A Discourse Approach to Explanation Aware Knowledge Representation

Andrew Potter

Sentar, Inc.
4900 University Square, Suite 8,
Huntsville, Alabama 35816 USA
anpotter@sentar.com

Abstract

This study describes a discourse approach to explanation aware knowledge representation. It presents a reasoning model that adheres to argumentation as found in written discourse, intended for use in intelligent human-computer collaboration and inter-agent deliberation. The approach integrates the Toulmin model with Rhetorical Structure Theory and Perelman and Olbrechts-Tyteca's (1958) strategic forms of argumentative processes to define a set of constraints for governing argumentative interactions and formulating explanations in an ontologically normalized manner. Arguments, when satisfied, are instantiated into a dynamic rhetorical network that represents the system's model of the situation. Two modalities of instantiation are proposed. Inferential instantiation is used when a claim may be inferred from a ground, and synthetic instantiation is used for descriptive argumentation where both ground and claim must be satisfied for the argument to be instantiated. The instantiation process maps arguments into the network using interaction links. Defined interactions include accrual, concomitance, backing, substantiation, dissociation, rebuttal, undercut, and confusion. It is envisioned that communities of agents endowed with reasoning capabilities would engage in collaborative explanatory argumentation, using these interactions as mechanisms for detecting and managing conflict and agreement.

Introduction

The notion that argumentation theory could be used to motivate the development of technologies for intelligent human-computer collaboration has been explored by numerous researchers. Among these, Ye (1995) and Ye and Johnson (1995) investigated expert system interaction with human users. They found that a system capable of presenting arguments persuasively is more likely to be regarded as a credible resource for resolving complex issues. Reed and Long (1998) proposed a system for generating natural language arguments that would use coherence relations, reasoning operators, and rhetorical maxims. Moulin, et al. (2002) proposed that argumentative reasoning strategies could be used to make agents more persuasive and proposed that Perelman and Olbrechts-Tyteca's (1969) analysis of argumentation could be used in this endeavor. Along similar lines Grasso (2002) used rhetorical schemas for modeling argumentative dialogues, with the objective of providing participants with a familiar behavioral model. Wærn and Ramberg (2004) proposed a system that would use Mann and Thompson's (1988) Rhetorical Structure Theory (RST) to construct explanation networks and Toulmin's (1958) model to find paths through these networks, resulting in a dual level knowledge system that would support both inferencing and explanation derivation. Dalianis and Johannesson (1999) proposed using the Toulmin model and RST for a system that would generate explanations for conceptual models used in requirements engineering. Thagard (2000) used connectionist technology to derive explanatory coherence from networks of propositions, where inter-propositional coherence was defined in terms of a set of principles. Sartor (1993) developed a model for non-monotonic and adversarial reasoning and applied it to legal contexts. The model was used a simple rule-based approach with inference based on several distinct types of consequence, including logical, grounded, plausible, and justified consequences. Rules were defined as a formalization of warrants, as defined by Toulmin.

Clearly, the weight of such research suggests that, if the human propensity for argumentation could be imparted to computers, computers could in turn be used to engage with humans in the complex problem-solving processes enacted through argumentation. And yet what has not emerged from previous studies is a general theory of reasoning for use in human-computer collaboration. For humans and computers to collaborate, they must reason together, and in order to reason together, they must share common ground in rhetoric and argumentation.

Establishing a basis for this common ground is the objective of the approach described here. Specifically, the argumentative reasoning theory described here is intended to support intelligent human-computer collaboration by providing a capability for representing argumentative structures in a way that is machine-processable, humanly intuitive, and amenable to discovery of new argumentative structures. The theory draws on Toulmin's (1958) model of argumentation, Mann and Thompson's (1988) Rhetorical Structure Theory (RST), and Perelman and Olbrechts-Tyteca's (1958) strategic forms of argumentative processes. None of these theories was originally conceived as a contribution to knowledge representation. Toulmin's model was presented as a critique of formal logic, RST was developed to address various problems in computational linguistics, and Perelman and Olbrechts-Tyteca's contribution comes from their treatise on rhetoric. As adopted here, the Toulmin model provides the framework for an ontology of argumentation. RST provides the schemas, constraints, and relations used in generating coherent argumentative structures. These are merged into an argumentation ontology. Associative and dissociative reasoning leads to the development of conceptual tools for defining argumentative strategies. Because the theory is modeled on natural discourse, rhetoric, and argumentation, it is expected that the resulting knowledge structures and processes would possess salient characteristics of intelligent collaboration.

