Revision Programming with Preferences

by

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Outline

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RP:

- Formalism for describing and enforcing constraints on databases
- Database - a collection of atomic facts from some universe.
- Revision rules
  - specify constraints on a database,
  - specify a preferred way to satisfy constraints.
- Arbitrary initial database.
- Justified revisions
  - satisfy all constraints,
  - all changes are justified by revision rules.

Basic concepts

- Universe U. Elements of U - *atoms*. Subsets of U - *databases*.
- Revision literals: $in(a)$, $out(a)$ $(a \in U)$.
- *Revision rules*:

$$in(a) \leftarrow in(a_1), \ldots, in(a_m), out(b_1), \ldots, out(b_n), \qquad \textit{(in-rule)}$$

$$out(a) \leftarrow in(a_1), \ldots, in(a_m), out(b_1), \ldots, out(b_n), \qquad \textit{(out-rule)}$$

  where a, a_i, $b_i \in U$ $(1 \leq i \leq n)$.

- *Revision program* - collection of revision rules.

Necessary change

- α^D - *dual* of a literal α. $\quad in(a)^D = out(a), \;\; out(a)^D = in(a)$.
- A set of literals is *coherent* if it does not contain a pair of dual literals.
- P – a revision program. The *necessary change* of P, $NC(P)$, is the least model of P, treated as a Horn program built of independent propositional atoms of the form $in(a)$ and $out(b)$.
- Coherent $NC(P)$ specifies a revision.

Example.

$$
\begin{array}{rcl}
P: \; in(Ann) & \leftarrow & \\
out(Bob) & \leftarrow & in(Ann) \\
out(Tom) & \leftarrow & out(Ann)
\end{array}
\qquad NC(P) = \{in(Ann), out(Bob)\}
$$

Justified revisions

- Given a database I and a coherent set of literals L, define

$$I \oplus L = (I \cup \{a\colon in(a) \in L\}) \setminus \{a\colon out(a) \in L\}.$$

- *Inertia set* for databases I, R:
$I(I,R) = \{in(a) : a \in I \cap R\} \cup \{out(a) : a \notin I \cup R\}$.

- *Reduct of P with respect to* (I,R) (denoted $P_{I,R}$) – the revision program obtained from P by eliminating from the body of each rule in P all literals in $I(I,R)$.

- P - a revision program, I and R - databases. R is called a *P-justified revision* of I if $NC(P_{I,R})$ is coherent and $R = I \oplus NC(P_{I,R})$.

Example

$$
\begin{aligned}
P: \quad in(Ann) &\leftarrow out(Bob) \\
in(Bob) &\leftarrow out(Ann) \\
in(David) &\leftarrow in(Tom) \\
out(Tom) &\leftarrow out(David) \\
out(Ann) &\leftarrow in(David) \\
out(David) &\leftarrow in(Bob)
\end{aligned}
$$

$$
\begin{aligned}
P_{I,R}: \quad in(Ann) &\leftarrow out(Bob) \\
in(Bob) &\leftarrow \\
in(David) &\leftarrow in(Tom) \\
out(Tom) &\leftarrow out(David) \\
out(Ann) &\leftarrow in(David) \\
out(David) &\leftarrow in(Bob)
\end{aligned}
$$

Initial database: $I = \{David, Tom\}$.

Revision: $R = \{Bob\}$.

Inertia (no justification is needed): *out(Ann)*.

Necessary change: $in(Bob)$, $out(David)$, $out(Tom)$.

Updating I: $(I \cup \{Bob\}) \setminus \{David, Tom\}$.

Basic properties

1. If a database R is a P-justified revision of I, then R is a model of P.
2. If a database B satisfies a revision program P then B is a unique P-justified revision of itself.
3. If R is a P-justified revision of I, then $R \div I$ is minimal in the family $\{B \div I : B \text{ is a model of } P\}$

Relation to Logic Programming

P-justified revisions of $\emptyset$ coinside with stable models of the logic program with constraints, $lp(P)$, obtained from P by replacing revision rules of the form

$$in(a) \leftarrow in(a_1), \ldots, in(a_m), out(b_1), \ldots, out(b_n)$$

by

$$a \leftarrow a_1, \ldots, a_m, not\ b_1, \ldots, not\ b_n$$

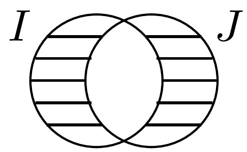
and replacing revision rules of the form

$$out(a) \leftarrow in(a_1), \ldots, in(a_m), out(b_1), \ldots, out(b_n)$$

by constraints

$$\leftarrow a, a_1, \ldots, a_m, not\ b_1, \ldots, not\ b_n.$$

Shifting



$$W = I \div J = (I \setminus J) \cup (J \setminus I)$$

W - a set of atoms that change status

Define a W*-transformation (shift)* as follows.

