# From Arguments in Natural Language to Argumentation Frameworks[*]

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February 2, 2010

## Abstract

For argumentation useful, the means must be found overcome the knowledge acquisition bottleneck between the source material and the translation into and out of an argumentation formalism. As source material is often expressed and understood in natural language, we should consider how to translate natural language arguments. The current state of the art in argumentation does not have any formal translation method. In this paper, we discuss this lacuna. First, there are robust, wide-coverage computational linguistic systems which automatically translate multi-sentential structures into first order logic. In restricted domain of discourse, this can be used to formalise the knowledge base. We then consider how such an approach could be extended to argumentation. We propose two different models of translation based on currently available argumentation formalisms – logic-based and logic graphs. The advantage of the logic-based approach is that the arguments input into the argumentation system are sets of first order logic expressions and what is inferred from them. The consistency of each argument is assured; the relationships between the arguments in an argumentation framework graph are determined by the logic-based approach. One disadvantage is that each argument cannot have any missing expressions (enthymemes) before it can be used in the argumentation formalism. A second disadvantage is that the theory requires a complex system to determine relationships between the arguments, which is particularly relevant as arguments are added over the course of a dialogue. The logic graphs approach allows reasoning to proceed even where there are enthymemes, and it is straightforward to determine the relationships between arguments in the network and

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[*] 2009 ©Adam Wyner. The author thanks Tony Hunter for comments. This paper was created 14.06.09 and revised over the summer. The current paper reflect some minor revisions. Errors rest with the author.

new arguments. On the other hand, it requires that sets of logically consistent statements be recalculated every time a statement is added to the argument network. To overcome this, we suggest that research be directed to support calculations over subgraphs. Additional problems for both approaches are outlined, providing an agenda for future research.

# 1 Introduction

Abstract Argumentation Frameworks (AFs) ([1], [2] [3], [4], among others) have been developed to explore. They are powerful in large part because arguments are atomic nodes and only one undifferentiated attack holds between them.

Abstract AFs are not adequate to account for uses of argumentation. In particular, they do not represent senses of argument where arguments have internal structure, e.g. $P \rightarrow Q$, *P, therefore Q*, is an argument two premises and a conclusion. Nor can they represent notions in argumentation such as *premise defeat* (where the premise is attacked), *rebuttal* (where the conclusion is attacked), or *undercutting* (where the rule is attacked).

Another line of research instantiates AFs with concrete examples ([5], [6], [7], [8], and [9]). In such systems, a knowledge base is given which is made up of facts along with strict and defeasible inference rules in a Defeasible Logic (*DL*) ([10] and [4]). The facts and rules of the knowledge base intially appear as linguistic expressions, *If Bill is single, then he goes out on a Friday night*, which are then informally translated into a logical form, $P \rightarrow Q$, where P is *Bill is single* and *Bill goes out on a Friday night* is Q. The nodes of an abstract AF are interpreted as instantiations of arguments from the knowledge base. A very elaborate version of this approach appears in [11], where an ordinary legal dispute is manually translated into a knowledge base, the attack relations between components are inferred from the dispute, and the arguments are abstracted into an AF.

However, all known approaches face a knowledge acquisition bottleneck – the arguments as expressed in natural language are manually translated into the knowledge base and thence into the AF. This is time-consuming and labour intensive, limiting the use of argumentation. Moreover, without some formalisation of the translation method, the translation cannot be systematically validated. Nor can we identify problems with the method, then systematically revise, and automate it.

In this paper, we propose some initial steps to providing a formalised translation method, then outline some problems as well as a future direction. We consider two approaches – logic-based [9] and logic graphs [12] – to instantiating arguments given a knowledge base comprised of formulae; the arguments are then related in an AF. In both approaches, logical formulae of the knowledge base is provided by state of the art computational linguistic tools which parse and represent in first order logic multi-sentential natural language input ([13] and [14]). Such tools are particularly useful and successful in constrained domains where the users are guided to input well-formed expressions. The main drawback of the logic -based approach is the treatment of *enthymemes*. Moreover, to determine well-formedness conditions of formulae in arguments and inconsistency between arguments, one must decompose the formulae. A further issue is that the sense of "argument" is problematic [15]. In a second approach, the formulae of the knowledge base are directly translated into an AF. Enthymemes are not problematic. It also must decompose the formulae. An advantage is that it represents alternative senses of arguments in a structured graph. The novelty of our paper is in highlighting the knowledge acquisition bottleneck, indicating tools to provide a knowledge base, and in discussing a range of problems and potential solutions over the course of translating from the knowledge base to an AF. In particular, we focus on the following questions:

1. What are the well-formedness conditions on premises and conclusions?
2. How is inconsistency between one statement and another determined?
3. What is the relevant notion of "attack" between arguments?
4. How is implicit information represented (enthymemes)?
5. Must an "argument" comprised of premises and a conclusion be introduced as a whole or can "arguments" be constructed incrementally?

In the following section, we discuss a working example, a graphical representation of the relationships among the statements, and representation of the arguments in an AF. We then outline a formal approach to translating a sentence in natural language to first order logic. This section shows that much of natural language in a specific domain of discussion and suitably constrained is not problematic to parse and semantically represent, that the central problem for argumentation is to determine intersentential semantic relationships such as raised in questions [1]-[5], and that state of the art computational lingustics provides a good model to develop a formal translation from natural language to an AF. In the subsequent two sections, we present elements of how logic-based and logic-graph approaches to argumentation use the knowledge base to construct arguments that are input to the abstract AF. For both, we indicate several problems for each approach in relation to questions [1.]-[5.]. In the discussion section, we propose that the problems for each suggest an alternative strategy in which we partially calculate extensions in an argument graph.

## 2 Example

The example is derived from a public discussion list concerning recycling. We are considering a restricted domain and normalising the language; it is not our intention to address issues related to unrestricted domains or the full range of linguistic forms. We follow approach to argument graphing as in [11], where ordinary legal disputes are formalised. Each statement is represented as a node, claims and premises are represented with continuous arrows between nodes, while contradictions or conflicts between statements are represented with dashed arrows. The question that is under discussion is: *How can a government reduce the amount of garbage*? Each statement is made separately by an individual on the discussion list, and the order of introducing in the discussion list have been different. We have graphed the relationships between the statements in Figure 1.

1. Every householder should pay tax for the garbage which the householder throws away.
2. No householder should pay tax for the garbage which the householder throws away.
3. Paying tax for garbage increases recycling.
4. Recycling more is good.
5. Paying tax for garbage is unfair.
6. Every householder should be charged equally.
7. Every householder who takes benefits does not recycle.
8. Every householder who does not take benefits pays for every householder who does take benefits.
9. Professor Resicke says that recycling reduces the need for new garbage dumps.
10. A reduction of the need for new garbage dumps is good.
11. Professor Resicke is not objective.
12. Professor Resicke owns a recycling company.
13. A person who owns a recycling company earns money from recycling.
14. Supermarkets create garbage.
15. Supermarkets should pay tax.
16. Supermarkets pass the taxes for the garbage to the consumer.

For example, an individual makes statement [1], another makes [4] as a reason or premise for [1], yet another makes [3] as an additional reason for [3], which can be understood to lend greater strength to the claim that [1] should hold. [9] supports the claim in [4]. However, this is undercut by the claim that the Professor is not objective, so the implication one might draw from his statement does not hold. In [2], we have a counter-proposal with a range of supporting reasons; the counter-proposal can be understood as a rebuttal to the previous argument in favour of taxing garbage. [16] attacks [15], which is one of the premises of the argument in favour of [2], so constitutes a premise defeat.

This “discussion” is not to be taken as a full, complete representation of all possible statements and counter-statements. Moreover, in some cases, there is an intuition that one statement attacks another statement – [16] attacks [15] – but much is left implicit. Argumentative discussion proceeds by such partial steps with missing premises.

