An Epistemic Architecture for Ampliative Inference

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Abstract

Nontrivial reasoning from contradictory premises is being acknowledged as one of the most important features in intelligent systems. Expert systems, planners and schedulers, and diagnosers, are almost always faced to potentially fallacious information, errors, uncertainty, and difference of opinions. In these cases, we expect that the reasoning systems will not collapse. Instead, the rational expected behavior is to isolate the source of contradiction.

Several systems for reasoning from contradictory premises have been advanced, usually within a context of strict, monotonic knowledge. In this work we investigate how defeasible knowledge can be also handled in these systems. The key idea is to represent pieces of defeasible knowledge ordered within an epistemic importance relation. A semantic characterization is provided, and a sound and complete procedure to compute conclusions is also given. Then, we show how nonmonotonic reasoning and other patterns of ampliative inference like abduction and induction can be adequately recast within the general pattern of reasoning from contradiction. We discuss some applications, in particular, a brief formalization of scientific research programmes.

1 Introduction

Management of uncertain or incomplete information may lead to contradictory statements, originated in erroneous knowledge or evidence, or contextually inadequate defeasible rules. Thus, nontrivial reasoning in the presence of inconsistency is a recurrent need in intelligent systems. In this cases we do not expect that the reasoning system collapse, since it would imply that a single wrong data may corrupt an entire knowledge base. A rational behavior, for example, is to isolate the contradictory knowledge from the rest of the knowledge base by means of a paraconsistent logic [13, 14, 23]. Another approach is to reject one or more knowledge pieces by means of an extralogical consideration (f.e., plausibility), so that consistency is reinstated [20, 21]. However, this kind of reasoning has not been considered as a solution to ampliative inference patterns, like nonmonotonic reasoning, induction or abduction.

In this work we propose an epistemic architecture that allows a full representation of all these ampliative inference patterns in an integrated framework. We start from considering an *epistemic structure* that incorporates knowledge of different *kinds*: a *context* consisting on a set of universally valid sentences and a set of evidence, a set of defeasible rules or conditionals, and a set of tentative information (reports, measurements, and conjectures). Within the structure, an *epistemic importance* or plausibility relation assigns priorities to every knowledge piece. Then, conclusions inferred by means of an ampliative inference rule can be represented within the epistemic structure with its corresponding epistemic importance. The set of accepted conclusions may be found by means of an exductive inference process. Every maximally plausible consistent subset of the epistemic structure, is a possible interpretation of the incomplete knowledge of the context that the sistem has. Then, the semantics of the system is to regard as definite the conclusions that pertain to the intersection of the maximally plausible consistent subsets. A computationally tractable proof procedure is also presented.

2 Ampliative Inference

Inference may be regarded as an epistemic support relation between a set of sentences called *antecedent* (every member of this set being a premise) and a sentence called *consequent*. An inference is *ampliative* if the informational content of the consequent exceeds the informational content of the antecedent [18]. It has been for very long exemplified how a rational reasoner needs to infer knowledge that "goes beyond" mere deduction, the most famous example being to infer that normally birds fly. Ampliative inference, however, cannot be sound, since we can find cases where the antecedent is true and the consequent not, as is inferring that a penguin flies. In this section we will introduce the most usual patterns of ampliative inference in artificial intelligence, namely nonmonotonic reasoning, plausible reasoning, induction and abduction.

2.1 Nonmonotonic Reasoning

Nonmonotonic reasoning refers to a kind of non-demonstrative reasoning that uses defeasible conditionals as premises of an ampliative inference pattern analogous to *modus ponens*. Formal styles of formalizing nonmonotonic reasoning range from material implications in a modal language [10, 11], to inference rules in the metalanguage [19], or as metalinguistic conditional operators [12], or as minimizing abnormality relations in incomplete theories [8], or as metalinguistic relation among set of literals [7]. In this work we adopt this last style of formalization, being the expression $\alpha \succ\!\!- \beta$ a representation of a *defeasible conditional* or *prima facie* implication for representing that reasons for accepting α provide reasons for tentatively accepting β, and both α and β are sets of open literals in a deductively closed first order language.

$$\frac{\begin{array}{l} a(t) \\ a(X) \succ\!\!- b(X) \end{array}}{b(t),} \tag{1}$$

that is, in words, *if $a(t)$ is a known or believed fact, and if among our accepted defeasible conditionals we have $a(X) \succ\!\!- b(X)$, then nonmonotonically infer $b(t)$.* We can also establish a defeasible entailment relation $\mid\!\sim$ extending the existing deductive entailment relation $\vdash$ in a way such that defeasible conditionals are used as material implication in the *modus ponens* inference rule.

