Development of a Belief Merging Framework for dlvhex

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Outline

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Usage of multiple belief bases

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- Many different merging techniques

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- fusion of business databases

Types of Incompatibility

Syntactic Incompatibility

- Sources are written in different formalisms
- Preprocessing step needed

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Examples

- relational databases
- object-orientated databases
- RDF ontologies
- logic programs

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Logic Inconsistencies

Union of data sets leads to contradictions:

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likewise

constraint violation: $\bigcup_i KB_i \not\models C$

Example

name is the primary key; a constraint forces the height to be unique for each person.

(a)

name	height
Marge	1,78m
Homer	1,82m
Bart	1,67m

(b)

name	height
Marge	1,78m
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Data Cleanness

- Remain after logic inconsistencies resolved
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Example

Merging of address tables, one with and one without abbreviations

Logic Programs as Belief Bases

Given

$\pi = (P_1, \ldots, P_n)$ vector of belief bases

Given as *logic programs* with answer sets $AS(P_i)$

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To define

$\Sigma^C = (\Sigma^C_c, \Sigma^C_p)$	common signature
$\mu = (\mu_1, \ldots, \mu_n)$	vector of mapping functions
$\omega = (\circ_1, \ldots, \circ_m)$	merging operators
R	merging plan

Common Signature and Mappings

Solve the problem of syntactic incompatibility

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Mappings

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- answer sets stay semantically equivalent!

Merging Operators

Resolve logic inconsistencies
(plus: may perform data cleansing tasks)

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$$\circ_i^{n,m} : \underbrace{2^{\mathcal{A}} \times \cdots \times 2^{\mathcal{A}}}_{n\ times} \times \underbrace{\mathcal{D}_1 \times \ldots \times \mathcal{D}_m}_{additional\ parameters} \rightarrow 2^{\mathcal{A}}$$

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Example for a merging operator

The union operator $\circ_{\cup}^{2,0}$ is defined as follows:

$$\circ_{\cup}^{2,0} : 2^{\mathcal{A}} \times 2^{\mathcal{A}} \rightarrow 2^{\mathcal{A}}$$

$$\circ_{\cup}^{2,0}(SAS_1, SAS_2) = \{AS_1 \cup AS_2 | AS_1 \in SAS_1, AS_2 \in SAS_2, AS_1 \cup AS_2 \not\models \perp\}$$

($\circ_{\cup}^{2}$ is binary, no additional parameters)

Merging Plans

A merging plan is hierarchical and defines

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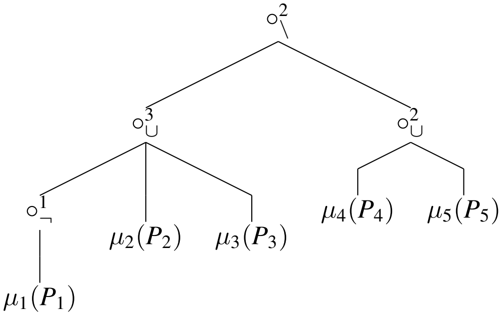
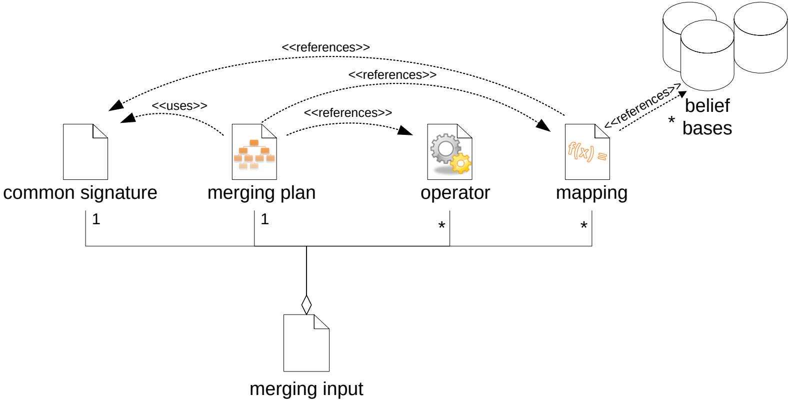
The result

