On Stein's paper: Resolving ambiguity in nonmonotonic inheritance hierarchies

Geneviève Simonet
L.I.R.M.M. 161,rue Ada
34392 Montpellier cedex 5 - France
email : simonet@lirmm.fr

Roland Ducournau
Sema Group
16, rue Barbès
92126 Montrouge - France
email: ducour@sema-taa.fr

Correspondence address:
Geneviève Simonet
L.I.R.M.M. 161,rue Ada
34392 Montpellier cedex 5 - France
email : simonet@lirmm.fr
Tel: (33) 67 41 85 78
Fax: (33) 67 41 85 00

Abbreviated title:
On Stein's paper: Resolving ambiguity ...

Abstract

Stein presents a theory of multiple defeasible inheritance in [15] which is different from Touretzky et al.'s [17, 6, 5, 16]. We show here that her way of defining an extension with respect to a focus node and as a subgraph of the inheritance graph, is very attractive and compatible with Touretzky et al.'s theoretic framework, but that her definition of admissibility is not intuitively satisfactory. However, her polynomial algorithm computing the ideally skeptical conclusion set in her theory according to this definition of admissibility provides an interesting heuristic to compute a *really* skeptical conclusion set, i.e. a subset of the ideally skeptical one, in Touretzky et al.'s theory, in which ideal skepticism is NP-hard.

1 Introduction

Stein presents a theory of multiple defeasible inheritance in [15] including a polynomial algorithm to compute the ideally skeptical conclusion set, i.e. the intersection of the conclusion sets of all the "preferred possible world-states" of an inheritance graph Γ in that theory. This remarkable result is referred to by Horty [5] and Thomason [16], with the mention in [5] that her theory is slightly different from his (i.e. that of Touretzky, Horty and Thomason), and without any mention of a difference in [16]. Stein's theory is more than slightly different from Touretzky et al.'s. We explain here why her treatment of specificity is not intuitively satisfactory, as the admissibility of a link only depends on the graph Γ and the focus node a and not on the credulous extension itself as it does in Touretzky et al.'s theory (section 2). We then show that her way of defining an extension, with respect to a focus node instead of globally, and as a subgraph instead of a path set of the inheritance graph Γ, is very attractive, compatible with Touretzky et al.'s theoretic framework, but simpler (section 3). Her polynomial algorithm computing the ideally skeptical conclusion set in her theory, though relying on an incorrect definition of admissibility, comes out as a useful one. It may not be used to compute the ideally skeptical conclusion set in Touretzky et al.'s theory, as ideal skepticism in their theory is NP-hard [9, 12], but it provides an interesting heuristic to compute a *really* skeptical conclusion set, i.e. a subset of the ideally skeptical one, in Touretzky et al.'s theory (section 4).

2 Flaw in Stein's definition of admissibility

In [15], Stein defines the notion of admissibility of a link with respect to a focus node a in an inheritance graph Γ according to a given specificity relation (on-path admissibility p. 266 and off-path p. 291). Informally, a link of Γ is admissible w.r.t. a according to a given specificity relation iff it is to be taken into account in deciding whether a inherits from some other node x of Γ, i.e. iff it is not dominated (or preempted) by a contradictory argument w.r.t. a according to the specificity relation. She then defines the "possible world-states" and the "preferred possible world-states" (according to a given specificity relation) in Γ w.r.t. a as follows:

General definitions

An inheritance graph is a directed graph $\Gamma = (V_\Gamma, E_\Gamma)$, each link of Γ having a *polarity*, i.e. being either *positive* or *negative*.

- A *path* in Γ is a nonempty sequence of consecutive links of Γ that either are all positive (*positive path*) or are all positive but the last one (*negative path*).
- Two paths in Γ are *contradictory* iff they have the same start and end nodes and opposite polarity.
- A *generalized path* in Γ is a nonempty sequence of consecutive links of Γ that are indifferently positive or negative.
- Γ is *acyclic* iff there is no generalized path in Γ starting and ending in the same node.

In the literature, an inheritance graph is often defined as an *acyclic* directed graph containing positive and negative links (in particular by Stein).

Stein's definitions

Let Γ' be a sugraph and a a node of Γ.