2.2 Induction

Induction is aimed to find a general rule from a set of particular cases, instances or examples [1]. Styles of formalizing induction are less diverse, since there is agreement in that induction infers an *abstraction*, in a way such that every particular case can be regarded as an instance. The most fundamental inference pattern for induction is to search in a systematic way. A decidable inductive inference rule in a first order language with a denumerable set of variables is

$$\frac{\begin{array}{l} a(t_1), a(t_2), \cdots, a(t_n) \\ b(t_1), b(t_2), \cdots, b(t_n), \cdots, b(t_{n+m}) \end{array}}{a(X) \succ\!\!- b(X),} \tag{2}$$

that is, *if in our knowledge base, every time that we find $a(t)$, we can also find $b(t)$, then infer the defeasible conditional $a(X) \succ\!\!- b(X)$.*

2.3 Abduction

According to philosophers, abduction is a reasoning process that provides the best fit or explanation for some unexpected data, that is, it goes from observations to *explanations*. Then, an abductive inference produce sentences that, added to the theory $\mathcal{T}$, imply deductively or nonmonotonically the surprising observations. Obviously there may be many suitable explanations for a given fact, and therefore there must exist criteria for assessing the "best" explanation, like coherence or simplicity (see for example the discussion in [22] and the bibliography cited therein). Abduction is of central importance in some AI areas, as in expert systems, diagnosis, and causal reasoning [5, 15]. A suitable schema for representing an inductive inference is the following.

$$\frac{\begin{array}{l} b(t) \\ \mathcal{T} \not\mid\!\sim b(t) \\ \mathcal{T} \cup a(X) \mid\!\sim b(X) \end{array}}{a(t).} \tag{3}$$

that is, *if the surprising fact $b(t)$ is observed, being b unpredicted in our theory $\mathcal{T}$, and if $a(X)$ added to the theory would entail $b(X)$, then infer $a(t)$.*

2.4 Plausible Reasoning

Plausible reasoning is a means to extend the domain of a theory incorporating information provided by potentially fallible sources [20, 21]. Among these sources we may consider reports from other agents, measurements, observations, guesses or conjectures. Following epistemological criteria, these reports must refer to observable facts, i.e., ground literals, and a formal means to represent them is to relate the informed literals to the source of information. Then, if the information source i provides the ground literal $a(t)$, this may be represented as $< a(t) >_i$. This information is considered as a *prima facie* truth, and so an inference pattern for representing plausible reasoning is

$$\frac{< a(t) >_i}{a(t),} \tag{4}$$

that is, *if information source i provides the report that $a(t)$, then infer $a(t)$.*

3 An Epistemic Architecture

In this section we will present an epistemic architecture, established in terms of a specific reasoning model. Knowledge is represented in a first order deductively closed language. We will refer to sets of general (nonground) sentences with calligraphic uppercase (as $\mathcal{K}$), to sets of particular sentences with italicized uppercase (as E), and to sentences with italicized lowercase (as $a(X)$). The language is extended to allow the representation of tentative knowledge in the form of defeasible conditionals $a(X) \succ\!\!- b(X)$ an of plausible literals $< l >_i$. Then, the linguistic classes in which knowledge is represented are

- $\mathcal{K}$, *mathematical and logical truths* and *definitions*, which are deductively valid, represented as a set of universally closed sentences;
- $\mathcal{G}$, *defeasible knowledge* represented as a set of defeasible conditionals that arose as an abstraction of a reasonably large set of examples;
- E, *evidence*, is the set of available particular knowledge, which also is deductively valid, and is represented as a set of ground literals;
- P, *plausible information* provided by information sources, represented as plausible ground literals.

