Integrating Answer Set Programming with Object-oriented Languages

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Outline

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  - presentation of results
  - interfaces to data sources
  - etc.

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- Typical end-user applications contain components which cannot be (easily) solved in ASP:
  - graphical user interfaces
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  - etc.
- Realizing such components is in the domain of traditional object-oriented (OOP) languages.

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- To this end, object-oriented code
  1. adds input as facts,
  2. evaluates the ASP program, and
  3. interprets the answer sets.
- But: An implementation from scratch is similar for most applications $\Rightarrow$ repetitive work.

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Contribution

- The ASP program is extended with annotations which specify input/output.
- Input specifications define how objects are mapped to facts.
- Output specifications define how answer sets are mapped back to objects.
- Based on annotations, the integration with object-oriented code is automated.

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- Input specifications define how objects are mapped to facts.
- Output specifications define how answer sets are mapped back to objects.
- Based on annotations, the integration with object-oriented code is automated.
- In contrast to existing approaches,
  ours is independent of a concrete OOP language.
- We provide a prototypical implementation PY-ASPIO for Python.

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Evaluating ASP Programs from Object-Oriented Code

Overview

- We want to use ASP programs similarly to subprocedures:
  an ASP program P performs a computation over input parameters $v_1, \ldots, v_n$,
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- Approach: the ASP program is annotated with input/output specifications.
  Annotations are added as special comments of form `%!` to the ASP code.
- We then provide an interpreter library for evaluating ("calling")
  such an annotated program:
  - it takes an annotated ASP program and a list of input parameters (objects) as input, and
  - returns a set of objects (corresponding the results of the ASP program).

Evaluating ASP Programs from Object-Oriented Code

Evaluation

More precisely, the interpreter library performs the following tasks:

1. Parameters $v_1, \ldots, v_n$ are converted to facts according to input specification ι.
2. These facts along with the ASP program P are passed to the ASP solver.
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Language independence

- The specification language is largely independent of a concrete OOP language
  $\Rightarrow$ porting the interpreter library to other OOP languages is easily possible.
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1. Data is organized in classes, which consist of named attributes and methods.
2. The language must provide the classes *str* and *int*.
3. We presuppose the following collection types:
   - $Set\langle T\rangle$:
     a collection of unique objects of type T.
   - $Dictionary\langle K, V\rangle$:
     a mapping from objects of type K (the *keys*) to objects of type V (the *values*).
   - $Tuple\langle T_1, \ldots, T_n\rangle$:
     an ordered list of fixed length n, where the component at position i is of type T_i for $1 \leq i \leq n$.
   - $Sequence\langle T\rangle$:
     a finite ordered sequence containing objects of type T, where elements are addressable by an integer index.

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Input Specification

Example (3-Colorability)

Assume we want to use a 3-colorability program from our object-oriented code.

Let the graph in the object-oriented code be represented by sets of nodes and edges, where

- nodes are instances of class Node with the attribute label as a unique string identifiying the node, and
- edges are instances of class Edge, where the attributes first and second are the nodes at both ends of the edge.

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Mapping of the input graph to predicates vertex and edge and problem encoding:

```
%! INPUT (Set<Node> nodes, Set<Edge> edges) {
%!     vertex(n.label) for n in nodes;
%!     edge(e.first.label, e.second.label) for e in edges; }
color(X,r) v color(X,g) v color(X,b) :- vertex(X)
:- color(X,C), color(Y,C), edge(X,Y)
```

Input Specification Language

Language Definition

- In general, an input specification ι is of the form
  $$\texttt{INPUT}\ (t_1\ v_1, \ldots, t_n\ v_n)\ \{s_1; s_2; \ldots s_k;\}$$
  where
  $v_1, \ldots, v_n$ are input parameters of types $t_1, \ldots, t_n$,
  $s_1, \ldots, s_k$ are predicate specifications defined as follows.

