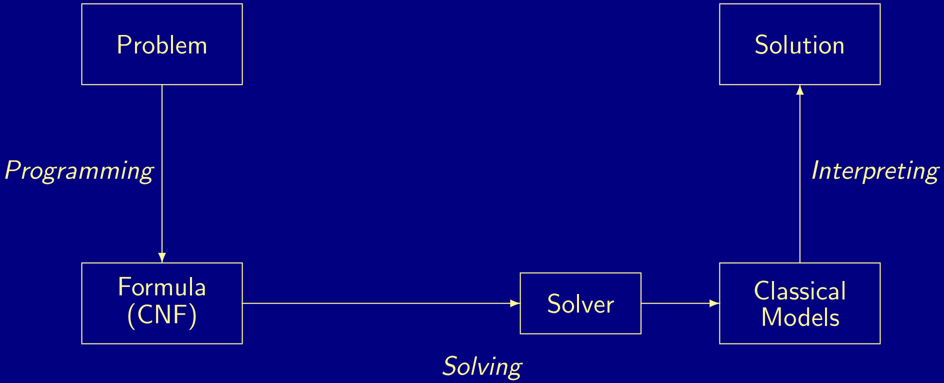
Stable Models
Solving
Elaborating

SAT solving


Problem
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Programming
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Formula
(CNF)
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Classical
Models
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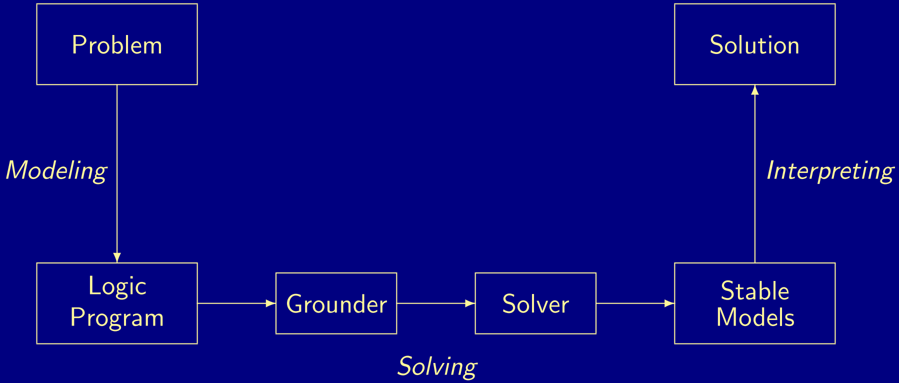
Rooting ASP solving



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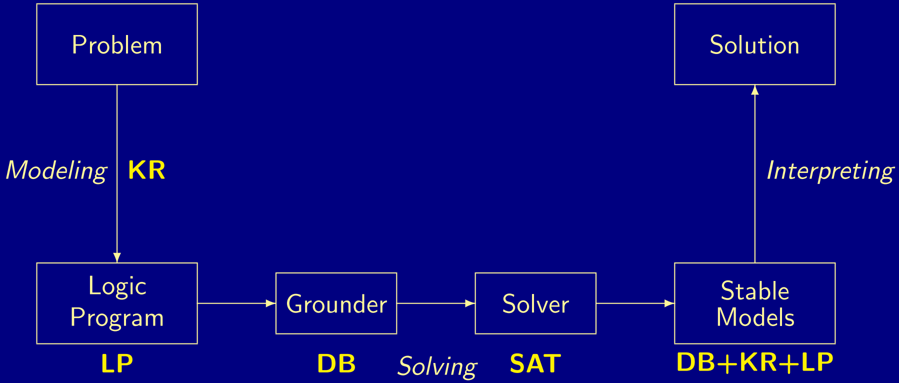

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Language constructs

- Variables `p(X) :- q(X)`
- Conditional literals `p :- q(X) : r(X)`
- Disjunction `p(X) ; q(X) :- r(X)`
- Integrity constraints `:- q(X), p(X)`
- Choice `2 { p(X,Y) : q(X) } 7 :- r(Y)`
- Aggregates `s(Y) :- r(Y), 2 #sum{ X : p(X,Y), q(X) } 7`
- Optimization

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:~ q(X), p(X,C) [C]
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- Aggregates `s(Y) :- r(Y), 2 #sum{ X : p(X,Y), q(X) } 7`
- Multi-objective optimization
  - Weak constraints `:~ q(X), p(X,C) [C@42]`
  - Statements `#minimize { C@42 : q(X), p(X,C) }`

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Basic methodology

Methodology

Generate and Test (or: Guess and Check)

- **Generator** Generate potential stable model candidates (typically through non-deterministic constructs)
- **Tester** Eliminate invalid candidates (typically through integrity constraints)

Peanutshell

Logic program = Data + Generator + Tester (+ Optimizer)

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Satisfiability testing

$$(a \leftrightarrow b) \wedge c$$

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```
{ a ; b ; c }.