DEFINITION 1 *Given a context* $< \mathcal{K}, E >$, *(mathematical and logical knowledge and evidence), an* **Epistemic Structure** $\mathcal{E}_{\mathcal{K},E}$ *is a knowledge structure* $\mathcal{E}_{\mathcal{K},E} =< \mathcal{G}, P >$, *where* $\mathcal{G}$ *is a finite set of defeasible conditionals* $\alpha \succ\!\!- \beta$, *and* P *is a finite set of plausible literals* $< l >_i$. *Whenever context remains inambiguously denoted, we will refer to an epistemic structure simply as* $\mathcal{E}$. □

DEFINITION 2 *Given an epistemic structure* $\mathcal{E}_{\mathcal{K},E}$ *in context* $< \mathcal{K}, E >$, *a* **Plausible Theory** $\mathcal{T}$ *is a pair* $\mathcal{T} =< \mathcal{E}_{\mathcal{K},E}, \prec >$, *where* $\prec$ *is a partial order on the elements of* $\mathcal{E}$, *referred to as an* **Epistemic Preference Relation** *or more simply, plausibility. We may consider that the deductively valid knowledge of the context is an element* $\mathcal{E}_\top$ *in the plausible theory, such that* $\forall \alpha \in \mathcal{E}. \alpha \prec \mathcal{E}_\top$, *and that any other knowledge piece, without epistemic importance, is another element* $\mathcal{E}_\bot$ *of the plausible theory, such that* $\forall \beta \in \mathcal{E}. \mathcal{E}_\bot \prec \beta$. *Then, in a plausible theory* $\mathcal{T}$, *its epistemic structure* $\mathcal{E}$ *is a lattice under the epistemic importance relation* $\prec$. □

DEFINITION 3 *Given a plausible theory* $\mathcal{T}$ *and a* subtheory $T \subseteq \mathcal{T}$, *the* **Epistemic Importance** *of* T *given* $\mathcal{T}$, *denoted as* $T_\prec$, *is defined as the set of greatest lower bounds of the elements of* T *under the relation* $\prec$ *of epistemic importance:* $T_\prec = \{\alpha \in T |\ \nexists \beta \in T. \beta \prec \alpha\}$. *Given two subtheories* T_1 *y* T_2, *we will say that* T_1 *is epistemically more important than* T_2 *(denoted as* $T_2 \prec T_1$*) ifff every statement in* T_1 *is at least as important in* $\mathcal{T}$ *as every statement in* T_2, *but there exists at least one statement in* T_1 *that is strictly more important than every statement in* T_2. □

Now, given a plausible theory $\mathcal{T}$, which is the consistent subset of most epistemic importance, or in other words, the most preferred subtheory? Since our epistemic importance relation is a partial order, there can be two or more maximally plausible consistent subtheores (wrt the context), each unrelated under epistemic importance. The semantics we propose here is to consider the intersection of every such subtheories as indisputed knowledge.

DEFINITION 4 *Let $\mid\!\sim$ be an entailment relation that extends the deductive entailment relation using members of an epistemic structures as premises, in particular, members of $\mathcal{G}$ as material implications and members of P as literals. Given a plausible theory $\mathcal{T} =< \mathcal{E}, \prec >$ in context $< \mathcal{K}, E >$, and a linear extension l of $\prec$*[1], *a* **Maximally Plausible Consistent Subtheory** *(MPCS) of $\mathcal{T}$ (wrt context $< \mathcal{K}, E >$) is a subset $\mathcal{E}^l$ of the epistemic structure $\mathcal{E}$ that satisfies*

1. $\mathcal{E}^l \subseteq \mathcal{E}$,
2. $(\mathcal{E}^l \cup \mathcal{K} \cup \mathcal{P}) \not\mid\!\sim \bot$,
3. $\forall \alpha \in \mathcal{E}^l . \forall \beta \in (\mathcal{E}/\mathcal{E}^l) . \beta \prec \alpha$,
4. $\nexists \mathcal{E}' . \mathcal{E}^l \subset \mathcal{E}' \subseteq \mathcal{E} . (\mathcal{E}' \cup \mathcal{K}) \not\mid\!\sim \bot$.