Theoretical Foundations

As shown in Figure 1, Toulmin defined an argument as consisting of six elements: a *claim*, a *ground*, a *warrant*, a *backing*, a *qualifier*, and a *rebuttal*. The *claim* is what the argument purports to demonstrate. The *ground* is the datum that supports the claim. The *warrant* establishes the linkage between ground and claim. The *backing* is a policy, law, argument, or fact that substantiates the warrant. The *qualifier* is an indication of the strength of the argument. The rebuttal is any counter-argument that might refute the argument. To use Toulmin's example, the claim *Harry is a British citizen* may be established by the ground that *Harry was born in Bermuda* and the warrant, *a person born in Bermuda is a British citizen*. The backing for the warrant would be the British laws that apply to such cases, and the qualification would be *presumably*, since although the warrant would apply to most cases, there are exceptions, and these could be used to advance a rebuttal; for example, if Harry's parents were citizens of the United States, Harry would also be a US citizen.

Rhetorical Structure Theory (RST) is a theory of text coherence. RST defines the coherence of a text in terms of the way its parts, or *text-spans*, relate to one another. It postulates a small number of schemas for defining the possible structural relationships among spans and defines a set of rhetorical relations that may be used when applying a schema to a set of text spans. An RST analysis of a coherent document defines a hierarchical structure representing the rhetorical interrelationships of the text spans comprising the document. A text span may be either an individual *segment* or it may be a *structure* consisting of several segments interrelated by one or more *relations.* Most relations are binary, consisting of two text spans, with one designated as the *nucleus* and the other as the *satellite*. The nucleus is the more salient of the two. The example shown in Figure 2 uses the EVIDENCE relation, where the satellite provides information that makes the nucleus more believable.

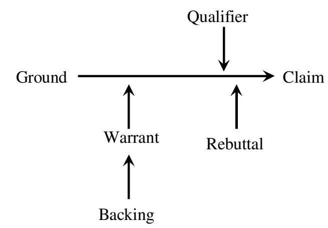

Figure 1: Toulmin Model

Perelman and Olbrechts-Tyteca's strategic forms of argumentative processes include *associative* and *dissociative* forms. *Associative* forms are either connective or disconnective. Connections are established when, to use Toulmin's terms, a claim is supported by ground and warrant. A disconnective form is used in a rebuttal which denies a claim by challenging the grounds. It breaks an argumentative link. *Dissociative* forms are disruptive, as they may challenge the underlying theory or backing that gives credence to the argument. Dissociative arguments do not merely rearrange the links; they alter the nature of the argument.

The Toulmin model and RST share a common characteristic with classic rule-based knowledge representations. They are both concerned with plausible relationships among portions of information. Toulmin warrants are comparable to rules to the extent that the ground is the condition, and the claim is the consequent (Sartor 1993). In an RST structure, the satellite typically gives evidence or explanation for the nucleus, as with the EVIDENCE and ELABORATION relations. An RST relation indicates that the nucleus relies on the satellite for support in a manner similar to rules, where the consequent requires the support of the condition.

However, both the Toulmin model and RST differ from rules in important ways. In stating that one situation is contingent on another, a rule says nothing about why this is so. As such it offers little in the way of explanation. The Toulmin model makes provision for information unavailable from the rule paradigm. The qualifier distinguishes the relationship between ground and claim with respect to certainty. The backing may be used to offer an assurance of the acceptability of the warrant. And the rebuttal provides the option of specifying possible counter-arguments or claims.