- Γ' is *a-connected* iff every node of Γ' distinct from a and every link of Γ' is in a path in Γ' starting from a (p. 265).
- Γ' is *unambiguous* w.r.t. a iff Γ' contains no contradictory paths starting from a (p. 265).
- A *credulous extension* (or *possible world-state)* w.r.t. a of Γ is a maximal unambiguous w.r.t. a a-connected subgraph of Γ (p. 270).
- A credulous extension w.r.t. a X_a^Γ of Γ is *preferred* to another one Y_a^Γ according to the specificity relation iff Y_a^Γ contains an inadmissible link u that X_a^Γ does not contain, X_a^Γ and Y_a^Γ agreeing on all links whose end node topologically precedes that of u (p. 273 and 291).
- The *preferred possible world-states* in Γ w.r.t. a are those credulous extensions of Γ w.r.t. a that are minimal for the relation of preference (p. 273 and 291).

A simpler (but equivalent) definition of the preferred possible world-states of Γ is those credulous extensions of Γ that contain no inadmissible link w.r.t. a. In Touretzky et al.'s theory, the "possible world-states" in Γ are the credulous extensions of Γ, where the definition of a credulous extension includes the specificity relation in the condition of preemption. In both theories, preemption is defined with respect to the graph Γ and the specificity relation. Touretzky et al. add respect to a credulous extension of Γ whilst Stein adds respect to a focus node of Γ. Stein's presentation has the advantage of making

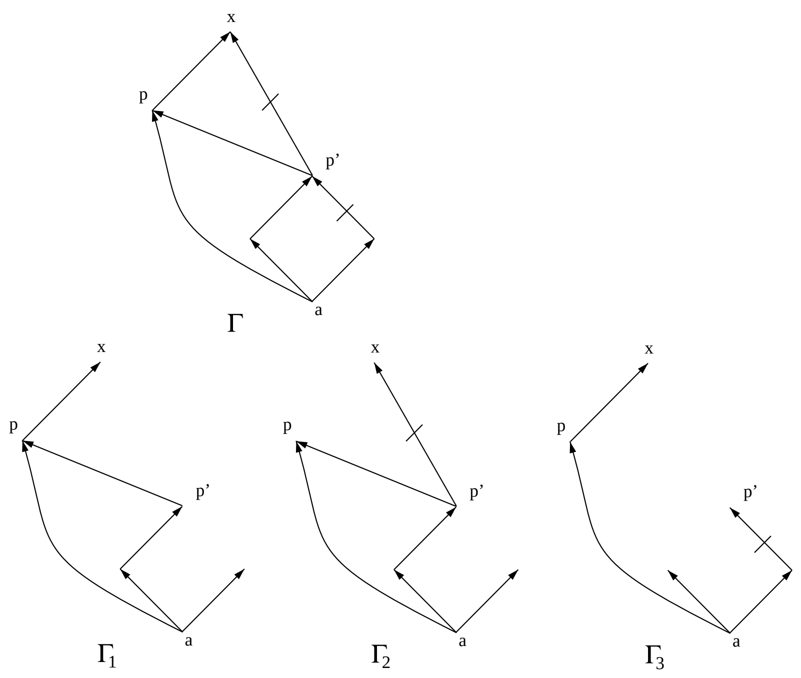

Figure 1: Admissibility of link $p \rightarrow x$ depends on the credulous extension.

ideal skepticism polynomial instead of NP-hard (see section 4), provided that Corollary 4.1. is true (see comment below). But, intuitively and as explained in more detail by Ducournau et al. in [2, 1], the admissibility of a link depends on the credulous extension considered, and not only on the focus node a, the graph Γ and the specificity relation. For instance, in figure 1, whatever preemption we take (on-path or off-path, defined in [5, 11]) as our specificity relation, link $p \rightarrow x$ should be inadmissible in any credulous extension of Γ w.r.t. a containing the positive path α from a through p' to p, as the negative path from a to x is then a preemptor of any positive one from a to x, but admissible in any credulous extension of Γ w.r.t. a not containing the path α. According to Stein's theory, link $p \rightarrow x$ is admissible in Γ w.r.t. a according to both on-path and off-path specificity relations, so that everyone of the three credulous extensions Γ_1, Γ_2 et Γ_3 is a preferred one. However, link $p \rightarrow x$ should be inadmissible in Γ_1, as Γ_1 contains the path α, so that Γ_1 should not be preferred. Touretzky et al.'s theory gives the (intuitively) right answer: Γ has two credulous extensions Φ_2 and Φ_3 (defined as path sets in Γ) such that the set of paths of Φ_2 (resp. Φ_3) from a is exactly the set of paths in Γ_2 (resp. Γ_3) from a.