Let $\mathcal{M}$ be the intersection of all MPCS of a given plausible theory, if we translate the defeasible conditionals in $\mathcal{M}$ to material implications and the plausible reports to literals, then we obtain the **Skeptical Subtheory** *$\mathcal{T}_{\not\perp}$ of $\mathcal{T}$ (wrt the context $< \mathcal{K}, E >$ and the epistemic importance relation $\prec$). The skeptical subtheory of a plausible theory is within plain first order language. The set C of conclusions of a plausible theory $\mathcal{T}$, then, is the deductive closure of the skeptical subtheory together with the context, i.e., $C = Th(\{\mathcal{K} \cup E \cup \mathcal{T}_{\not\perp}\})$.* □

A proof procedure to determine if a given sentence is among the set of conclusions of a plausible theory is the following:

DEFINITION 5 *Given a plausible theory $\mathcal{T} =< \mathcal{E}_{\mathcal{K},E}, \prec >$ and a query q such that neither $\mathcal{K} \cup E \vdash q$ nor $\mathcal{K} \cup E \vdash \neg q$. Then we define:*

(Support) *q is supported if there exists a support set $\mathcal{E}_s \subseteq \mathcal{E}$, such that $\mathcal{E}_s \cup \mathcal{K} \cup E \mid\!\sim q$.*

(Doubt) *q is doubted if there exists a doubt set $\mathcal{E}_d \subseteq \mathcal{E}$, such that $\mathcal{E}_d \cup \mathcal{K} \cup E \mid\!\sim \neg q$.*

(Accept) *q is accepted either if it is supported but not doubted, or if there exists a support set $\mathcal{E}_s$ such that the epistemic importance of $\mathcal{E}_s$ is higher than those of any doubt set $\mathcal{E}_d$, that is, $\mathcal{E}_d \prec \mathcal{E}_s$.*

□

THEOREM 1 *Given a plausible theory $\mathcal{T} =< \mathcal{E}_{\mathcal{K},E}, \prec >$, then q is accepted with support $\mathcal{E}_s$ such that $\emptyset \subset \mathcal{E}_s \subseteq \mathcal{E}$, if and only if q is in the set C of conclusions of the theory.* □

The procedure described in the definition 5, inspired in Wagner's skeptical reasoning [23], is computationally tractable, since it is based in recursive backward chaining. Then, a PROLOG implementation is straightforward.

4 Ampliative inference in the epistemic architecture

We will present in this section some examples of ampliative inference as they are represented within the epistemic architecture presented in the previous section. To simplify notation in these examples, we will adopt Geffner's notation for defeasible rules: every conditional in $\mathcal{G}$ is indexed with a number that represents it, in a way such that the conditional $\alpha \xrightarrow[i]{} \beta$ may be represented as δ_i.

[1] A linear extension of a partial order r is a linear order relation l over the same elements of r that contains r.

4.1 Nonmonotonic and plausible reasoning

In the definition 4 of consequence of a plausible theory, and in its operational counterpart of definition 5 of accepted query, there are implicit the nonmonotonic inference pattern 1, and the plausible inference pattern 4. Then, our epistemic architecture performs a plausible reasoning and a nonmonotonic reasoning based on preference among defeasible conditionals. It can be easily shown that, disregarding or ignoring a preference relation among conditionals, the set of conclusions coincides with the nonmonotonic logic of McDermott and Doyle [10] and of autoepistemic logic [11]. If we were to compute sets of conclusions from the deductive closure of every MPCS together with the context, the result would be a set of mutually incompatible sets of conclusions that are identical to multiple extensions of Reiter's default reasoning [19]. However, the preference relation breaks the duality of credulous *vs.* skeptical reasoning.