- the set of answer sets delivered by the topmost operator

Example merging plan



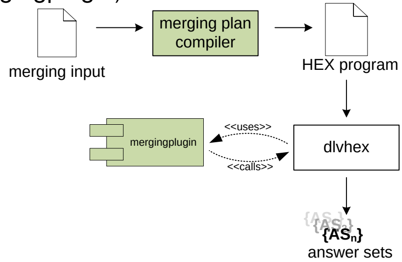
Merging Input



Approach

Steps

1. designing a merging language
2. implementing the merging plan compiler
3. implementing external atoms (mergingplugin)



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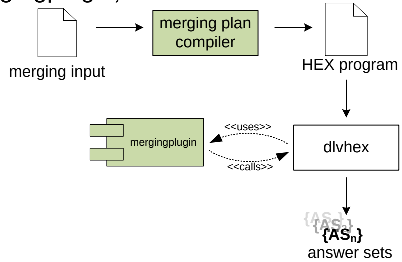

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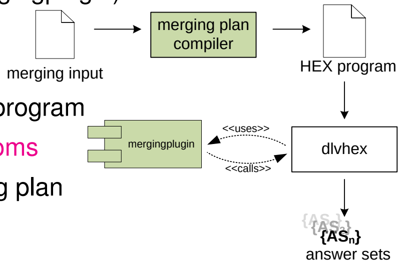
- translates merging plan into HEX program
- program makes use of external atoms
- answer sets = result of the merging plan



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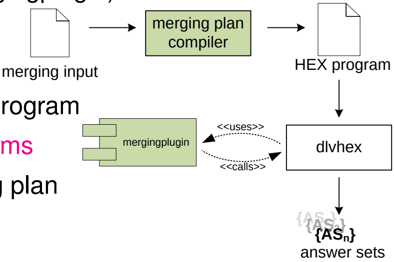

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mergingplugin

defines external atoms for:

- calling of nested HEX programs
- calling of merging operators

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- Experiment with different merging plans and operators by parameterizing them
- Develop merging operators once, apply them in many scenarios

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Steps

1. Define your merging task “`merging.mp`”
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Typical call

- Command-line:

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$ mpcompiler merging.mp | dlvhex --filter=a,b,c --
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Typical call

- Command-line:
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$ mpcompiler merging.mp | dlvhex --filter=a,b,c --
```
- Alternatively:
```
$ dlvhex --merging --filter=a,b,c merging.mp
```

Merging plan language: `merging.mp`

```
[common signature]
    predicate: a/0;
    predicate: b/0;
    predicate: c/0;
    predicate: p/1;
    predicate: q/3;

[belief base]
    name:bb1;
    mapping: “some_rule.”;        % query external source here
    mapping: “q(X, Y, Z) :- &rdf[“...”](X, Y, Z).”;

[belief base]
    name:bb2;
    source: “some_program.hex”;     % or within this program
...
```

Merging plan language: `merging.mp` (ctn'd.)