Stein claims that the preferred credulous extensions of Γ w.r.t. a are exactly the credulous extensions of Σ_a^Γ w.r.t. a, where Σ_a^Γ is the specificity extension of Γ w.r.t. a, i.e. the subgraph of Γ whose links are the admissible links of Γ w.r.t. a (Corollary 4.1. p. 278). In fact they are not. In particular, there may be no preferred credulous extensions of Γ, whereas Σ_a^Γ has at least one credulous extension. For instance, in figure 2, none of the credulous extensions Γ_1 and Γ_2 of Γ w.r.t. a is preferred, as each one is preferred to the other, but Σ_a^Γ has two credulous extensions Σ_1 and Σ_2 distinct from Γ_1 and Γ_2. Although the definitions can be fixed to make Corollary 4.1 true, the more important

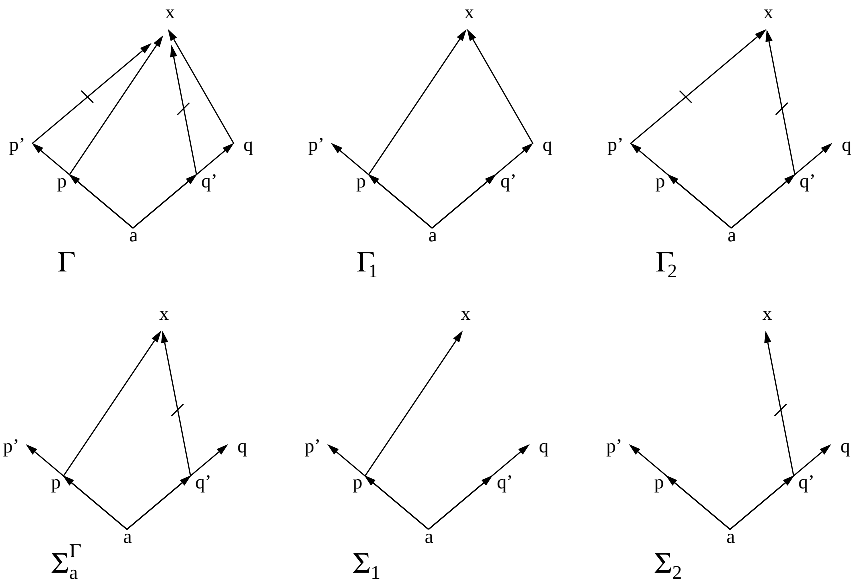

Figure 2: The preferred credulous extensions of Γ w.r.t. a are not the credulous extensions of Σ_a^Γ w.r.t. a.

issue is that admissibility cannot be defined solely in terms of Γ and a; admissibility must take the extension into account. We shall see in sections 3 and 4 that despite that flaw in the definition of admissibility, Stein's theory presents very positive features.

3 Subgraph-based versus path-based theories

Stein's theory is *subgraph-based*, which means that an extension is defined with respect to a focus node a and as a subgraph (or the set of paths starting from a of a subgraph) of Γ, whereas Touretzky et al.'s is *path-based*, which means that an extension is defined as a path set in Γ. Subgraph-based theories are special cases of path-based ones, and they present some conceptual and computational advantages over the latter : first it is simpler to consider an extension with respect to a focus node than a global one, and second it is much easier to handle a subgraph than a set of paths in Γ, as these paths may be in exponential number. Moreover, subgraph-based theories are compatible with Touretzky et al.'s: actually any variant of Touretzky et al.'s defeasible or mixed inheritance theory using construction by forward chaining and off-path or with reinstatement preemption is subgraph-based. This is not the case for theories with on-path preemption without reinstatement (the notion of reinstatement has been introduced in [18] and more formally defined in [13]). This result is proved in [13] and largely discussed in [2, 1] (only for the case of defeasible inheritance, but easily extendable to mixed). For instance, the following definition **Def 1** of a credulous extension of Γ w.r.t. a presented in [2, 1] is equivalent to that in Touretzky et al.'s defeasible theory using construction by forward chaining and off-path preemption with reinstatement defined in [13], provided that Γ is acyclic and contains no contradictory links. In the same conditions, the following definition **Def 2**, presented in [2, 1] too, is equivalent to that in Touretzky et al.'s defeasible theory using construction by forward chaining and off-path preemption without reinstatement defined in [4, 5, 11, 12, 16, 13].