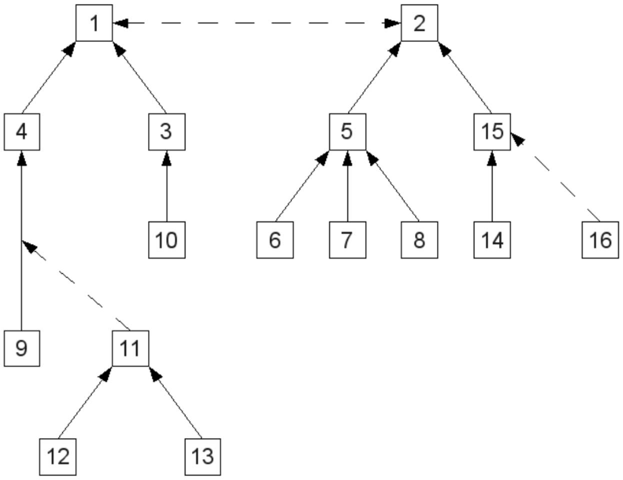

Figure 1:

## 3 Arguments in an AF

For our purposes, we consider the AF of [1], where there is one set of undifferentiated objects, *arguments*, which are nodes in a graph as well as one undifferentiated relationship between the nodes, the *attack* relation, which can be represented as a graph in which attacks are arcs between nodes representing the arguments.

**Definition** An argumentation framework AF is a pair $< \mathcal{X}, \mathcal{R} >$, where $\mathcal{X}$ is a set of *objects*, $\{a_1, a_2, \ldots, a_n\}$ and $\mathcal{R}$ is an *attack* relation between objects. For $\langle a_i, a_j \rangle \in \mathcal{R}$ we say the the object $a_1$ attacks object $a_2$. We assume that no object attacks itself.

Some of the relevant auxiliary definitions are as follows, where $S$ is a subset of $\mathcal{X}$:

**Definition** We say that $p \in \mathcal{X}$ is *acceptable with respect to* $S$ if for every $q \in \mathcal{X}$ that attacks $p$ there is some $r \in S$ that attacks $q$. A subset, $S$, is *conflict-free* if no argument in $S$ is attacked by any other argument in $S$. A conflict-free set $S$ is *admissible* if every $p \in S$ is acceptable to $S$. A *preferred extension* is a maximal (w.r.t. $\subseteq$) admissible set. The object $p \in \mathcal{X}$ is *credulously accepted* if it is in at least one preferred extension, and *sceptically accepted* if it is in *every* preferred extension.

Given the graph of statements in Figure 1, we abstract the "arguments" and represent the relationship as an AF. We assume, for the moment, that argument *a1* is comprised of statements {1, 3, 4, 9, 10}, *a2* of {11, 12, 13}, *a3* of {2, 5, 6, 7, 8, 14, 15}, and *a4* of {16}. Rebuttals, premise defeats, and undercutting are abstracted into the one abstract argument relation *attack*. The resulting graph is in Figure 2.

In this AF, there are several preferred extensions depending on what is asserted to be true: if neither of a2 or a4 hold, then {a1} and {a3}; if a2 holds, but a4 not hold, then {a2, a3}; if a4 holds, but a2 does not, then {a4, a1}.

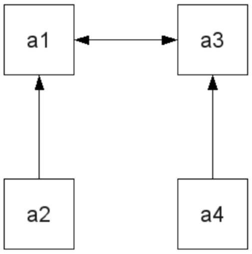

Figure 2: Recycling Debate in an AF

## 4 Parsing and Semantic Representation

Each of the sentences in [1]-[16] have been parsed and semantically represented in first order logic using the *C & C/Boxer* system, which is robust, wide-coverage natural language system for English [14].[1] We give a very brief overview, leaving aside many other features and skipping a range of details. Our point is that there are automated systems which can parse and semantically represent multi-sentential structures such as rules with premises and conclusions; therefore, this aspect of natural language processing is not especially problematic as a component of an argumentation system. In addition, this section suggests that successful techniques from computational semantics, the syntax-semantics interface along with compositional semantic rules, might be fruitfully extended to argumentation. Finally, the discussion here highlights the questions [1]-[5], namely, that the central problems in the translation and representation of arguments from natural language is primarily about the intersentential semantic relationships among the statements.

The *C & C* parser uses a *Categorial Grammar*, where each lexical item is assigned a category, and categories combine to form larger phrases; a well-formed sentence has a parse given the categories and mode of combination, whether combining with an element to the right, given by a rightward slash $/$, or to the left, given by a leftward slash $\backslash$.