```
[merging plan]
{
    operator: setminus;
        {
            operator: union;
                {
                    operator: neg;
                        {bb1};
                };
                {bb2};
                {bb3};
        };
        {
        operator: union;
            {bb4};
            {bb5};
        };
}
```

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Definition of implemented version

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$$d(A, P_i) = \min_{J \in AS(P_i)} \underline{d}(A, J)$$

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$$D^d(A, K) = D(d(A, P_1), \ldots, d(A, P_n))$$

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$$D^d(A, K) = D(d(A, P_1), \ldots, d(A, P_n))$$

- $\circ^n(K) = \arg \min_{G \in \mathcal{A}: consistent} D^d(G, K)$

Fault Diagnosis

Finding an explanation for some observation

Definition

Propositional abduction problem (PAP): $\mathscr{P} = \langle V, H, M, T \rangle$

- V is a finite set of propositional variables
- $H \subseteq V$ is a set of hypothesis
- $M \subseteq V$ is the set of manifestations
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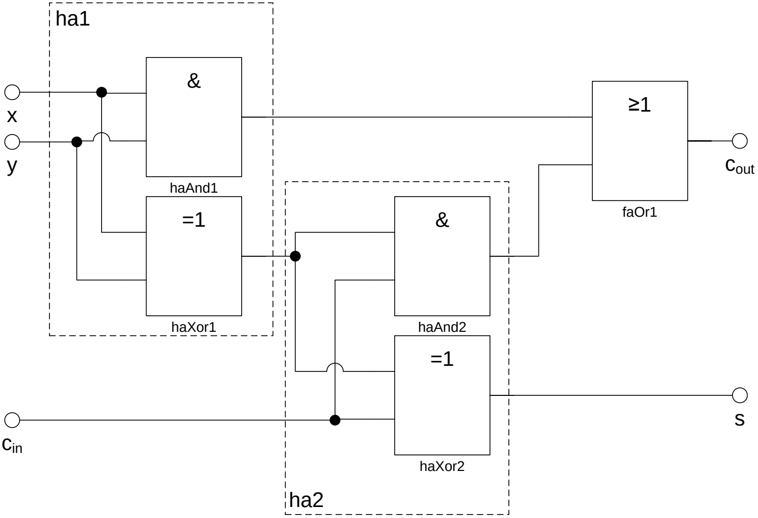
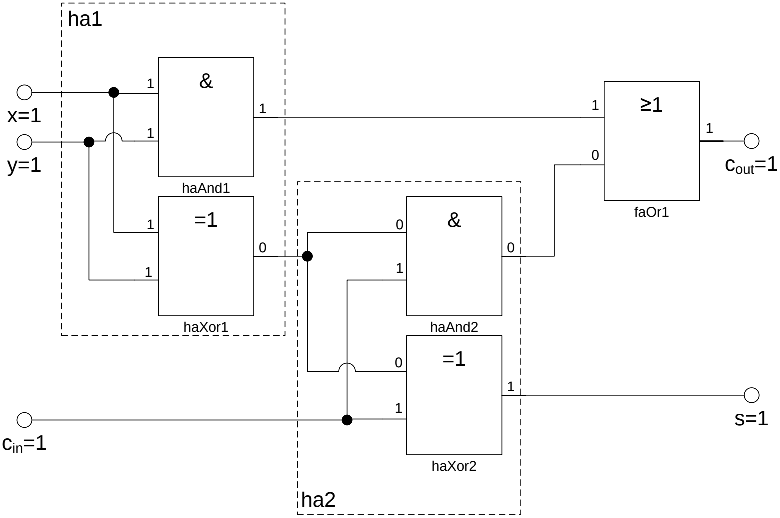
Challenge: *multiple* experts with *different* explanations S_i
Task: Finding a group decision S_G s.t.

- S_G is a solution to $\mathscr{P}$
- S_G is as similar to S_i $\forall i$ as possible

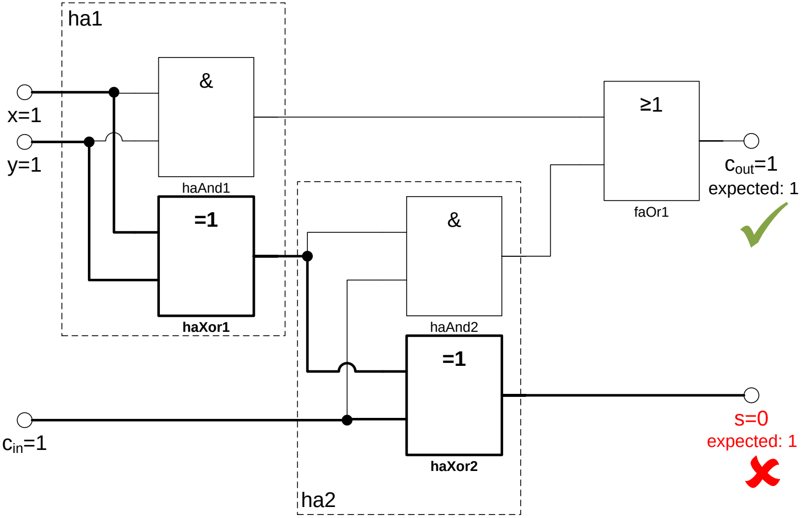
Full Adder



Full Adder - Example interpretation



Full Adder - Malfunctioning



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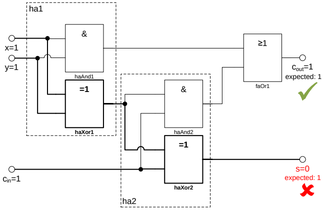

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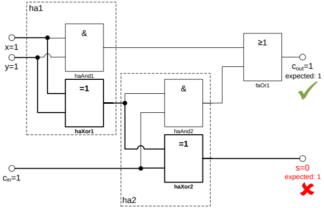

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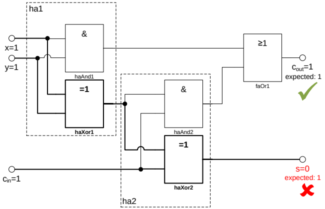

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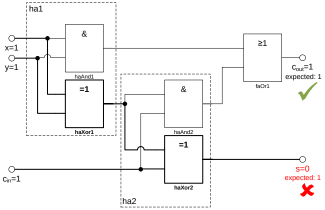
(Minimal) Solutions

1. $AS(P_{J_1}) = \{\{ab(haXor1)\}, \{ab(haXor2)\}\}$
2. $AS(P_{J_2}) = \{\{ab(haXor2)\}\}$
3. $AS(P_{J_3}) = \{\{ab(haXor1)\}\}$



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3. Penalize both (1) and (2), i.e.,
   $|I \Delta G|$

Full Adder