Path-based definition of a credulous extension

In the literature, preemption is generally defined without reinstatement in credulous theory and with reinstatement in skeptical one. As far as we know, credulous theory using preemption with reinstatement is only defined in [13]; it may be seen as the credulous version of the skeptical theory using off-path preemption with reinstatement defined in [6]. The following definition of an extension in credulous path-based theory using off-path preemption with (resp. without) reinstatement is exactly that of [13] (resp. [4, 5, 11, 12, 16, 13]). These credulous extensions are defined through a fixedpoint equation as follows:

Let α be a path and Φ a path set in Γ.

We define the inheritability of α in (Γ, Φ):

If α is a link then α is *inheritable* in (Γ, Φ).

If α is a compound path formed by concatenation of the positive path α_1 from a to z and the link u from z to y then:

- α is *constructible* (by forward chaining) in (Γ, Φ) iff α_1 is in Φ.
- α is *contradicted* in (Γ, Φ) iff there is a path α' in Φ such that α and α' are contradictory.
- α is *off-path preempted* in (Γ, Φ) iff there is a positive path α'_1 in Φ from a to z and a node z' of α'_1 distinct from z such that Γ contains a link from z' to y of the opposite polarity to that of u.
- α is *inheritable* in (Γ, Φ) iff:

  1) α is constructible in (Γ, Φ)

  2) α is not contradicted in (Γ, Φ)

  3) There is a path in Γ from a to y of the same polarity as α that is either a link or a compound path constructible and not preempted in (Γ, Φ) (resp. α is not preempted in (Γ, Φ))

Φ is a (path-based) *credulous extension* of Γ iff Φ is equal to the set of paths in Γ inheritable in (Γ, Φ).

Subgraph-based definition of a credulous extension

We now turn to the equivalent definition **Def 1** (resp. **Def 2**) in terms of subgraph. Let a be the focus node and Γ' a subgraph of Γ.

- Γ' is *a-consistent* iff Γ' is a-connected and unambiguous w.r.t. a.

Let Γ' be an a-connected subgraph of Γ and u a link of Γ' from z to y.

- u is *forbidden* (or *inadmissible*) *in* Γ' iff there is a node z' in Γ' such that there is a positive path in Γ' from z' to z and a link in Γ from z' to y of the opposite polarity to that of u.

An equivalent definition derived from that of off-path preemption is: let α be a path in Γ' starting from a whose last link is u and Φ the set of paths in Γ' starting from a.

- u is *forbidden in* Γ' iff α is compound and off-path preempted in (Γ, Φ).

Here, the admissibility of a link clearly depends on the extension Γ' (or Φ).
Stein's credulous extensions of Γ w.r.t. a are defined as the maximal a-consistent subgraphs of Γ, so that following **Def 1** is very close to her definition of the preferred credulous extensions in Γ.

Def 1
A (subgraph-based) credulous extension of Γ w.r.t. a is a maximal a-consistent subgraph Γ' of Γ such that for any node y in Γ' distinct from a, there is a link in Γ' ending in y that is not forbidden in Γ'.

Let $\Gamma' = (V_{\Gamma'}, E_{\Gamma'})$ be a subgraph of Γ.

- Γ' is *a-free* iff Γ' is a-consistent and no link of Γ' is forbidden in Γ'.
- For any node y in Γ, V_Γ^y denotes the set of nodes z in Γ such that z is y or there is a generalized path in Γ from z to y, Γ^y the subgraph of Γ induced by V_Γ^y, and Γ'^y the subgraph of Γ' induced by $V_{\Gamma'} \cap V_\Gamma^y$.

Def 2
A (subgraph-based) credulous extension of Γ w.r.t. a is a subgraph Γ' of Γ such that for any node y in Γ, Γ'^y is a maximal a-free subgraph of Γ^y.

