Ampliative Patterns in Argumentative Reasoning

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***Abstract*— There are good characterizations of ampliative inference in monotonic theories. However, a problem that faces ampliative inference, in particular abduction, is the explanation of *anomalous* observations, *i. e.*, observations that are contradictory with the current theory. For this reason, in this work we will consider the problem of embedding abduction of surprising and anomalous observations in argumentative theories. We discuss some issues arising the pragmatic acceptance of abductive inferences in defeasible theories, and how to accommodate anomalous observations and characterize all the possible outcomes that a defeasible theory may face when confronted with new evidence. Finally, we discuss an application of our system as a formal device for representing the methodology of scientific research programmes.**

I. Introduction

The need of non-deductive reasoning was recognized in AI research from its very beginning. A large number of applications were built that performed more or less *ad hoc* inference procedures that were indispensable to serve to a given pragmatical purpose (for instance, in planning, natural language processing, "expert systems" and many other). Also, non-deductive forms of reasoning (based on the use of ampliative inference) are common in many fields of knowledge. A remarkable case is in Scientific Reasoning (SR), *i. e.*, the branch of the Theory of Science that copes with the discovery, justification and assimilation of knowledge by means of a "scientific method". There seems to be a striking similarity between the defeasible rules proposed in early defeasible reasoning systems (for example in Reiter's Default Logic [11]) or in more modern formulations (for instance in Vreeswijk's Abstract Argumentation Systems [14]) and what epistemologists refer to as *accidental generalizations* or *lawlike statements* [5]. Therefore, the analogy between defeasible reasoning and scientific prediction is tight.

For this reason, in this work we propose a model for incorporating ampliative inference in argumentative theories. Our reasoning scheme is based on assuming a *defeasible theory*, consisting of a closed set of first order sentences with the addition of a set of lawlike sentences or defeasible rules, that is, expressions in which the acceptance of the antecedent may trigger the acceptance of the consequent unless better reasons are found to claim its rejection. Given a piece of evidence we look for *arguments* (which are, very roughly, similar to deductions in CL with the only addition that they may use defeasible rules in the MP rule) that may have led to it as a prediction. The arguments are compared and the "best" ones (in terms of indefeasibility) are chosen and their preconditions are seen as "explanations" for the evidence. In the interplay between argument generation and abductive hypothesis formation, several kinds of conflicts may arise, and therefore we establish some possible criteria for the defeat among arguments.

II. Abduction in Defeasible Reasoning

Abduction plays a central rôle in many applications, such as diagnosis, expert systems, and causal reasoning [6], [12]. In a very broad sense we can state that abduction is the inference process that goes from observations to explanations within a more general context or theoretical framework. That is to say, abductive inference looks for sentences (named *explanations*), which, added to the theory, enable deductions for the observations. Most of the times there are several such explanations for a given observation. For this reason, in a narrower sense, abduction is regarded as an inference to the best explanation. Given a theory $\mathcal{T}$ and an observed evidence e, then e is *surprising* if neither $\mathcal{T} \vdash e$, nor $\mathcal{T} \vdash \neg e$, and e is *anomalous* if $\mathcal{T} \vdash \neg e$ [1]. The first situation has received considerable interest since Peirce, who coined the word *abduction*, and characterized it as the third member of the triad of syllogistic reasoning (together with deduction and induction)[1]. The second situation (abduction of anomalous observations) has received only occasional attention.

There are good characterizations of abduction of surprising observations in monotonic theories [6], [7], but the general problem of anomalous observations is not well understood still. In this work we will present a syntactical reasoning system that may use abduction as an inference rule in defeasible theories. The system regards defeasible rules $a(X) \succ\!\!-\, b(X)$[2] as material implications *only* for the *modus ponens* inference rule (that is, contraposition, left strengthening, right weakening, and similar inferences are explicitly left out). Defeasible rules can be "fired" in MP only when their antecedent is fully instantiated, *i. e.*, there is a ground substitution for X such that all the literals in $a(X)$ have been inferred. This ground instance of $a(X)$ is an *activator* for the rule. That is, neither generic nor universally quantified inferences are allowed with defeasible rules. The reasoning system, then, will chain inferences in a way very similar to (classical) deductions, with the addition of inferences in which a fully activated defeasible rule was used. This chains of inferences are *(sub)-theories* in Brewka [2] and Poole [10], and *arguments* in Loui [8], Simari-Loui [13] and Vreeswijk [14]. We will adopt this later denomination. If a defeasible rule can be regarded as a *prima facie* material implication, then an argument for an observation o (which has to be a ground literal) is a *prima facie* proof or a *prediction* for o. We can then extend the (classical) consequence operator $\vdash$ to the new operator $\mid\!\sim$, where $\mathcal{T} \mid\!\sim o$ means that there is an argument for o in theory $\mathcal{T}$.

