Integration Schemas for Constraint Answer Set Programming: a Case Study

Marcello Balduccini
Drexel University

Yulia Lierler
University of Nebraska at Omaha
Introduction

- Different KR&R techniques for different domains
- Planning: ASP
- Scheduling: CP
- Scheduling + Planning: ?

- Possible solution:
  - Hybrid approaches
    - Satisfiability modulo theories (SMT)
    - Constraint answer set programming (CASP)
CASP

- Modeling capabilities of ASP
- SAT-like solving technology
- Constraint processing for non-Boolean constructs

- Multiple CASP solvers:
  - ACSolver
  - Clingcon
  - EZCSP
  - IDP

- Applications:
  - Commercial printing
  - Robotics
Motivation

- Similarities and differences between CASP solvers are unclear
- Implications of integration schemas used are unclear
  - EZCSP: black-box architecture
  - ACSolver, clingcon: tighter integration
- Development of CASP solvers is hard
  - Requires expertise in SAT, ASP, CSP areas

- Principled and general study of development methods needed
- Need for standardized techniques to integrate computational methods from multiple research areas
In This Paper

• Case study of CASP integration schemas and their performance
• 3 integration schemas
  – Black-box
  – Grey-box
  – Clear-box
• 2 domains from ASPCOMP 2011
  – Weighted Sequence
  – Incremental Scheduling
• 3 types of encodings
  – Pure ASP
  – True CASP
  – Pure CSP
Generally, rules are of the form:
\[ l_0 \leftarrow l_1, \ldots, l_k, \text{not } l_{k+1}, \ldots, \text{not } l_m \]
- \( l_i \): regular or constraint atoms

Example: \( p \leftarrow q, x > 2 \).

Semantics (intuition):
1. Constraint atom \( c \) treated as regular atom; \( \Pi' \) is \( \Pi + \) choice rules \( \{c\} \)
2. \( A \) is answer set of \( \Pi \) if \( A \) is answer set of \( \Pi' \) and \( A \) satisfies all relevant constraint atoms
Integration Schemas Considered

- **Black-box**
  - ASP solver finds an answer set, $A$, and **terminates**
  - CP solver checks if constraint atoms of $A$ have a solution
  - No a solution: denials added to $\Pi$ and ASP solver is **called again**
  - **Pros**: solver-independent implementation; CP solver called rarely
  - **Cons**: full answer set must be computed; ASP search space discarded

- **Grey-box**
  - ASP solver finds an answer set, $A$, and is **suspended**
  - CP solver checks if constraint atoms of $A$ have a solution
  - No a solution: ASP solver is **resumed** and looks for another answer set
  - **Pros**: CP solver called rarely; ASP search space re-used
  - **Cons**: slight dependence on ASP solver API; full answer set must be computed

- **Clear-box**
  - ASP and CP solver are interleaved:
    - While ASP solver computes an answer set, $A$, and **suspended**
    - If constraint atoms of $P$ have no solution, CP triggers backtracking in ASP
  - **Pros**: early pruning; ASP and CP search space are re-used
  - **Cons**: complete dependence on ASP and CP solver APIs; CP solver called often
Encodings Considered

- Encodings can be written to rely on solving capabilities of either side
- Pure ASP
  - Constraint atoms not used
- Pure CSP
  - ASP component is trivial (e.g. no loops through negation, no choice rules)
- True CASP
  - Both ASP and CP component are non-trivial
Experiments

• EZCSP used as testbed
  – Extended to support black-box, grey-box and clear-box integration schemas
  – MiniSAT API used for grey-box and clear-box
• Also compared with cmodels and clingcon
• ASPCOMP11 domains:
  – Weighted-sequence
  – Incremental scheduling
Experimental Results

Instances
- Weighted sequence:
  - 30, ASPCOMP11
- Incremental scheduling:
  - 50, ASPCOMP11: easy, in paper
  - 30, manual: hard, shown here

Timeout: 6,000 seconds
Conclusions

• Best integration schema is domain-dependent
• Finer-grained schemas may be useful
  – Between grey-box and clear-box
• Hybrid systems should support various integration schemas
  – Standardized, flexible APIs for ASP and CP solvers are necessary
• Solvers and problem instances available online

http://www.mbaluccini.tk/ezcsp/aspocp2013/ezcsp-binaries.tgz
http://www.mbaluccini.tk/ezcsp/aspocp2013/experiments.tgz