Dependency-Directed Reconsideration

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Introduction and Background

If a knowledge representation and reasoning (KRR) system gains new information that, in hindsight, might have altered the outcome of an earlier belief change decision, the earlier decision should be re-examined. We call this operation reconsideration (Johnson & Shapiro, 2004), and the result is an optimal belief base regardless of the order of previous belief change operations. This is similar to how discussion in a jury room can help jurors to optimize their interpretation of the evidence in a trial, regardless of the order in which that evidence was presented.

To simplify our example, we assume a global decision function is used in the belief change operations, and it will favor retaining the most preferred beliefs as determined by a linear preference ordering ($\succeq$). Any base can be represented as a sequence of beliefs in order of descending preference: $B = p_1, p_2, \ldots, p_n$, where $p_i$ is preferred over $p_{i+1}$ ($p_i \geq p_{i+1}$).

Reconsideration requires maintaining a set of all beliefs that have ever been in the belief base at any time (effectively, the union of all past and current bases), $B^{\cup\!}$. The base produced by reconsideration is defined as $B^{\cup!}$ where ! is a consolidation operation (which eliminates any and all inconsistencies) (Hansson, 1999).

A base, $B = p_1, p_2, \ldots, p_n$, is optimal if it has the most credible beliefs possible without raising an inconsistency: i.e. it is consistent and there is no $B' = q_1, q_2, \ldots, q_n$ s.t. $B' \subseteq B^{\cup!}$, $B'$ is consistent, and either $B \subseteq B'$ or $\exists q_i$ s.t. $q_i \geq p_i$ and $p_1, p_2, \ldots, p_{i-1} = q_1, q_2, \ldots, q_{i-1}$.

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Figure 1: A graph showing the elements of $B^{\cup!}$ (circles/ovals) of a KS connected to their minimally inconsistent sets (rectangles), where $B^{\cup!] = \neg p, p, p \rightarrow q, p \rightarrow r, m \rightarrow r, s \rightarrow t, w \rightarrow v, w \rightarrow k, p \rightarrow v, z \rightarrow v, n, w, s, m, z, s \rightarrow v, s, m, z, \neg k$.

Consider the base beliefs in Figure 1 prior to the addition of $\neg p$. The optimal base would be $B1 = \{p, p \rightarrow q, p \rightarrow r, m \rightarrow r, s \rightarrow t, w \rightarrow v, w \rightarrow k, p \rightarrow v, z \rightarrow v, n, w, s, m, z\}$, with $\neg q, \neg r, \neg v, \neg t,$ and $\neg k$ removed. Adding $\neg p$ to $B1$ now forces the retraction of $p$. MOST SYSTEMS STOP HERE.

A literal implementation of reconsideration would examine all removed beliefs. Dependency-Directed Reconsideration (DDR), however, only reconsiders removed beliefs whose inconsistent sets have had changes in the belief status of their elements. It reconsiders these beliefs in decending order of preference, updating the base as it goes and maintaining a global priority queue of beliefs yet to be reconsidered. A removed belief can return as long as any inconsistency it raises is resolved through the removal of a less preferred belief.

As with a literal implementation of reconsideration, DDR first produces the following changes: (1) $\neg q$ returns to the base, and (2) $\neg r$ returns to the base with the simultaneous removal of $m$, because $\neg r \succ m$ (consistency maintenance). However, once DDR determines that $\neg v$ cannot return to the base (due to its being the culprit for the inconsistent set $\{w \rightarrow v, w, \neg v\}$), it would prune off the examination of the inconsistent sets containing $\neg k$ and $z$. The inconsistent set containing $s$ would also be ignored by DDR — it is not connected to $p$ in any way. This latter case is representative of the possibly thousands of unrelated inconsistent sets for a typical belief base which would be checked during a literal $B^{\cup!]$ operation of reconsideration, but are ignored by DDR.

DDR is an anytime algorithm: if starting with a consistent base, a consistent base is always available, and the optimality of that base improves with increased execution time. Additionally, an interrupted DDR can be continued at a later time as long as the priority queue has been maintained. If run to completion, the base will be optimal (as with reconsideration) — thus, the KRR system can make the most reliable inferences, and belief change operation order will have no effect.

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References