Figure 3: Categorial Grammar Parse of *Every man is happy*

For example, in Figure 3, the determiner DT *every* combines with the common noun NN *man* to produce a noun phrase NP[nb] *every man*; the verb VBZ *is* combines with

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[1] See: http://svn.ask.it.usyd.edu.au/trac/candc

the adjective JJ *happy* producing a category of type (S[dcl]\NP). This latter category combines with the NP *Every man* on the left to produce S[dcl], which indicates that this structure is a sentence of the declarative type. More complex parses can be provided.

The parse is then input to *Boxer*, which provides semantic representations in *Discourse Representation Theory* (DRT) as in Figure 4. DRT is a form of first order logic which allows, among other things, the representation of anaphoric relations between sentences (*A man walked in. He sat down.* where the pronoun anaphorically links to the man who walked in) as well as events (see [16] for discussion of event-theoretic semantics in natural language).

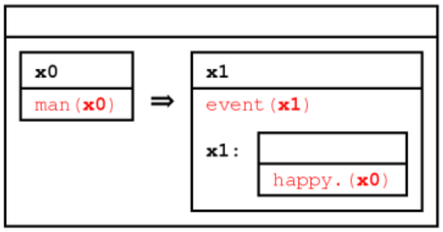

Figure 4: DRT representation of *Every man is happy*

This representation is the DRT equivalent to $\forall x$ *[man(x) → happy(x)]*. The main difference is the way that discourse entities such as x0 and x1 are introduced and treated by the system; in addition, we have events such as x1, where the men are happy.

In computational semantic approaches to natural language syntax and semantics such as DRT, each lexical item is associated with a semantic type; every syntactic unit is also associated with a semantic type or a rule of interpretation such that the meaning of the whole expression is determined by the meanings of the parts and the mode of composition, which generally is that a function applied to an argument. For instance, the meanings of the lexical items are given in the $\lambda$-calculus, where the semantic interpretations are as follows:

- *happy* is $\lambda$x happy'(x), which is the set of happy objects in the domain.
- *man* is $\lambda$y man'(y), which is the set of men objects in the domain.
- *every* is $\lambda$P.$\lambda$Q. $\forall$z [P(z) → Q(z)], where P and Q are predicates of individuals in the domain.

Following the syntactic structure, we have an initial structure, then followed by three applications of $\lambda$-reduction; notice the bracketting, which indicates the order of application:

- ($\lambda$P.$\lambda$Q. $\forall$z [P(z) → Q(z)]($\lambda$y man'(y)))($\lambda$x happy'(x))
- $\lambda$Q. $\forall$z [$\lambda$y man'(y)(z) → Q(z)]($\lambda$x happy'(x))
- $\forall$z [$\lambda$y man'(y)(z) → $\lambda$x happy'(x)(z)]

- $\forall$x [man(x) $\rightarrow$ happy(x)]

In this framework, the syntactic parse provides a structure on which the semantic interpretation of the lexical items and phrases can function, thus providing an interpretation of the whole expression.

More complex, multi-sentential expressions can be input to *C & C/Boxer* such as conditionals: *If a man is happy and rich, then his family is happy*. *C & C/Boxer* is a tool under development, and there are a range of limitations. Nonetheless, it represents significant progress in natural language processing. Our main point in this section is that we can presume that parsing and semantic representation of multi-sentential structures are not, in and of themselves, an insurmountable problem, albeit in a limited domain and abiding by some linguistic conventions. It recommends that a similar approach be extended to the argumentation (see [17] for efforts in this direction).

Let us return to our questions. A system such as *C & C/Boxer* begins to address [1.]. [14] reports that the system (along with an inference engine) is highly successful in identifying inference patterns in the *Recognising Textual Entailment* task. In large measure, the success is due to *decomposing* complex expressions into simpler expressions that the inference engine can apply to. In turn, this depends on having a rich syntactic and semantic analysis. Notions of the *coherence* of an argument might be address with respect to the decomposed analysis. With respect to [2.], inconsistency depends on negation of classical logic. Thus, intuitions of inconsistent statements must be decomposed and translated into the logical analysis. However, there remain questions as to whether all forms of *conceptual incompatibility* can be reduced to logical inconsistency (see [18] for a variety of other forms of *opposition*). The issue of attack [3.] is not raised with respect to *C & C/Boxer*, however, it too may be based on negation, though undercutting (where a rule is attacked) may be an issue in some systems. The problem of enthymemes in question [4.] is significant; as with any system based on classical logic, *C & C/Boxer* cannot draw inferences if insufficient information is provided. Just how to provide such background, presupposed knowledge remains a topic of research [19]. Finally, DRT is specifically designed to address [5.], for statements can be introduced incrementally over the course of a dialogue; however, given our observations concerning [4.], inferences may not be drawn at every point. In sum, a computational semantic system takes us some of the way to addressing the questions [1.]-[5.].