EXAMPLE 1 *Suppose in our plausible theory we have* $E = \{a, \neg(c \wedge d)\}$, $\mathcal{G} = \{a \underset{1}{\rightarrow} b, b \underset{2}{\rightarrow} c, a \underset{3}{\rightarrow} d\}$ *and* $\prec = \{\delta_1 \prec \delta_3, \delta_2 \prec \delta_3\}$. *In this case we can show from the definitions that* d *is among the conclusions of the theory, since* $\{\delta_3\}$ *gives support to* d *and is epistemically stronger than the doubt set* $\{\delta_1, \delta_2\}$. □

It is important to remark that in the example, neither b nor $\neg b$ are conclusions of the plausible theory, since the support set for b, δ_1, is not comparable to its doubt set $\{\delta_2, \delta_3\}$ (and the same goes for $\neg b$. If in $\prec$ we add $\delta_2 \prec \delta_1$, then b would also be conclusion. On the other hand, if $\delta_1 \prec \delta_2$, was added, then $\neg b$ would be conclusion. This behavior is not observed in other ranking based default reasoning systems like prioritized circumscription [9, 17]. At the same time, it is easy to show that this reasoning model avoids deadlocks and cascaded ambiguity traps that are common in inheritance networks.

EXAMPLE 2 **Cascaded Ambiguities** *(Horty et. al., 1987) [4]. Knowledge about political attitudes can be represented in the following statements:*

Republicans are not pacifists	$r \underset{1}{\rightarrow} \neg p$
Quakers are pacifists	$c \underset{2}{\rightarrow} p$
Republicans are football fans	$r \underset{3}{\rightarrow} ff$
Football fans are belicists	$ff \underset{4}{\rightarrow} b$
Pacifists are not belicists	$p \underset{5}{\rightarrow} \neg b$
Nixon is Republican	r
Nixon is Quaker	q

What can be concluded about Nixon's belicism? In particular, we have the following reasoning lines: $\{\delta_2, \delta_5\} \cup \mathcal{K} \cup E \mid\!\sim \neg b$, $\{\delta_1, \delta_5\} \cup \mathcal{K} \cup E \mid\!\sim b$, *and* $\{\delta_3, \delta_4\} \cup \mathcal{K} \cup E \mid\!\sim b$. *The accepted conclusion will depend, then, on the preference among the sets* $\{\{\delta_2, \delta_5\}, \{\delta_1, \delta_5\}, \{\delta_3, \delta_4\}\}$. □

4.2 Inductive reasoning

On producing a new defeasible conditional within our epistemic architecture, we are confronted with the problem of assigning it a suitable epistemic importance. This was already discussed in Philosophy of Science as the "problem of induction" (see [16], for example) in search of statistical criteria for the confirmation of scientific theories. These criteria were found inadequate for confirmation [6], but we claim that they can be applied to the assessment of epistemic importance. For instance, in the inductive inference schema 2, the number n of regular cases remains indeterminate.

Space considerations do not allow an adequate discussion of this issue, but we can briefly state that the number n of regular cases can be related to the epistemic importance of the inferred conditional, a higher n meaning the conditional is closer to $\mathcal{E}_{\top}$.

EXAMPLE 3 *We consider our knowledge about nourishment habits and religiousness of some of our friends, in particular, about vegetarianism v and Buddhism b:*
$E = \{b(john), b(ana), v(john), v(ana), v(pat)\}$.
In addition, we accept that Buddhism is the majority religion in India:
$\mathcal{G} = \{(i(X) \succ\!\!- b(X)\}$.
What can be conclude about the nourishment habits of our new friend trilok, born in India? By induction in E, we can pose the defeasible conditional $b(X) \succ\!\!- v(X)$, which can be chained with $i(X) \succ\!\!- b(X)$ to consistently conclude $v(trilok)$. □

4.3 Abductive reasoning

As in induction, in abduction we do not infer a conclusion, but instead we infer the necessary base for arriving to an observed conclusion. Therefore, we also face the problem of assessing an epistemic importance to the inferred explanation. This problem was also studied in confirmation theory, mostly on probabilistic grounds. But there is another problem, namely the existence of more than one putative explanations, inferred by abduction, from which the most adequate should be chosen. Again, space considerations do not allow for an adequate discussion of this issue, but we can briefly state that the epistemic importance may not always be an adequate measure (as stated by Boutilier and Becher [2], good explanations are not necessarily good implications).