 :- not a, b.
 :- a, not b.
 :- not c.
```

Maximum satisfiability testing

"$(a \leftrightarrow b) \land c$"

```
{ a ; b ; c }.

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```

```
{ a ; b ; c }.

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 :~ a, not b.  [10@2]
 :~ not c.    [100@1]
```

n-Queens

Basic encoding

```
{ queen(1..n,1..n) }.

 :- { queen(I,J) } != n.
 :- queen(I,J), queen(I,JJ), J != JJ.
 :- queen(I,J), queen(II,J), I != II.
 :- queen(I,J), queen(II,JJ), (I,J) != (II,JJ), I-J = II-JJ.
 :- queen(I,J), queen(II,JJ), (I,J) != (II,JJ), I+J = II+JJ.
```

n-Queens

Advanced encoding

```
{ queen(I,1..n) } = 1 :- I = 1..n.
{ queen(1..n,J) } = 1 :- J = 1..n.

 :- { queen(D-J,J) } > 1, D =   2..2*n.
 :- { queen(D+J,J) } > 1, D = 1-n..n-1.
```

Traveling salesperson

Basic encoding

```
1 { cycle(X,Y) : edge(X,Y) } 1 :- node(X).
1 { cycle(X,Y) : edge(X,Y) } 1 :- node(Y).

reached(X) :- X = #min { Y : node(Y) }.
reached(Y) :- cycle(X,Y), reached(X).

:- node(Y), not reached(Y).

#minimize { C,X,Y : cycle(X,Y), cost(X,Y,C) }.


node(X) :- edge(X,_).
node(X) :- edge(_,X).

edge(1,2).   edge(1,3).   edge(1,4).
edge(2,4).   edge(2,5).   edge(2,6).   [...]
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Company Controls

```
controls(X,Y) :-
        #sum+ { S: owns(X,Y,S);
                S,Z: controls(X,Z), owns(Z,Y,S) } > 50,
        company(X), company(Y), X != Y.
```

```
company(c_1).   owns(c_1,c_2,60).
                owns(c_1,c_3,20).
company(c_2).   owns(c_2,c_3,35).
company(c_3).   owns(c_3,c_4,51).
company(c_4).
```

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Reasoning modes

- ASP solvers offer
  - Satisfiability testing
  - Enumeration
  - Projection
  - Intersection
  - Union
  - Optimization

  - and combinations of them

- For instance, *clasp* allows for
  - ASP solving (*smodels* format)
  - MaxSAT and SAT solving (extended *dimacs* format)
  - PB solving (*opb* and *wbo* format)

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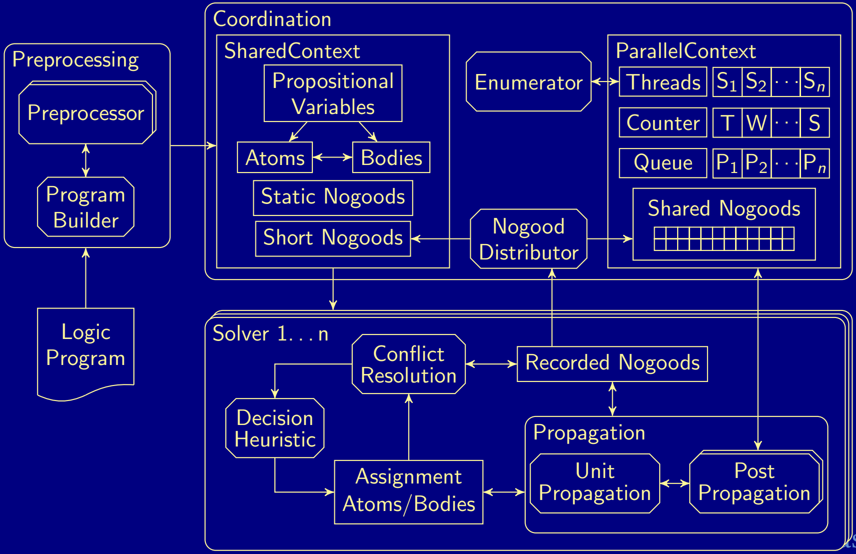
Multi-threaded architecture of *clasp*



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ASPyclopedia

- Systems
  - asperix http://www.info.univ-angers.fr/pub/claire/asperix
  - assat http://assat.cs.ust.hk
  - clasp, gringo, clingo, etc. http://potassco.sourceforge.net
  - cmodels http://www.cs.utexas.edu/users/tag/cmodels
  - dlv http://www.dlvsystem.com
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- Systems — *best suited for beginners*
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