# 5 Logic-based Approach

Argumentation based on classical logic ([9] and [20]) represents arguments in terms of classical logic, statements are expressed as atoms, complex expressions are formulae constructed using the logical connectives of conjunction, disjunction, negation, and implication. The classical consequence relation is denoted by $\vdash$. Given a knowledge base $\Delta$ comprised of formulae and a formula $\alpha$, $\Delta \vdash \alpha$ denotes that $\Delta$ entails $\alpha$. $\Delta$ can be inconsistent and comprised of a range of declarative statements. We assume a set of formulae $\Delta$ from which arguments are constructed. Where $\perp$ denotes inconsistency, $\Delta \vdash \perp$ denotes that $\Delta$ is inconsistent. An argument is an ordered pair $< \phi, \alpha >$, where

$\phi \subseteq \Delta$, $\phi$ is a minimal set of formulae such that $\phi \vdash \alpha$, and $\phi \nvdash \bot$. $\phi$ is the support for the claim $\alpha$.

The notions of *premise defeat*, *rebuttal*, and *undercut* are defined as relations between arguments. $< \Psi, \beta >$ is a premise defeater for $< \Phi, \alpha >$ where $\beta \vdash \neg(\phi_1 \wedge \ldots \wedge \phi_n)$ for some $\{\phi_1 \ldots \phi_n\} \subseteq \Phi$; in essence, the claim of one argument is the negation of a formula in the knowledge base of another argument. $< \Psi, \beta >$ is a rebuttal for $< \Phi, \alpha >$ if and only if $\beta \leftrightarrow \neg\alpha$ is a tautology; the claims of the arguments are inconsistent. The notion of undercut is somewhat related to premise defeater (the claims of one are inconsistent with the knowledge base of the other); however, there are varying notions of rebuttal (see [12]) where the rule is reified so that it can be attacked and deemed inapplicable.

Given the notions of argument and their relations, arguments can be mapped to an abstract AF, each argument being a node in the graph and the attack relation being an abstraction over the argument relations of premise defeat, rebuttal, and undercut. Significant considerations are given to how knowledge bases of various arguments relate to on another (e.g. whether one argument subsumes another relative to the formulae of the knowledge base). In many respects, the logic-based approach shares with other approaches (see [4]) the proposal that "arguments" are "objects" in the AF that, at another level of analysis, are comprised of logical formulae. In [15], researchers use the notion "argument" in different senses, not all of which suit the function of arguments in an AF.

Considering the questions [1.]-[5.], *C & C/Boxer* and the logic-based approach are highly compatible *with respect to the logic of arguments*. That is, where $< \Phi, \alpha >$ is an argument of the logic-based approach, *C & C/Boxer* could be used to provide the natural language semantic intepretations for the knowledge base $\Phi$ as well as what is inferred from $\Phi$, $\alpha$. Given the arguments, the tools of the logic-based approach could be applied to derive the AF. Thus, the strengths of *C & C/Boxer* with respect to the questions [1.]-[5.] carry over to the logic-based approach. The logic-based approach explicitly addresses the question of attack relations between arguments. Furthermore, incremental development of the AF graph is feasible since arguments can be added relative to the domain statements $\Delta$ and their relations determined. The main problem, both for *C & C/Boxer* and the logic-based approach is the identification of enthymemes since inference in classical logic cannot proceed without all the required information. As such a logic-based approach is not useful in a domain where participants argue about subjects rich in enthymematic information.

# 6 Logic Graph Approach

The logic graph approach of [12] takes a different route to relating formulae of a knowledge base to an AF. We present here a simplified, updated version. As with the logic-based appoach, we presume that the statements of natural language are translated into logical formulae by a system such as *C & C/Boxer*. Thus, it has the advantages of the logical-based approach as well. The main differences are in the treatment of enthymemes and the senses of argument. We give a brief overview by way of examples.