For a literal α $\quad (\alpha = in(a)$ or $\alpha = out(a))$, $\quad T_W(\alpha) = \begin{cases} \alpha^D, & \text{when } a \in W \\ \alpha, & \text{when } a \notin W. \end{cases}$

For a set of literals L, $\quad T_W(L) = \{T_W(\alpha) \colon \alpha \in L\}$.

For a set of atoms X,

$$T_W(X) = \{\, a : \; in(a) \in T_W(\{in(b) \colon b \in X\} \cup \{out(b) \colon b \notin X\})\}.$$

For a revision program P, $\quad T_W(P)$ is obtained from P by applying T_W to each literal in P.

Shifting theorem

For any databases I_1 and I_2, database R is a P-justified revision of I_1 if and only if $T_{I_1 \div I_2}(R)$ is a $T_{I_1 \div I_2}(P)$-justified revision of I_2.

Corollary. *For each I and R, R is P-justified revision of I if and only if $T_I(R)$ is $T_I(P)$-justified revision of $\emptyset$.*

Computing justified revisions

by means of LP

1. Given P and I, apply T_I to obtain $T_I(P)$ and $\emptyset$.
2. Convert $T_I(P)$ into the logic program $lp(T_I(P))$.
3. Compute its answer sets.
4. Apply T_I to the answer sets to obtain the P-justified revisions of I.

Robot example

A robot is equipped with sensors which provide observations:

$$observation(Par, Value, Sensor)$$

View of the world has exactly one value for each parameter:

$$world(Par, Value, Sensor)$$

RP updates the view of the world, consists of rules of types:

$\mathbf{in}(observation(Par, Value, Sensor)) \;\leftarrow$

$\mathbf{in}(\mathit{world(Par, Value, Sensor)}) \leftarrow \mathbf{in}(\mathit{observation(Par, Value, Sensor)}).$

$\mathbf{out}(\mathit{world(Par, Value, Sensor)}) \leftarrow \mathbf{in}(\mathit{world(Par, Value1, Sensor1)}).$

(where Sensor $\neq$ Sensor1 and/or Value $\neq$ Value1)

Syntax

An *ordered revision program* is a pair $(P, \mathcal{L})$ where $\mathcal{L}$ is a function which assigns to revision rules in P unique labels. $\mathcal{L}(P)$ - set of labels in P.

$$l : \alpha_0 \leftarrow \alpha_1, \ldots, \alpha_n$$

A *preference* on rules in $(P, \mathcal{L})$ is an expression of the form

$$prefer(l_1, l_2) \leftarrow initially(\alpha_1, \ldots, \alpha_k), \alpha_{k+1}, \ldots, \alpha_n,$$

where l_i are labels, α_j are revision literals.

A *revision program with preferences* is a triple $(P, \mathcal{L}, S)$, where $(P, \mathcal{L})$ is an ordered revision program and S is a set of preferences on rules in $(P, \mathcal{L})$.
S - the *control program.*

$(P, \mathcal{L}, S)$ is translated into ordinary RP:

$$U^{\mathcal{L}(P)} \; = \; U \; \cup \; \{ok(l), defeated(l), prefer(l, l') \; : \; l, l' \in \mathcal{L}(P)\}$$

Define $P^{S,I}$ over $U^{\mathcal{L}(P)}$ to be a revision program consisting of rules:

- for each $l \in \mathcal{L}(P)$

$$\begin{aligned} head(l) &\leftarrow body(l), in(ok(l)) \\ in(ok(l)) &\leftarrow out(defeated(l)) \end{aligned}$$

- for each preference

$$prefer(l_1, l_2) \leftarrow initially(\alpha_1, \ldots, \alpha_k), \alpha_{k+1}, \ldots, \alpha_n,$$

  in S such that $\alpha_1 \ldots, \alpha_k$ are satisfied by I

$$\begin{aligned} in(prefer(l_1, l_2)) &\leftarrow \alpha_{k+1}, \ldots, \alpha_n \\ in(defeated(l_2)) &\leftarrow body(l_1), in(prefer(l_1, l_2)) \end{aligned}$$

$(P, \mathcal{L}, S)$-justified revisions

A database R is a $(P, \mathcal{L}, S)$-*justified revision* of I if there exists $R' \subseteq U^{\mathcal{L}(P)}$ such that R' is a $P^{S,I}$-justified revision of I, and $R = R' \cap U$.

