Theory of Answer Set Programming

Introduction to Answer Set Programming

Ira A. Fulton Schools of Engineering
Arizona State University

Objectives

Objective

Explain the difference between declarative programming and traditional programming

Objective

Explain Answer Set Programming as a declarative programming method

Problem Solving and Programming

Problem Solving

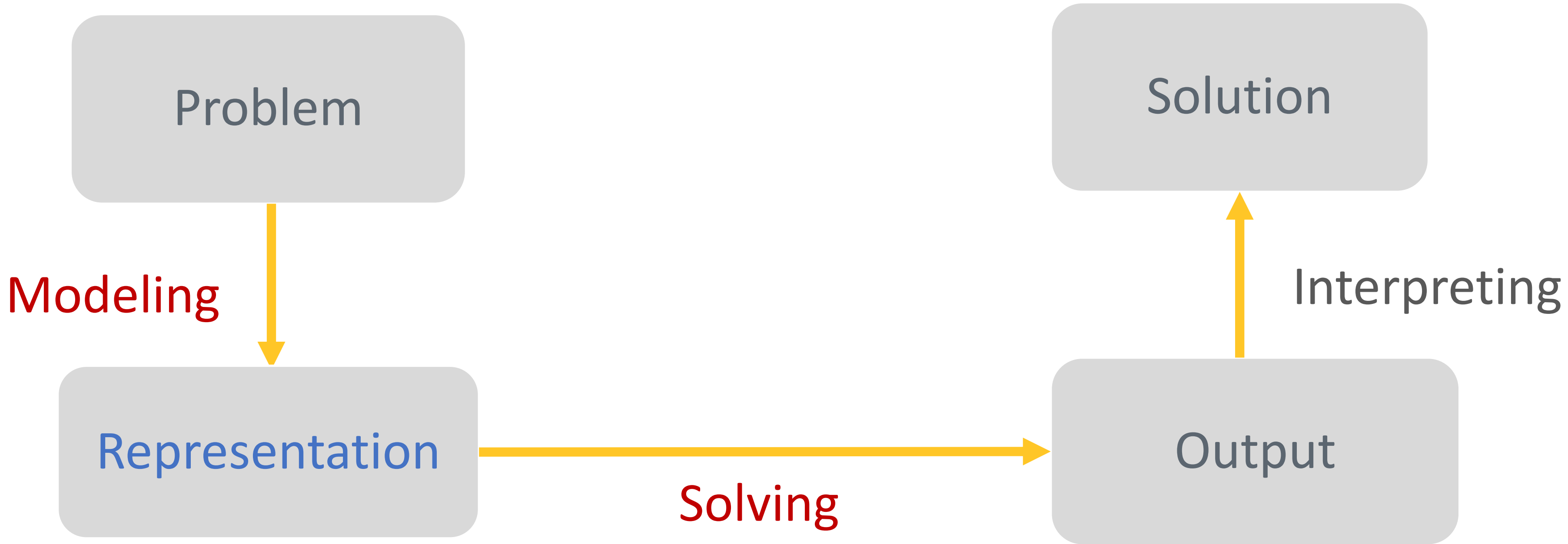
<u>“What is the problem?”</u> versus <u>“How to solve the problem?”</u>

Traditional Programming

<u>"What is the problem?"</u> versus <u>"How to solve the problem?"</u>

Declarative Programming

"What is the problem?" versus "How to solve the problem?"



What is Answer Set Programming

- **Declarative programming paradigm suitable for knowledge intensive and combinatorial search problems**
- **Theoretical basis: stable model semantics (Gelfond and Lifschitz, 1988)**
- **Expressive representation language**
  - defaults
  - negation as failure
  - recursive definitions
  - aggregates
  - preferences
  - etc.