Rather than the creation of an intermediate "object" which is an argument as in the logic-based approach, every formula of the knowledge base is directly translated into a AF structure of nodes and arcs. The simpliest example is of strict → and defeasible ⇝ implications with a single literal in the head or body. We assume that the literals are introduced in the graph along with their negations, and that these literals attack one another. We simplify the knowledge base to only those rules with conjunctive literals in the body and a single literal in the head; disjunctive bodies require an additional node. The rule is reified and represented as a node as well, being attacked and attacking the negation of the literal of the head or body. The only difference between strict and defeasible implication in this approach is that for strict implication, the rule node attacks and is not attacked by the negation of the head literal, while for defeasible implication, the rule node both attacks and is attacked by the negation of the head literal. An assertion is a strict or defeasible rule with a head literal and no body literals. A conjunctive body adds nodes for the positive and negative literals, where the negative form attacks the rule.

We illustrate this as follows:

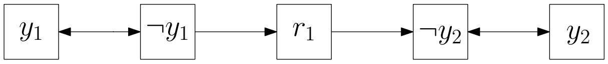

Figure 5: $y_1 \longrightarrow y_2$

In the AF which defines this graph, the preferred extensions are:

$$\{y_1, r_1, y_2\}$$
$$\{\neg y_1, y_2\}$$
$$\{\neg y_1, \neg y_2\}$$

In general, in any preferred extension where the body literals of the rule hold, the positive form of the head literal of the rule must hold as well.

A defeasible formula appears as:

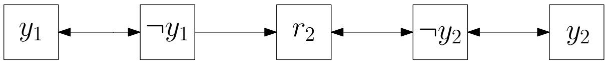

Figure 6: $y_1 \rightsquigarrow y_2$

In an AF, the preferred extensions are as follows. In contrast to strict implication, the body literals of the rule may hold, but either the positive or negative form of the head literal of the rule can hold.

$$\{y_1, r_2, y_2\}$$
$$\{\neg y_1, y_2\}$$
$$\{\neg y_1, \neg y_2\}$$
$$\{y_1, \neg y_2\}$$

The notions of premise defeat, rebuttal, and undercutting relate to which part of the graph is attacked, relative to the underlying rule of the knowledge base.

In this approach, logical consistency is given preferred extensions, which are maximal sets of literals which do not contain a literal and its negation. The approach keeps a very "clean" semantics for AFs since we only have nodes for literals and rules along with one attack relation.. It can be used to distinguish among the various senses of "argument". [15] claim that the basic notion of "argument" is a strict or defeasible formula; there are no "subarguments" that are intermediate conclusions; there are no subarguments which can be attacked. In Figures 5 and 6, we have arguments in this sense. A "case" is a collection of arguments linked and are in support of a particular literal; in logic, this is a proof $y_i$, $y_i \rightarrow y_j$, $y_j \rightarrow y_k$, so $y_k$. For [20], an "argument" is instead comprised of $y_i$, $y_i \rightarrow y_j$, $y_j \rightarrow y_k$ and the claim $y_k$; one argument can attack the support of another argument. An additional sense is a "debate", which are just two cases where one case supports a literal and the other case supports the negation of that literal.

In terms of the questions [1.]-[5.], the main difference is that arguments themselves are not defined in terms of logical consistency or implication, in contrast to [20]. The main advantage is that reasoning can proceed with the arguments at hand without regard to enthymemes. As further information is added to the knowledge base, the correlated elements in the AF are added, and preferred extensions are calculated. However, as the approach is not logic-based, we cannot directly use the results of classical logic, but must prove desireable properties such as contraposition, which remains to be done.

# 7 Discussion

We have discussed issues concerning the translation of arguments in natural language to AFs, focussing on two current approaches. One of our main claims is that utilising systems from computational semantics will support translation; indeed, argumentation theories such as logic-based approaches seem to be naturally supported and provide computational semantic systems with an additional "level" that represents argumentation. However, one of the main problems is to address not just how argumentation theories can utilise computational semantic systems, but how to overcome the problem of enthymemes, which interferes with logical inference.

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