About Abuctive Reasoning

Abstract: In natural languages, the modes of reasoning are seldom deductive. In most cases (anaphoras, negation,...) they involve a "bet" which is tested in the sequel of the text. We consider here a kind of such reasoning: the abductive one, and give two examples of application.

Note: To avoid misunderstandings about our concepts, we present most examples in French (with English translation)

1. Abduction in Natural Language

The management of knowledge linked to texts in natural language possesses a number of characteristics of its own and implements specific reasoning. We consider that the progression of a discourse facilitates the management of the "objects" contained within it.

The knowledge base of this discourse, named discourse memory and labeled $M$, is updated in a dynamic way. This updating uses in particular a mode of reasoning that we call abduction and that functions in three steps (BERRENDONNER, ROUAULT - 1991). Imagine that the natural language analyser processes a sequence $T_0$ of the discourse: this sequence is represented in the language of the knowledge base by an expression $T$. The steps of the abduction are the followings:

A matching (the definition of which varies widely, depending on the application) allows one to determine which object from $M$ is likely to correspond to $T$.

If $T$ matches several objects we have to stack them in a temporary memory. An ad-hoc heuristic chooses the "best one".

If $T$ matches one object of $M$, the information carried out by $T$ is added to this object. If $T$ matches no object, a new object is added to the knowledge base, with the properties associated to it in $T$. The object so modified, or created, is considered as valid in $M$ and, ipso facto, its sub-objects are also valid.

A classical example of abductive reasoning consists in going up from a property exhibited by an individual to this individual: for example going from une anglaise bien carrossée ("an English car with a well-designed body") to Rolls Royce or from bavard ("talkative person") to avocat ("barrister").

Contrary to deductive reasoning, abduction is reversible: it can happen that the continuation of the discourse invalidates the choice made in the second step of abduction, which is, in fact, a "bet". It is then necessary to backtrack on the other possible solutions and try the second "best one" as a new bet. The process is repeated until we reach a non-revisable state of the discourse memory.

The abduction is constantly seen in reasoning implemented in texts: associative anaphoras, treatment of negation, restitution of presuppositions, determination of "actions" capable of leading to a certain state of the universe of discourse.

The aim of this communication is to propose a formal framework for this type of reasoning and to examine two simple cases of abduction: associative anaphoras and negation.
2 Abductive Reasoning

2.1 The logical option

Within the framework of classical logic, the abductive reasoning can be formulated as follows: one knows a certain number of premises $A_i$ ($0 < i < n$) from proposition $B$ (so $A_i \Rightarrow B$) and one wants to know which one implies $B$ under certain circumstances (that is to say in general when the $A_i$'s imply other conclusions). Such a problem is obviously undecidable in classical logic and finds no simple statement in mathematical logic (classical or otherwise). We are proposing here another way of dealing with the problem in a particular context.

2.2 Hypothesis 1: knowledge base

We are placing ourselves in the framework of a knowledge base system (KBS), designated to take account of knowledge and reasoning associated with texts in natural language.

The knowledge is represented by "objects" in the sense of object-oriented languages or object-oriented databases. There are three types of objects (GALLO, ROUAULT - 1992):

1. The individuals which correspond to "discursive objects" (whose surface realizations are certain nominal phrases),
2. The action-schemata which correspond to the predicates of the discourse processes (associated with the "action verbs") and which connect individuals,
3. The state-schemata which formalize the properties of individuals.

The knowledge base itself is composed of two parts:

1. The presupposed knowledge, linked to the domain of the application; this knowledge allows non-trivial reasoning;
2. The knowledge extracted from the text, obtained by automatic processing through advanced text analysis.

The reasoning deals mainly with individuals and ultimately must modify the discursive memory $M$. The deductive reasoning of standard logic is rarely used in this type of knowledge base. A first example of "non-logical" reasoning involves the result of an "action", it uses relations between action-schemata and state-schemata. Another example is abduction.

2.3 Hypothesis 2: Logical Types of Objects

The objects from the knowledge base have a recursive structure, the sub-objects are themselves objects. So, these objects must be typed if one wishes to avoid contradictions. As the abduction allows the passage from one object to another which "contains" it, this reasoning passes from one logical type to another logical type, of a higher order.

2.4 Structure of Abductive Reasoning

The management of the individuals in the discourse memory $M$ is based on the exploitation of certain nominal phrases (NP) of the discourse, that is the NPs which are not "predicative". The textual sequence $T_0$, analysed according to the classical methods of computational linguistics (LALLICH et al. 1990), will be represented ultimately by a formula $T$ in the formalism of the knowledge base.

Knowing that the abduction must resolve the problem of updating $M$, we consider abductive reasoning as consisting of the steps defined previously.

Our method is then more "algorithmic" than purely logical. It allows us to take account the approximate character of abduction, and to merge it into a dynamic of the discourse being analysed, whereas the mathematical logic takes time into account with difficulty.
3. Structure of Individuals in the Knowledge Base

The implementation of the abduction operating on individuals assumes a structure of these individuals adapted to the texts, that is to say to functioning (natural) language. An individual object in the knowledge base is built up of two parts: its status in the discourse and its definitional part. Each of the two parts is formed from a certain number of sub-objects, the principal ones being listed below.

3. 1. Status

1. World: a discourse can express numerous "points of view" and contain "digressions" that are not subsequently referenced, such as in the case of dialogue discourses. This can lead to contradictions which render the knowledge base incoherent. We consider the discursive memory formed at first from a world by default. The sentences that may lead to incoherence set off the creation of other worlds associated with certain objects of the discourse. The underlying idea is that objects in a world are coherent.