```
[common signature]
predicate:ab/1;

[belief base]
name:juror1;
dlvargs: "-FRmin fulladder.dl abnormal1.hyp fault.obs";

[belief base] name:juror2; ...
[belief base] name:juror3; ...

[merging plan]
{
operator: dalal; aggregate:"sum";
penalize: "ignoring";
constraints: "fulladder.dl"; constraints: "fault.obs";
{juror1}; {juror2}; {juror3};
}
```

Full Adder - Group Decision

Individual explanations

1. $AS(P_{J_1}) = \{\{ab(haXor1)\}, \{ab(haXor2)\}\}$
2. $AS(P_{J_2}) = \{\{ab(haXor2)\}\}$
3. $AS(P_{J_3}) = \{\{ab(haXor1)\}\}$

Possible group explanations

1. $E_1 = \{ab(haXor1), ab(haXor2)\}$
2. $E_2 = \{ab(haXor1)\}$
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Distances to Individuals

Penalizing ignoring only

	$AS(P_{J_1})$	$AS(P_{J_2})$	$AS(P_{J_3})$	Sum
$\mathbf{E_1}$	0	0	0	$\mathbf{0} \Leftarrow$
E_2	0	1	0	1
E_3	0	0	1	1

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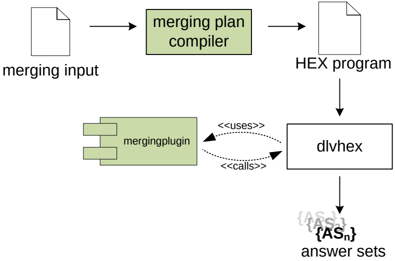
Distances to Individuals

Penalizing ignoring and unfounded group beliefs ($|I \Delta G|$)

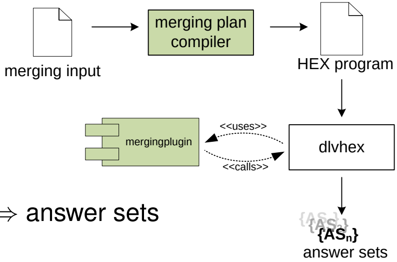
	$AS(P_{J_1})$	$AS(P_{J_2})$	$AS(P_{J_3})$	Sum
E_1	1	1	1	3
$\mathbf{E_2}$	0	2	0	**2** $\Leftarrow$
$\mathbf{E_3}$	0	0	2	**2** $\Leftarrow$

Summary

- Task: Merging of several belief bases

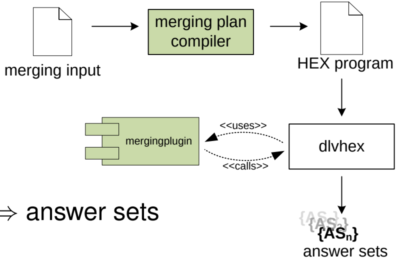


Summary



- Task: Merging of several belief bases
- Approach: Merging language
  - with user-defined merging operators
- merging input ⇒ compiler ⇒ dlvhex ⇒ answer sets

Summary



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Advantages

- Develop merging operators only once or select one of the preinstalled ones (like Dalal)
- No need for manual re-merging after each change of the setting
- Try out several operators and evaluate which behaves best
- No routine tasks (like information flow between sources)
- User can focus on development and optimization of merging procedures in narrower sense!