Properties

- Justified revision semantics for revision programs with preferences extends justified revision semantics for ordinary revision programs
- Shifting property holds
- Not every $(P, \mathcal{L}, S)$-justified revision is a model of P

When $(P, \mathcal{L}, S)$-justified revisions are models of P?

Two rules r, r' of P are *in conflict* if one of the following conditions is satisfied:

1. $(head(r))^D \in body(r')$ and $(head(r'))^D \in body(r)$; or
2. $body(r) \cup body(r')$ is incoherent.

A set of preferences is *conflict-resolving* if it contains only preferences between conflicting rules.

Theorem. *Let $(P, \mathcal{L}, S)$ be a revision program with preferences where S is a set of conflict-resolving preferences and is cycle-free. For every $(P, \mathcal{L}, S)$-justified revision R of I, R is a model of P.*

Soft revision rules with weights

Revision program is divided into hard and soft rules: $P = HR \cup SR$

All hard rules must be satisfied.

Only a subset of soft rules may be satisfied.

The subset of soft rules that is satisfied is optimal with respect to some criteria.

Maximal number of rules

Definition 1 *R is a (HR, SR)-preferred justified revision of I if R is a $(HR \cup S)$ - justified revision of I for some $S \subseteq SR$, and for all S' if $S \subset S' \subseteq SR$, then there are no $(HR \cup S')$-justified revisions of I.*

Implementation

For each I, translate $P = HR \cup SR$ into an `smodels` program $lp(T_I(HR)) \cup lp'(T_I(SR))$.

lp' translates a rule

$$in(a) \leftarrow in(p_1), \ldots, in(p_m), out(s_1), \ldots, out(s_n)$$

into the rules

$$\begin{array}{lll} \{rule_i\} & :- & p_1, \ldots, p_m, not\ s_1, \ldots, not\ s_n. \\ a & :- & rule_i \end{array}$$

lp' translates a rule

$$out(a) \leftarrow in(p_1), \ldots, in(p_m), out(s_1), \ldots, out(s_n)$$

into the rules

$$\begin{array}{lll} \{rule_i\} & :- & p_1, \ldots, p_m, not\ s_1, \ldots, not\ s_n. \\ & :- & rule_i, a. \end{array}$$

Implementation, cont'd

`smodels` statement

$$\texttt{maximize}\{rule_1, \ldots, rule_k\}.$$

(k is the number of rules in SR)

allows to compute one (not all) (HR, SR)-preferred justified revision, which has max size.

Weighted rules

Each $r \in SR$ is assigned a weight , $w(r)$ (its importance).

Definition 2 *R is called a rule-weighted (HR, SR)-justified revision of I if the following two conditions are satisfied:*

1. *there exists a set of rules $S \subseteq SR$ such that R is a $(HR \cup S)$-justified revision of I, and*
2. *for any set of rules $S' \subseteq SR$, if R' is a $(HR \cup S')$-justified revision of I, then the sum of weights of rules in S' is less than or equal than the sum of weights of rules in S.*

Implementation

Same translation of soft rules into **`smodels`** program, but different **`maximize`** statement:

$$\texttt{maximize}[rule_1 = w(1), rule_2 = w(2), \ldots, rule_k = w(k)].$$

Weighted atoms.

Each $a \in U$ is assigned a weight $w(a)$
(the more the weight the less we want to change its status)

Definition 3 *R is called an atom-weighted (HR, SR)-justified revision of I if the following two conditions are satisfied:*

1. *there exists a set of rules $S \subseteq SR$ such that R is a $(HR \cup S)$-justified revision of I, and*
2. *for any set of rules $S' \subseteq SR$, if Q is a $(HR \cup S')$-justified revision of I, then the sum of weights of atoms in $I \div Q$ is greater than or equal to the sum of weights of atoms in $I \div R$.*

Implementation

Same translation of soft rules into `smodels` program, but different `maximize` statement:

$$\texttt{minimize}[a_1 = w(a_1), a_2 = w(a_2), \ldots, a_n = w(a_n)]$$

where $a_1, \ldots, a_n$ are all the atoms in U.

Minimal size difference

Definition 4 *R is called a minimal size difference P-justified revision of I if the following two conditions are satisfied:*

1. *R is a P-justified revision of I, and*
2. *for any P-justified revision R', the number of atoms in $R \div I$ is less than or equal to the number of atoms in $R' \div I$.*

Implementation

Use minimize statement:

$$\texttt{minimize}\{a_1, a_2, \ldots, a_n\}$$

where $a_1, \ldots, a_n$ are all the atoms in U.