Title
Dependency-Directed Reconsideration

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 26(26)

ISSN
1069-7977

Authors
Johnson, Frances L.
Shapiro, Stuart C.

Publication Date
2004

Peer reviewed

Dependency-Directed Reconsideration

Frances L. Johnson (flj@cse.buffalo.edu)
Department of Computer Science and Engineering; Center for Cognitive Science
University at Buffalo, The State University of New York, 201 Bell Hall, Buffalo, NY 14260-2000, USA

Stuart C. Shapiro (shapiro@cse.buffalo.edu)
Department of Computer Science and Engineering; Center for Cognitive Science
University at Buffalo, The State University of New York, 201 Bell Hall, Buffalo, NY 14260-2000, USA

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 decending preference: $B = p_1, p_2, \ldots, p_n$, where p_i is preferred over p_{i+1} $(p_i \succeq p_{i+1})$.

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 $B' = q_1, q_2, \ldots, q_m$ s.t. $B' \subseteq B^{\cup}$, B' is consistent, and either $B \subset B'$ or $\exists q_i$ s.t $q_i \succeq p_i$ and $p_1, p_2, \ldots, p_{i-1} = q_1, q_2, \ldots, q_{i-1}$.

Dependency-Directed Reconsideration

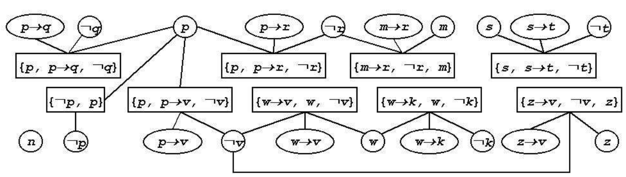

Figure 1: A graph showing the elements of $B^{\cup}$ (circles/ovals) of a KS connected to their minimally inconsistent sets (rectangles), where $B^{\cup} = \neg p, p, p \rightarrow q, p \rightarrow r, m \rightarrow r, s \rightarrow t, w \rightarrow v, w \rightarrow k, p \rightarrow v, z \rightarrow v,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

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 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.

Acknowledgments

This work was supported in part by the US Army Communications and Electronics Command (CECOM), Ft. Monmouth, NJ through Contract #DAAB-07-01-D-G001 with Booze·Allen & Hamilton. The authors appreciate the insights and feedback of the SNePS Research Group.

References

Hansson, S. O. (1999). *A Textbook of Belief Dynamics*, vol 11 of *Applied Logic*. Kluwer, Dordrecht, The Netherlands.

Johnson, F. L. & Shapiro, S. C. (2004). Knowledge state reconsideration: Hindsight belief revision. To appear in *Proceedings of AAAI-2004*, Menlo Park, CA. AAAI Press.