Since we may reasonably expect that these inferences will eventually generate a pair of contradictory ground literals, and since we want to avoid trivialization, then our reasoning system must incorporate some kind of strengthening or restriction among the structural rules. Given a *context*, composed of a defeasible theory $\mathcal{T}$ (*i. e.*, set of defeasible rules) and a set of *evidence* E (*i. e.*, a set of ground literals that are observed to be the case), an abduction for an observation $o \in E$ should be a hypothetical explanation H that is compatible with $\mathcal{T}$, neither $\mathcal{T}$ nor H should jointly (but not separately) explain o, and any other explanation H' should also explain H itself. Formally:

Definition 1: Given a context $\mathcal{T} \cup E$ with an underlying knowledge $\mathcal{K}$, and an *observation* $o \in E$.

1) $\mathcal{K}, \mathcal{T}, E \not\mid\!\sim o$ (there is no argument for o in the context),
2) $\mathcal{K}, H \not\vdash o$ (H is not trivial),
3) $\mathcal{K}, \mathcal{T}, H \mid\!\sim o$ (there an argument for o given H)
4) Any other set H' that satisfies the four conditions above is such that $H' \cup \mathcal{T} \mid\!\sim H$ (*i. e.*, H is the most "shallow" explanation for o).

Example 1: Suppose that in a knowledge-based system we find the rules

$w(X) \succ\!\!- i(X)$
Normally, if X has work, then X receives an income.
$w(X) \succ\!\!- t(X)$
Normally, if X has work, then X pays taxes.
$w(X) \succ\!\!- \neg s(X)$
Normally, if X has work, then X does not study.
$s(X) \succ\!\!- w(X)$
Normally, if X studies, then X has work.
$c(X) \succ\!\!- s(X)$
Normally, if X has a scholarship, then X studies.
$c(X) \succ\!\!- i(X)$
Normally, if X has a scholarship, then X receives an income.
$c(X) \succ\!\!- \neg t(X)$
Normally, if X has a scholarship, then X does not pay taxes.

Given this, what can we expect about $Scott$, of whom we only know that he pays taxes? By abduction, we can show that $t(Scott)$ because $w(Scott)$ (he pays taxes because he works), and from this inference, we can predict that he has an income, and that he does not study. It is a desirable feature here that further (iterated) abductions (for example, $c(Scott)$ because $i(Scott)$) are blocked

[1]This shortest account of Peirce is surely unfair, since his purpose was much wider, for in his semiotic analysis of inference, abduction was central as the source of creativity and new knowledge [3].

[2]Both antecedent a and consequent bt of a defeasible rule are restricted to be *sets of literals* (interpreted as a conjunction), and X is a tuple of free variables.

for being inconsistent.

If we knew about another person, say Kim, of whom we knew only that she received an income, then we could generate two abductive explanations for her income. The first one, $i(Kim)$ because $w(Kim)$, allows further predictions ($t(Kim)$ and $\neg s(Kim)$). The second one, $i(Kim)$ because $c(Kim)$, allows other predictions ($s(Kim)$ and $\neg t(Kim)$). In this situation we have two unrelated explanations, of which we can not choose one over the other. However, knowing further that, for instance, $s(Kim)$, will block the first explanation in favor of the second.

III. Combining Defeaters

In the last Section we introduced a "shallow" abductive operator. Here we show how it can be iterated to produce "deeper" (more specific) explanations, we consider the defeat among arguments and abduction in a defeasible theory, and we show some theoretical properties of our system.

Example 2: (After [6] and [9]). Suppose we have the following theory $\mathcal{T}$.

$\{\ r(T) \succ\!\!- wr(T),$
(if it rains, the road is wet),
$r(T) \succ\!\!- wl(T),$
(if it rains, the lawn is wet),
$r(T) \succ\!\!- \neg s(T),$
(if it rains, it's not sunny),
$s(T) \succ\!\!- \neg r(T),$
(if it's sunny, it does not rain),
$so(T) \succ\!\!- wl(T),$
(if the sprinklers are on, the lawn is wet),
$s(T) \wedge h(T) \succ\!\!- so(T),$
(if it's sunny and hot, the sprinklers are on),
$wl(T) \succ\!\!- ws(T),$
(if the lawn is wet, the shoes are wet),
$wr(T) \succ\!\!- ws(T)\ \}.$
(if the road is wet, the shoes are wet).