EXAMPLE 4 *In an expert system for occupational diagnosis, we find that a normal employed person earns a wage $e(X) \xrightarrow[1]{} w(X)$, pays taxes $e(X) \xrightarrow[2]{} t(X)$, and does not study $e(X) \xrightarrow[3]{} \neg s(X)$; a normal student also is employed $s(X) \xrightarrow[4]{} e(X)$; and that a student that won a fellowship $f(X) \xrightarrow[5]{} e(X)$, earns a wage $f(X) \xrightarrow[6]{} w(X)$. We regard δ_2 y δ_3 as more important than δ_1, that is, wages and taxes are more "normal" facts about working people than studying. With respect to students, we regard δ_5 y δ_6 as more important than δ_4, that is, it is more established that fellows are students and that earn a wage, than that students work. Finally, we regard δ_4 as of more importance than δ_1, that is, it is more "normal" that working people do not study than that students work.$\prec = \{\delta_4 \prec \delta_5, \delta_4 \prec \delta_6, \delta_1 \prec \delta_2, \delta_1 \prec \delta_3, \delta_4 \prec \delta_1\}$.*

In this state of affairs, what can we say about john, about whom we know that he pays taxes?

By abductive inference, from $t(john)$ we can conclude that $e(john)$ without contradiction, and since $\delta_4 \prec \delta_1$, we can conclude also $\neg s(john)$.

What about ana, about whom we know that earns a wage?

In condition $w(ana)$, we can find by abductive inference two justifications, namely $e(ana)$ and $f(ana)$. Following the first justification, we find also that $t(ana)$ and $\neg s(ana)$ and therefore $\neg f(ana)$, that is, ana earns a wages because she is employed, and therefore she pays taxes, does not study is not fellow. Following the second justification we find that $s(ana)$ and also that $w(ana)$ and $t(ana)$, that is, ana is a fellow and therefore she studies, but also ana is employed and pays taxes. Since our epistemic structure is skeptical, we conclude that an abductive explanation is accepted only if it belongs to every possible justification, being indeterminate if there is no common justification. In the case of ana, the system accepts that she is employed as a justification of her wages, and therefore predicts that she pays taxes, a fact to be corroborated.

What about peter, about whom we know that he earns a wage but does not pay taxes?

In this case, the explanations for peter's wages are identical to ana's, but the additional fact that peter does not pay taxes "blocks" the first explanation, and then the only consistent explanation is that peter is a fellow that studies but does not work. □

5 Applications in Scientific Reasoning

The relations between KR&R and Philosophy of Science are subtle and have not been fully uncovered. Here we propose an application of our epistemic architecture to the formalization of scientific reasoning. Scientific theories are aimed to find the least knowledge set (or hypotheses) H that adequately represents or *covers* the evidence set E of a given domain. Early attempts in the Vienna Circle proposed a schema $E \vdash H$ in which the theory follows from the evidence. It was Hempel the first to show that the hypotheses, as underlying explanations for the evidence, should *entail* the observations, i.e., $H \vdash E$ (hypothetico-deductive paradigm) [3]. Popper then showed that scientific theories cannot be shown to be true, confirmations notwithstanding, but a single counterexample may render them false [16]. A further contribution was made by Lakatos, who analyzed the most relevant historical cases, and showed that underlying inference procedures in scientific reasoning are of a more pragmatic nature, and tend to "protect" theories from reputations by means of a "belt" of ancillary hypotheses [6]. We will elaborate on Lakatosian ideas later.

EXAMPLE 5 *Our knowledge about gravitation is reduced to:*

H_1: *There is a force that attracts massive objets to earth.*
$\forall X.o(X) \Rightarrow a(earth, X)$

e_1: *This stone is attracted to the earth.*
$a(earth, stone)$

e_2: *This zeppelin is not attracted to the earth.*
$\neg a(earth, zepp)$

In a Hempelian account, we have $H_1 \vdash e_1$, but $H_1 \not\vdash e_2$. This should render false H_1. In this work we propose to regard scientific knowledge as defeasible, and then our account for reasoning with plausible theories should be adequate in scientific reasoning.