For instance, in figure 1, the credulous extensions of Γ w.r.t. a are Γ_2 and Γ_3 according to both definitions **Def 1** and **Def 2** (link $p \rightarrow x$ is forbidden in Γ_1) and in figure 2, the credulous extensions of Γ w.r.t. a are Γ_1 and Γ_2 according to definition **Def 1** and Σ_1 and Σ_2 according to definition **Def 2** (link $q \rightarrow x$ is forbidden in Γ_1 and link $p' \rightarrow x$ is forbidden in Γ_2).

Proposition 1:
Let Γ be an acyclic inheritance graph containing no contradictory links and Φ a set of paths in Γ. Φ is a (path-based) credulous extension of Γ using off-path preemption with (resp. without) reinstatement iff for any node a of Γ, there is a (subgraph-based) credulous extension Γ' of Γ w.r.t. a according to **Def1** (resp. **Def2**) such that the set of paths of Φ starting from a is exactly the set of paths in Γ' starting from a.

Proof: Let us prove the equivalence in the case of off-path preemption with reinstatement (the case of off-path preemption without reinstatement is proved in a similar way). Let Φ be a set of paths in Γ.

1) We suppose that Φ is a (path-based) credulous extension of Γ. Let a be a node in Γ, and Γ' the subgraph of Γ whose links are the last links of the paths of Φ starting from a. It has been proved in [13] that the set of paths of Φ starting from a is exactly the set of paths in Γ' starting from a. Let us show that Γ' is a (subgraph-based) credulous extension of Γ w.r.t. a.

- Γ' is an a-consistent subgraph of Γ such that for any node y in Γ' distinct from a, there is a link in Γ' ending in y that is not forbidden in Γ'.

- Suppose Γ' is not a maximal a-consistent subgraph of Γ. Let Γ'' be an a-consistent subgraph of Γ strictly containing Γ'. Let u be a link of $E_{\Gamma''} - E_{\Gamma'}$, α a path in Γ'' whose last link is u and α_1 the shortest prefix of α that is not in Φ. α_1 is inheritable in (Γ, Φ), but not in Φ. Contradiction.

2) We suppose that for any node a of Γ, there is a (subgraph-based) credulous extension of Γ w.r.t. a, noted Γ'_a, such that the set of paths of Φ starting from a is exactly the set of paths in Γ'_a starting from a. Let us show that Φ is a (path-based) credulous extension of Γ. Let α be a path in Γ and a the start node of α.

- if α is in Φ then α is inheritable in (Γ, Φ)

- We suppose that α is inheritable in (Γ, Φ). Let us show that α is in Φ. Let u be the last link of α. $\Gamma'_a \cup \{u\}$ is an a-consistent subgraph of Γ containing Γ'_a, then $\Gamma'_a \cup \{u\}$ is equal to Γ'_a and α is in Φ. $\Box$

Proposition 1 remains true in case of contradictory links in Γ through a slight modification of definitions **Def 1** and **Def 2**.

A (subgraph-based) credulous extension w.r.t. a is a maximal a-consistent subgraph of Γ according to **Def 1**, but not always according to **Def 2**. For instance(in figure 2, the credulous extensions Σ_1 and Σ_2 of Γ w.r.t. a according to **Def 2** are not maximal a-consistent subgraphs of Γ, as they are proper subgraphs of a-consistent Γ_1 and Γ_2 respectively. In fact, maximality implies reinstatement.

Def 2 may seem somewhat complicated, certainly the definition of a credulous extension of Γ w.r.t. a as a maximal a-free subgraph of Γ would seem more natural. Actually, any credulous extension w.r.t. a according to **Def 2** is a maximal a-free subgraph of Γ, but some maximal a-free subgraphs of Γ have nothing to do with credulous extensions of Γ w.r.t. a. For instance, in figure 3, Γ' and Γ'' are the maximal a-free subgraphs of Γ, but it is intuitively clear that Γ' is the only credulous extension of Γ w.r.t. a. In fact, Γ''^p is not a maximal a-free subgraph of Γ^p.