What is Answer Set Programming, cont'd

ASP solvers

- smodels (Helsinki University of Technology, 1996)
- dlv (Vienna University of Technology, 1997)
- cmodels (University of Texas at Austin, 2002)
- pbmodels (University of Kentucky, 2005)
- Clasp/clingo (University of Potsdam, 2006) – winning several first places at ASP, SAT, Max-SAT, PB, CADE competitions
- Wasp (University of Cabria, 2013)
- dlv-hex for computing HEX programs
- oClingo for reactive answer set programming
- …

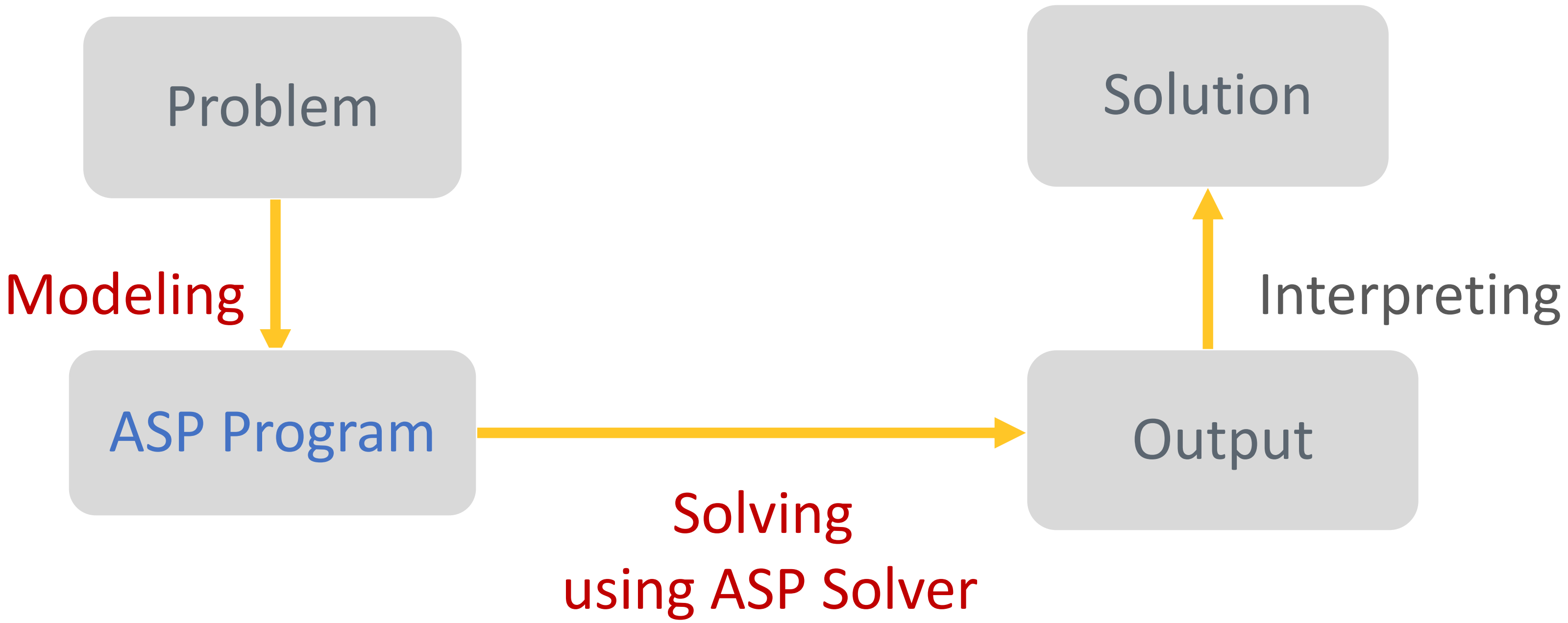
ASP Core 2: Standard language

Annual ASP Competition

Declarative Problem Solving using ASP

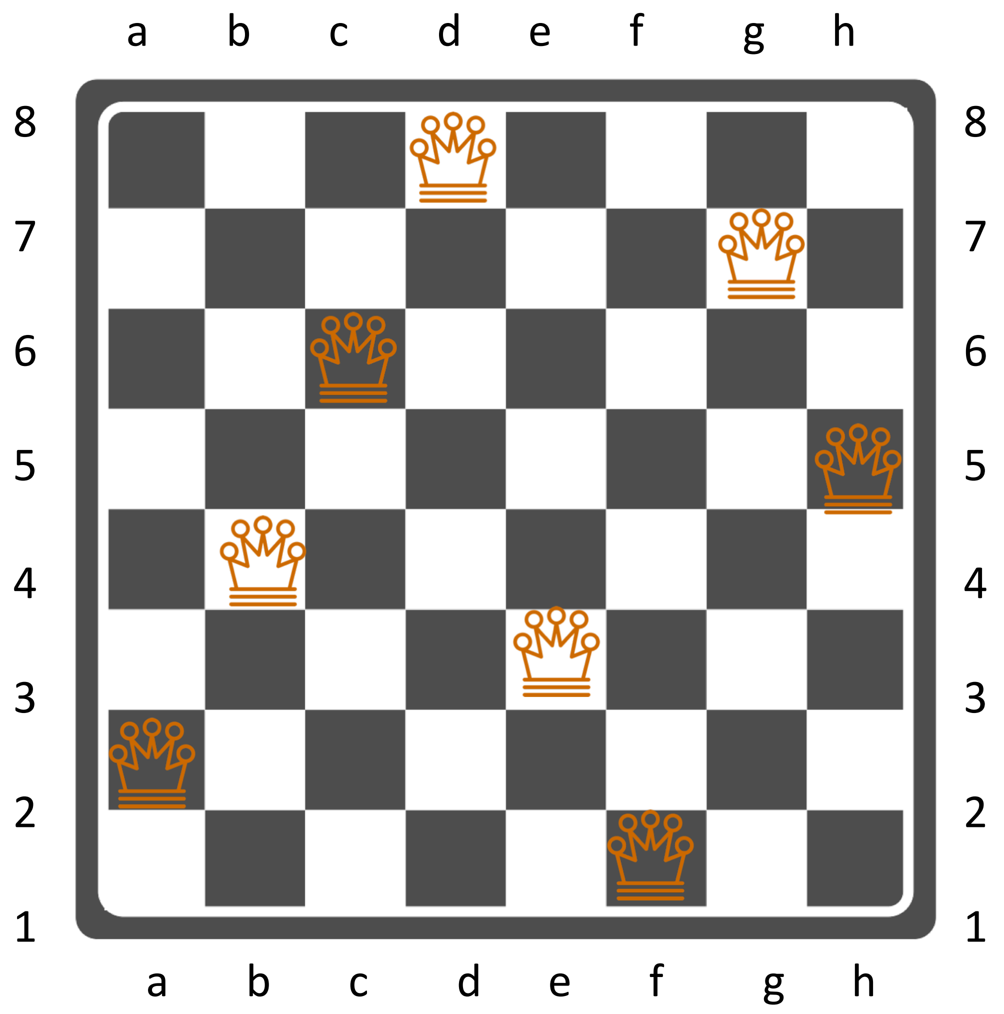
The basic idea is

- to present the given problem by a set of rules,
- to find answer sets for the program using an ASP solver,
- and to extract the solutions from the answer sets.