H_1: *Massive objets tend to fall to earth.*
$o(X) \succ\!\!- a(earth, X)$

e_1: *This stone is attracted to the earth.*
$a(earth, stone)$

e_2: *This zeppelin is not attracted to the earth.*
$\neg a(earth, zepp)$

Here e_1 is explained, but e_2 is an exception of unknown nature. Further experiments tend to confirm Archimedes and Torricelli's hypothesis of an atmospheric influence.

H_1: *Objects heavier than air fall to earth.*
$o(X) \wedge h(X) \succ\!\!- a(earth, X)$

H_2: *Objects lighter than air do not fall to earth.*
$o(X) \wedge \neg p(X) \succ\!\!- \neg a(earth, X)$

c_1: *This stone is heavier than air.*
$h(stone)$
c_2: *This zeppelin is lighter than air.*
$\neg h(zepp)$
e_1: *This stone is attracted to the earth.*
$a(earth, stone)$
e_2: *This zeppelin is not attracted to the earth.*
$\neg a(earth, zepp)$
$\square$

This toy example shows an underlying common drive in most scientific communities, namely to avoid the relinquishment of an otherwise fruitful theory when confronted to counterexamples, at least, whenever there are no other competing theories that seems to do better. There need not be a single *method* in scientific reasoning, and that there can be different communities of researchers in a field, each adopting different methodological practices. Lakatos dubbed the term *scientific research programmes* to refer to such that association of theory plus methodology. Our contribution to the Lakatosian epistemology is to consider that research programmes emerge simply from giving different epistemic importance to the same knowledge pieces, that is, competing research programmes can be regarded as plausible theories in which the epistemic structure is common, but the epistemic importance relation is different.

EXAMPLE 6 *Let a scientific theory be* $\mathcal{T} = \{a, a \succ\!\!\!- b\}$. *This theory predicts* b. *What happens if there is evidence that* $\neg b$ *is the case? In this situation we can consider several cases.*

In the first, it is created a theory $\mathcal{T}_1 = \{a, \neg b, a \succ\!\!\!- b\}$, *where tacitly* $\{a \prec \neg b, a \prec (a \succ\!\!\!- b)\}$. *Following* $\mathcal{T}_1$, *the culprit for defeat is* a, *which is not adequately justified, but* $a \succ\!\!\!- b$ *can be safely preserved, and, even more, creates the abductive presupposition that* $\neg a$ *should be the case.*

In the second case, it is created a theory $\mathcal{T}_2 = \{a, \neg b, a \succ\!\!\!- b\}$, *with a tacit preference* $\{a \prec \neg b, (a \succ\!\!\!- b) \prec a\}$. *Following* $\mathcal{T}_2$, *the culprit is* $a \succ\!\!\!- b$ *which is rendered false by the evidence, but the datum* a *can be preserved.*

There can be other cases, which can be the most interesting, where auxiliary hypotheses are generated to protect the original theory from defeat, evolving to a theory $\mathcal{T}_3 = \{a, c, \neg b, a \succ\!\!\!- b\}$, *where* $\{(a, c) \succ\!\!\!- \neg b\}$. *Following* $\mathcal{T}_3$, *the rule* $a \succ\!\!\!- b$ *is incomplete, and must be specialized to consider further cases, for example* $(a, c) \succ\!\!\!- \neg b$ *completes the rule when the particular circumstance* c *is observed.* $\square$

6 Conclusion

We proposed an epistemic architecture that allows a full representation of ampliative inference patterns in an integrated framework. An *epistemic structure* incorporates knowledge of different kinds: a context, a set of defeasible rules or conditionals, and a set of tentative information. An epistemic importance relation assigns priorities to every knowledge piece. Conclusions inferred by means of an ampliative inference rule can be represented within the epistemic structure with its corresponding epistemic importance. The semantics of the system is to regard as definite the conclusions that pertain to the intersection of the maximally plausible consistent subsets. A computationally tractable proof procedure was also presented. Then we showed how relevant patterns of ampliative inference can be represented in our architecture. Finally, some aplications in Philosophy of Science were discussed.

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