4 A really skeptical theory

Polynomiality of ideal skepticism (i.e. computing the intersection of the conclusion sets of the "preferred possible world-states" in Γ) in Stein's theory comes from that of computing the intersection of the conclusion sets of the credulous extensions (with no notion of

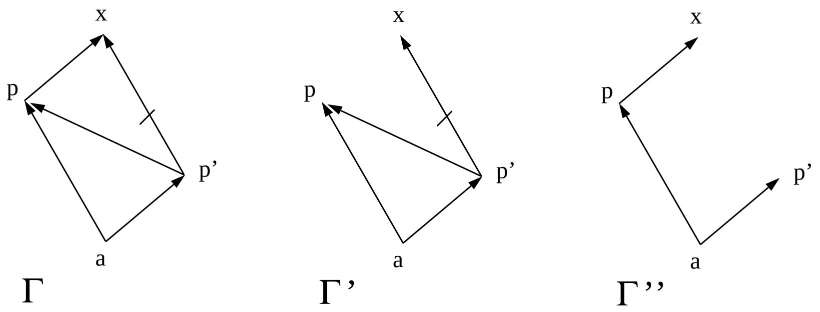

Figure 3: Credulous extension w.r.t.a and maximal a-frre subgraph of Γ

preemption) of Σ_a^Γ. However, as mentioned in section 2, the identity between the set of preferred credulous extensions of Γ and the set of credulous extensions of Σ_a^Γ stated in Corollary 4.1. is false. In this section, we "forget" the preferred credulous extensions and suppose that Stein's "possible world-states-taking-specificity-into-account" are defined as the credulous extensions of Σ_a^Γ in the first place.

In fact, computing the intersection of the conclusion sets of the credulous extensions of a graph is polynomial if the definition of a credulous extension includes no notion of preemption and NP-hard otherwise. The first result was proved by Kautz et al. [7] and the second by K. Schlechta [9, 10] from a reduction from NP-complete SAT problem and Selman et al. [12] from a reduction from NP-complete PWFP problem, both reductions being available in all variants of Touretzky et al.'s nonmonotonic inheritance theory, namely defeasible or mixed inheritance using construction by forward or double chaining and on-path or off-path preemption with or without reinstatement (except for Selman's reduction and on-path preemption with reinstatement, which is not a natural variant of preemption anyway). But, according to our discussion in section 2, we think that including preemption in the definition of a credulous extension, and therefore NP-hardness of ideal skepticism, is unavoidable. In case Γ has not a great number of credulous extensions, ideal skepticism is tractable in Γ, as we may explicitly compute all its credulous extensions. Otherwise (the credulous extensions may be in exponential number [17]) we are led to look for a *really* skeptical conclusion set of Γ, defined as a subset of the ideally skeptical one (i.e. guaranteed to only contain conclusions that are concluded in every credulous extension of Γ), polynomially computable and as large as possible (i.e. as close as possible to the ideally skeptical one). An example of such a theory is given in [13] in the case of off-path preemption without reinstatement. We can show the following results:

Proposition 2:
The ideally skeptical conclusion set of Γ in Stein's theory using on-path or off-path preemption is a really skeptical one in Touretzky et al.'s theory using off-path preemption with reinstatement (equivalent to **Def 1** above).
The ideally skeptical conclusion set of Γ in Stein's theory using a restricted definition of on-path preemption (with no notion of redundancy) is a really skeptical one in Touretzky et al.'s theory using off-path preemption without reinstatement (equivalent to **Def 2**

above) and incomparable for inclusion with the really skeptical one proposed in [13].

A generalization of these results using a refined version of Stein's on-path and off-path preemption is presented and proved in [14].

These really skeptical theories may be still improved, compared to other propositions and eventually combined with them, as the union of several incomparable-for-inclusion really skeptical conclusion sets will provide a better approximation of the ideally skeptical one than each conclusion set alone.

The *strictly skeptical* conclusion set of Γ is defined as the conclusion set of the intersection of the credulous extensions of Γ [2, 1], while the ideally skeptical one is the intersection of the conclusion sets of the credulous extensions of Γ. The strictly skeptical conclusion set is a really skeptical one different from the ideally skeptical one: it does not contain the conclusions of all the credulous extensions of Γ supported by different paths in these extensions, called "floating conclusions" in [8]. Its computation is a NP-hard problem [2, 1]. Any really skeptical conclusion set defined as the conclusion set of a path set Φ whose paths are constructible in (Γ, Φ) or as the conclusion set of a subgraph with respect to a focus node a is included in the strictly skeptical one [15] (Theorem 6 p. 288) et [8, 13] (it is the case of the really skeptical one proposed in [13]). But the ideally skeptical conclusion set of Γ in Stein's theory is not always included in the strictly skeptical one. In fact it is identic to the ideally skeptical one in Touretzky et al.'s theory in every graph containing no case of preemption: for instance the typical example of floating conclusion presented in [15] figure 12 p. 288.