In this situation, suppose we observe that our shoes are wet ($E = ws(today)$). The possible (shallow) explanations for this are that either the road is wet, or that the lawn is wet, or both. However, none of these suffices to generate a "most specific" explanation.

To generate a more specific explanation we can iterate the abductive inference, that is, to generate a new "evidence" set E' that contains E plus any of the independently generated explanations, and then use this new context to try to generate a new abductive explanation. This procedure may be easy to formalize, but, as we will see, it may be that an argument is conflicting with some of these abductive hypotheses, and a criterion for combining defeat should be taken into account.

Example 3: (After [4], with slight modifications). Let us consider the following theory $\mathcal{T}$.

$\{\ q(X) \succ\!\!- p(X)$, (Quakers are pacifists),
$q(X) \succ\!\!- rel(X)$, (Quakers are religious),
$r(X) \succ\!\!- b(X)$, (Republicans are belicists),
$p(X) \succ\!\!- \neg b(X)$, (pacifists are not belicists),
$b(X) \succ\!\!- \neg p(X)$, (belicists are not pacifists),
$b(X) \succ\!\!- sw(X)$, (belicists support star wars),
$b(X) \succ\!\!- pm(X)$, (belicists are politically motivated),
$p(X) \succ\!\!- pm(X)\ \}$. (pacifists are politically motivated).

Suppose that our starting point is the observation that Dick is politically motivated ($pm(Dick)$), and that we believe that an explanation for this is Dick being a Quaker ($q(Dick)$).

However, new information leads us to accept that Dick supports star wars ($sw(Dick)$). This is not an anomalous observation ($\neg sw(Dick)$ was not conclusion of our belief state), but any attempt to find an abductive explanation for the new observation will force us to change beliefs. In particular, the only possible explanation is ($b(Dick)$), which generates a conflict with our previous beliefs. In this state of affairs, we have two competing arguments.

A_1={
$q(Dick)$ (previous assumption),
$q(Dick) \succ\!\!- rel(Dick)$ (prediction to be confirmed),
$q(Dick) \succ\!\!- p(Dick)$ (prediction to be confirmed),
$p(Dick) \succ\!\!- \neg b(Dick)$ (prediction to be confirmed),
$p(Dick) \succ\!\!- pm(Dick)\ \}$ (confirmed prediction).

A_2={
$sw(Dick)$ (new observation),
$b(Dick) \succ\!\!- sw(Dick)$ (abductive explanation),
$b(Dick) \succ\!\!- \neg p(Dick)$ (prediction to be confirmed),
$b(Dick) \succ\!\!- pm(Dick)\ \}$ (confirmed prediction).

The possible conclusions to which we could arrive in this competition between A_1 and A_2 can be grouped in three cases.

I) We keep accepting $q(Dick)$ but we reject the abductive explanation $b(Dick)$ because it is contradictory with other knowledge, and it is the consequence of a weak inference pattern. Then, the explanation for $sw(Dick)$ must come from another rule, still unknown.

II) Quite on the contrary, we accept $b(Dick)$ and reject $q(Dick)$ because it was in fact an assumption (this would not be the case if $q(Dick)$ was an observation in the context).

III) We accept the abductive explanation $b(Dick)$ and continue to believe that $q(Dick)$, but we reject that the later is a reason to reject the former (*i. e.*, we reject the argument $\{q(Dick) \succ\!\!- p(Dick), p(Dick) \succ\!\!- \neg b(Dick)\}$, thus establishing the conjecture that some kind of exception must be the case here (Dick is a kind of belicist Quaker).

We can summarize the possible strategies to solve the conflicts between abductive inference and arguments.

I) We include only the abductive inferences that do not generate conflicting arguments with previous beliefs.

II) We consider that abductive inferences are defeaters for arguments that supported previous beliefs.

III) Conclusions of arguments and abductive explanations are on an equal footing, and if there are contradictions, then they must be attributed to an exception in one or more defeasible rules.

IV. CONCLUSION

We presented a treatment of ampliative inference in argumentative theories. This inference context is the only way to cope with the problem of anomalous observations without changing the underlying theory. We will discussed some issues arising from the pragmatic acceptance of ampliative inferences in defeasible theories, in particular, the existence of multiple explanations, the strength of explanations (wrt predictions) and the accrual of explanations. We discussed the problem of the combination of defeat among arguments and abductions, showing how a defeasible theory evolves when confronted with new evidence. A remarkable similarity can be found among the formalization of scientific research programmes and our system. For this reason, we may regard a research programme as a special case of a defeasible theory, where the accidental generalizations and other lawlike statements are the default rules, and the conjectures are abductions that "protect" the theory from refutation.

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