2. Universe (of discourse): two types of objects are present in the discursive memory; those that are the expression of supposedly shared knowledge constitute the intension. The objects related to particular situations are in the extension (their characteristics are not shared).

3. Individual: an object can refer to a single individual (Felix the Cat) or to a class (Cats in general). The intensional individuals are called types; an intensional class is a collection of types and is itself a type (butters=different types of butter). The individual/ class distinction, such as found in mathematics, is thus limited to an extensional universe.

3. 2. The definitional part

The sub-objects which concern us here are as follows:

1. Denominations: principal names of the object referent.
2. Functives: predicates having an object as one of its arguments. The other arguments, if they exist, represent other objects of the discursive memory. These predicates are linked, according to the case, to action-schemata or state-schemata.

4. The Associative Anaphoras

The reasoning implemented by the associative anaphoras concern the structure of objects. Let us recall that this type of anaphora does not repeat the preceding sequence as being identical (as would be the case in: The man came in. He was carrying an umbrella). In these conditions, the matching between the representation \( T \) of the textual sequence and the objects of the discursive memory \( M \) involves a calculation between \( T \) and sub-objects of \( M \). This calculation can concern, for example:

1. The denomination: \( \text{Le but de Papin: en marquer un 327e} \) ("Papin's goal: mark it a 327th.");

2. The transition from an extensional individual to a type: \( \text{L'année 1987 ne finit pas bien. J'espère qu'elle commencera mieux en 88} \) ("The year 1987 did not finish very well. I hope it will go better in 88");

3. The transition from a type to an extensional individual: \( \text{Je connais bien le grillon parce que j'ai eu (...) l'opportunité de passer toute la nuit avec lui dans mon sac de couchage} \) ("I know the cricket well because I had (...) the opportunity to pass the entire night with it in my sleeping bag").
In this last example, the identification of "it" (extensional individual) as an object from the discursive memory cannot be made directly with the object $\bullet \theta$ whose denomination is "cricket", which has been created as a type. It is thus necessary to store a new extensional object which is identical to its underlying type $\bullet \theta$ apart from its universe, which is now "extension". At this moment, the new object is valid in the knowledge base.

5. Negations

5.1. Negation and Coherence

In classical logic, negation is a unary connective defined by a set of axioms or by a realization in a two-element Boolean algebra. The classical negation is linked to coherence if a formula and its negation are both theorems, the set of theorems is identical to the set of formulas and the resulting logic has no interest.

The presence in a discourse of a sentence and its negation does not always imply incoherence. First, the conditions of enunciation must be the same in the two sentences to allow a contradiction; more, one of these two sentences may be a remark which is "forgotten" in the sequel of the discourse. Another reason is that the functioning of negation in natural languages is seldom the same as in logic (classical, or not).

5.2. Two Families of Negations

One can distinguish between two types of negations (CULIOLI - 1990): the first one simply asserts a characteristic (negative) of an object - *He did not send a letter*. It is close to the logical negation. The other type uses the negation to assert a positive sentence - *He does not eat, he devours*. The latter implements an abduction, as explained below.

5.3. Negation and Domain

When we say *Peter is not tall*, we understand a positive information (*he is small, he is medium, ...*). This inference supposes a domain (called *height, size, ...*) reachable from *tall*; inside this domain, the negation eliminates the value negated ("tall") and retains the other ones.

The abduction is the process which allows us to infer the domain from the sequence negated. In fact, contrary to hypotheses used often in artificial intelligence, the domain is not unique: in the preceding example it can concern other notions of "size", for example: "greatness", "magnanimity", etc. This is related to the lack of a semantic norm.

Two problems are to be posed here, determination of the domain and the nature of it. If the knowledge base gives no information about the domain, we only can post it under an unknown denomination; often, the remainder of the discourse gives this information.

The formal nature of the domain is generally the same as that of the negated constituent: if it is an individual, then the domain is a set of such individuals: *Ce n'est pas Pierre qui est venu* determines a domain which is a set of individuals of the knowledge base and we can name it "person". If the constituent is a predicative phrase, so is the domain: *Pierre n'est pas grand* *Marie n'est pas le père de Jean* Jean ne marche pas, il court.

5.4. Negation of individuals

Such a negation is represented at the surface level by morphemes, dependant (an example is prefix *-in* as in *incapable*) or independent (*Ce n'est pas Pierre qui est venu*). Note that in this case, negation is associated with an operation of thematisation.

We consider that the domain is defined inside the intension: the types are structured into

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a "forest" (concatenation of trees). If the negated sequence $T$ represents a type $O_0$, we first search for the domain in this hierarchy; in fact we try to identify the domain with one of the parents $O_I$ of $O_0$. If the identification (achieved by an abduction) is possible according to the characteristics associated to $T$ and $O_0$, the domain is $O_I$. If $T$ represents an extensional object $O$, we consider its underlying type $O_0$, and we are brought back to the previous case. Ultimately, the objects of the domain are extensional ones, with $O_I$ as an underlying type.

Of course, the method has to be generalised to take account of cases where negated constituents are predicative.

6. Conclusion

It would be easy to quote other uses of abductive reasoning. For example, if the transition to the result in a discourse is of deductive nature (Moi, quand je mange un biscuit, ajoute Arthur, il le reste. Mangé. - "When I eat a biscuit, added Arthur, it remains just that. Eaten"), the search of processes having lead to a certain state is of abductive nature (si le biscuit est mangé, l'a-t-on mangé, englouti, mâché, etc.? - If "the biscuit is eaten" has one "eaten it", "gobbled it", "chewed it", etc.?).

We see that abduction plays an essential part in the reasoning that comes into play in the discourse.

References

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