5 Conclusion

Stein's theory is presented as a subgraph-based one, which is a very interesting alternative to traditional path-based ones and quite compatible with them. Moreover, her idea of considering the credulous (without preemption) extensions of the "specificity extension" of Γ, where the specificity relation may be defined in many ways, comes out as a source of tractable really skeptical approximations of the ideally skeptical conclusion set in Touretzky et al.'s theory.

[3]

References

[1] R. Ducournau, M. Habib, and G. Simonet. Méta-héritage et héritage non-transitif. *Revue de l'Intelligence Artificielle*, 1993. (submitted to R.I.A.).

[2] R. Ducournau, M. Habib, and G. Simonet. Meta-inheritance and nontransitive inheritance. Research Report 93-022, L.I.R.M.M., 1993.

[3] E. Gregoire. Skeptical inheritance can be more expressive. *ECAI-90*, pages 326–332, 1990.

[4] J.F. Horty. A credulous theory of mixed inheritance. In M.Lenzerini, D.Nardi, and M.Simi, editors, *Inheritance Hierarchies in Knowledge Representation and Programming Langages*, chapter 2. John Wiley, 1991.

[5] J.F. Horty. Some direct theories of nonmonotonic inheritance. In D.Gabbay and C.Hogger, editors, *Handbook of Logic in Artificial Intelligence and Logic Programming*. Oxford University Press, 1991.

[6] J.F. Horty, R.H. Thomason, and D.S. Touretzky. A skeptical theory of inheritance in nonmonotonic semantic networks. *Artificial Intelligence*, 42:311–348, 1990.

[7] H.A. Kautz and B. Selman. Hard problems for simple default logics. In *Proceedings of the Firth International Conference on Principles of Knowledge Representation and Reasoning*, pages 189–197, Toronto, Ont., Canada, 1989. Morgan Kaufmann.

[8] D. Makinson and K. Schlechta. Floating conclusions and zombie paths: two deep difficulties in the "directly skeptical" approach to defeasible inheritance nets. *Artificial Intelligence*, 48:199–209, 1991.

[9] K. Schlechta. Defeasible inheritance: coherence properties and semantics. In M. Morreau, editor, *Proceedings of Tübingen Workshop on Semantic Networks and Nonmonotonic Reasoning*, pages 98–127, D-7400, Tübingen, Germany, 1989. SNS Report 89-48, Seminar fur Naturlichsprachliche Systeme.

[10] K. Schlechta. Results on non-monotonic logics. Technical Report IWBS Report 204, IBM Stuttgart, January 1992. POB 800880, 7000 Stuttgart 80, Germany.

[11] B. Selman and H.J. Levesque. The tractability of path-baed inheritance. In M.Lenzerini, D.Nardi, and M.Simi, editors, *Inheritance Hierarchies in Knowledge Representation and Programming Langages*, chapter 6. John Wiley, 1991.

[12] B. Selman and H.J. Levesque. The complexity of path-baed defeasible inheritance. *Artificial Intelligence*, 62:303–339, 1993.

[13] G. Simonet. Rs theory: a really skeptical theory of inheritance with exceptions. In C. Rich B. Nebel and W. Swartout, editors, *Proceedings of the Third International Conference on Principles of Knowledge Representation and Reasoning (KR92)*, pages 615–626, Boston, MA, USA, 1992. Morgan Kaufmann.

[14] G. Simonet. Héritage non monotone à base de chemins et de graphes partiels. Thesis, University of Montpellier II France, 1994.

[15] L.A. Stein. Resolving ambiguity in nonmonotonic inheritance hierarchies. *Artificial Intelligence*, 55:259–310, 1992.

[16] R.H. Thomason. Netl and subsequent path-based inheritance theories. *Computers and Mathematics with Applications*, 23(2-5):179–204, 1992. Pergamon Press plc, printed in Great Britain.

[17] D.S. Touretzky. *The Mathematics of Inheritance Systems.* Pitman, London, 1986.

[18] D.S. Touretzky, R.H. Thomason, and J.F. Horty. A skeptic's menagerie: Conflictors, preemptors, reinstaters and zombies in nonmonotonic inheritance. *IJCAI-91*, 1:478–483, 1991.