- Each predicate specification s_i for $1 \leq i \leq k$ is of form
  $$p(x_1, \ldots, x_m)\ \texttt{for}\ w_1\ \texttt{in}\ y_1 \ldots \texttt{for}\ w_\ell\ \texttt{in}\ y_\ell \quad (1)$$
  where
  p ... predicate symbol,
  $x_1, \ldots, x_m$ are objects of any type,
  $w_1, \ldots, w_\ell$ are (iteration) variables,
  $y_1, \ldots, y_\ell$ are collections.

  Here, the constructs $\texttt{for}\ w_i\ \texttt{in}\ y_i$ are iteration clauses which are used to let w_i iterate over the contents of a collection object y_i.

Output Specification

Example (3-Colorability (cont'd))

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%!    vertex(n.label) for n in nodes;
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%! OUTPUT {
%!    colorednodes = set { query: color(X,C);
%!                         content: ColoredNode(X,C); }; }
color(X,r) v color(X,g) v color(X,b) :- vertex(X)
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```

The output is a set containing instances of ColoredNode, which are created by calling the constructor of the class with arguments X and C for each atom color(X,C) in the current answer set.

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Example (3-Colorability (cont'd))

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This program can be called with two parameters of types Set<Node> resp. Set<Edge> and its output is a set of type Set<ColoredNode>.

Output Specification Language

Language Definition

- Building blocks are (possibly nested) expressions which transform atoms, sets of atoms, and/or results of subexpressions to objects.

  Support types:

  - Basic Expressions are integer and string constants e.
  - Collection Expressions are of one of the following forms:
    - **set** { **query**: q; **content**: e; }
    - **sequence** { **query**: q; **index**: i; **content**: e; }
    - **dictionary** { **query**: q; **key**: k; **content**: e; }
  - Composite Expressions are instances of custom classes of the object-oriented language.

- An output specification ω is then of the form

$$\textbf{OUTPUT}\ \{w_1 = e_1; \dots w_k = e_k;\}$$

  where

  $w_1, \dots, w_k$ are pairwise distinct attributes and $e_1, \dots, e_k$ are expressions.

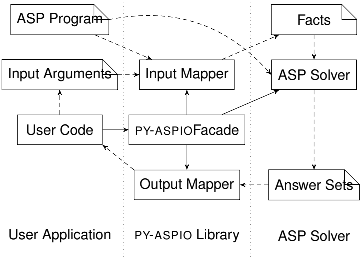
Outline

Implementation

PY-ASPIO

- We implemented an interpreter for our specification language for Python.
- ASP Interface to Object-oriented programs for Python.
- Available at `https://github.com/hexhex/py-aspio`.
- dlvhex is used as ASP solver (switching to other solvers is easily possible).

Implementations for other object-oriented languages are left for future work.



Example: Using the Library from Python

Suppose the ASP program from above is stored in file `coloring.dl`.

Example (3-Colorability (cont'd))

```
from collections import namedtuple
import aspio

# Define classes and create sample data
Node = namedtuple('Node', ['label'])
ColoredNode = namedtuple('ColoredNode', ['label', 'color'])
Edge = namedtuple('Edge', ['first', 'second'])
a, b, c = Node('a'), Node('b'), Node('c')
nodes = {a, b, c}
edges = {Edge(a, b), Edge(a, c), Edge(b, c)}

# Register class names with aspio
aspio.register_dict(globals())

# Load ASP program and input/output specifications from file
prog = aspio.Program(filename='coloring.dl')

# Iterate over all answer sets
for result in prog.solve(nodes, edges):
    print(result.colored_nodes)
```

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Potential industrial applications

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- Interfaces to databases, Web services, etc. might be needed.

Upcoming research application

- ASP extensions support epistemic negation (quantification over answer sets).
- The evaluation algorithm for such programs is based on evaluating sets of programs and reasoning about their answer sets.
- An implementation of epistemic ASP based on PY-ASPIO is work in progress.

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Existing approaches

- Focus on a particular language, cf. e.g. [**?**], [**?**], [**?**].
- Tweety [**?**] and PyASP (`https://pypi.python.org/pypi/pyasp`) provide only a generic atom-based interface, but no customizable mapping.

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Future work

- Language extensions.
- Implementation for other object-oriented languages.

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