N-Queens Puzzle

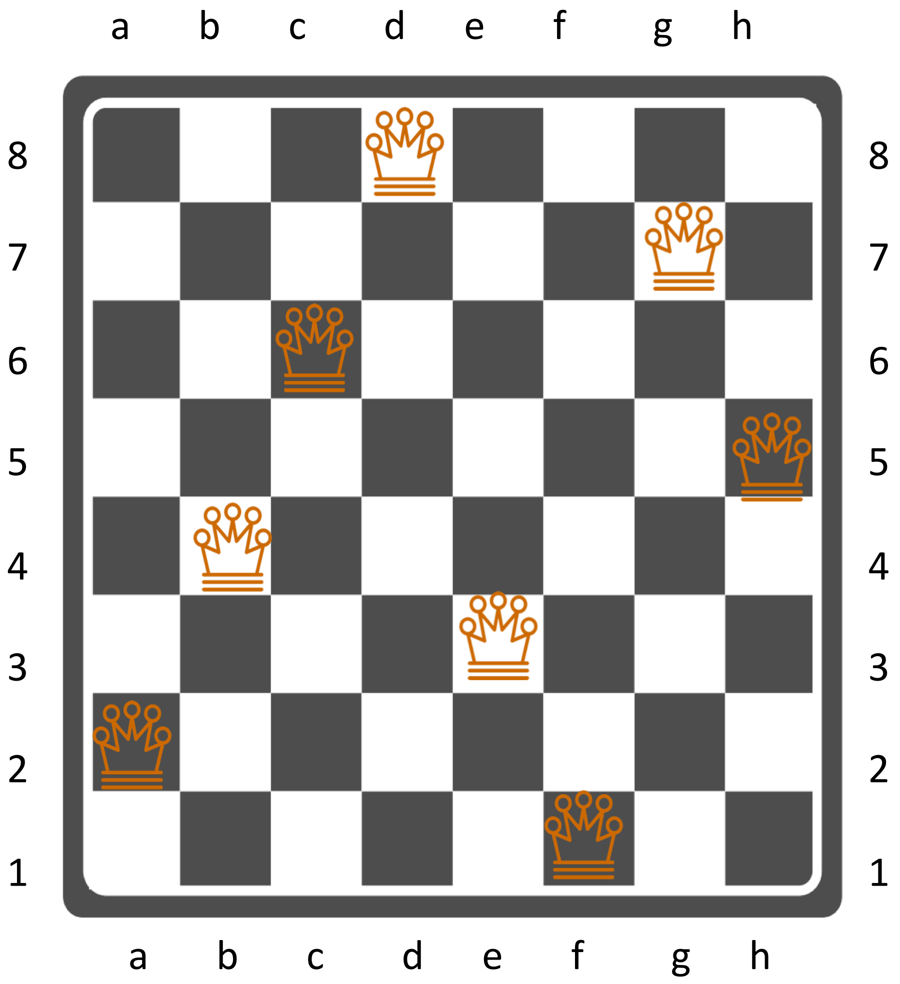
No two queens can share the same row, column, or diagonal



n	# sol
3	none
4	2
5	20
6	4
7	40
8	92

N-Queens Puzzle, cont'd

No two queens can share the same row, column, or diagonal




```
% Each row has exactly one queen
1 {queen(R,1..n)} 1 :- R=1..n.


% No two queens are on the same column
:- queen(R1,C), queen(R2,C), R1!=R2.


% No two queens are on the same diagonal
:- queen(R1,C1), queen(R2,C2), R1!=R2, |R1-R2|=|C1-C2|.
```

Finding One Solution for the 8-Queens Puzzle

```
$ clingo queens.lp -c n=8
clingo version 5.2.1
Reading from queens.lp
Solving...
Answer: 1
queen(4,1) queen(6,2) queen(8,3) queen(2,4) queen(7,5) queen(1,6)
queen(3,7) queen(5,8)
SATISFIABLE


Models       : 1+
Calls        : 1
Time         : 0.004s (Solving: 0.00s 1st Model: 0.00s Unsat: 0.00s)
CPU Time     : 0.004s
```

Finding All Solutions for the 8-Queens Puzzle

```
$ clingo queens.lp -c n=8 0
clingo version 5.2.1
Reading from queens.lp
Solving...
Answer: 1
queen(4,1) queen(6,2) queen(8,3) queen(2,4) queen(7,5) queen(1,6)
queen(3,7) queen(5,8)
Answer: 2
[[ truncated ]]
Answer: 92
queen(5,1) queen(1,2) queen(8,3) queen(4,4) queen(2,5) queen(7,6)
queen(3,7) queen(6,8)
SATISFIABLE

Models       : 92
Calls        : 1
Time         : 0.011s (Solving: 0.01s 1st Model: 0.00s Unsat: 0.00s)
CPU Time     : 0.010s
```

Lecture Wrap-Up