RST provides the means to specify the rhetorical relationship between one text-span and another, and it provides a means for expressing a much richer array of inter-propositional relationships than possible through either rules or Toulmin arguments. RST provides a model for representing a complex hierarchical structures consisting of multiple interlocking relationships. Toulmin and RST provide more expressive models of the situation than can be specified using rules. This presents the possibility for dynamic construction of expressive argumentative networks.

1. The testimony against Scrushy was overwhelming.
2. He should have been found guilty.

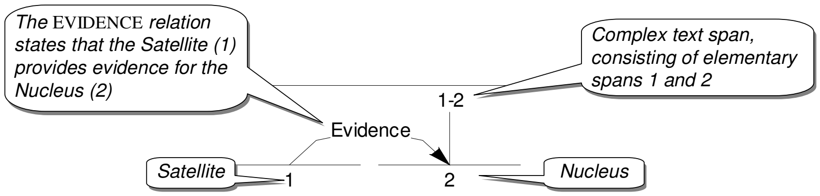

Figure 2: RST of the EVIDENCE Relation

An Argument Ontology

The argument ontology defines a conceptualization for representing argumentative knowledge above the sentence level. As a theory of how the constituents of an argument interrelate, it integrates the Toulmin model with Rhetorical Structure Theory. Generally, Toulmin's grounds and claims correspond with RST satellites and nuclei. To this extent, RST supplies relations for describing the nature of the relationship between ground and claim. However, argumentative discourse goes beyond this to include a variety of structures useful in rhetorical elucidation. Directly argumentative structures such as CONCESSION, EVIDENCE, ANTITHESIS, MOTIVATION, and JUSTIFY play important roles in argument discourse (Azar 1999), and ultimately the full range of rhetorical relations may be needed if the knowledge representation model is to support human computer collaboration. To realize this, it is necessary to formalize these concepts ontologically. By representing discourse ontologically, arguments thus specified are not merely a means of affirming claims on the basis of grounds; they are objects of knowledge and may be treated accordingly.

As shown in the ontology in Figure 3, an *Argument* defines a *Warrant* and a set of *Interactions*. The Warrant defines the *Nucleus* (Claim) and the *Satellite* (Ground). The Nucleus is a *Statement*, which is an ontologically normalized expression, usually of a domain specific nature. The Satellite specifies the satellite Statement and its *Relation* to the Nucleus. The Relation identifies the RST relation and characterizes its *modality* as either *synthetic* or *inferential.* As will be discussed in detail in the next section, the modality of an argument determines the conditions under which it may be instantiated.

The Argument also identifies a *qualifier, qualification ratio,* and argument *interactions.* The qualifier is a static value indicating the level of certainty of an individual argument, and may be either *conclusive* or *supportive*. The qualification ratio is dynamic and is defined by the interactions in play between an instantiation of the argument and other argument instantiations.

Interactions define the possible relations an instantiated argument may have with some other argument. In the rhetorical network, arguments may be linked together by means of such interactions. For example, when the nucleus of one argument unifies with the satellite of another, the *substantiation* interaction is specified; when the warrant of an argument appears as the nucleus of another, the *backing* interaction is used; and when two arguments converge on the same claim, the *accrual* interaction is specified. Argumentative interactions such as these are used in the construction of rhetorical networks that that represents the system's model of the situation. The full set of argumentative interactions is discussed in the next section.

Rhetorical Networks

Arguments are generally thought of as consisting of premises and conclusions, such that for a conclusion to be accepted, adequate premises must be provided to support it (Juthe 2005). Rule-based representations are consistent with this, to the extent that the conditions play the part of premises and the consequent is the conclusion. Following this view, a rule is triggered when its condition is satisfied, resulting in the consequent being asserted. While definitions of this sort may be sufficient for use in logical and quasi-logical inferencing, argumentative reasoning requires a more encompassing approach. Argumentative discourse seldom follows a simple premise-conclusion linkage. This can be seen in the following antithetical argument:

Rather than waste time attending classes, Alan bought his diploma on the Internet.

The example is argumentative to the extent that the ground (wasting time attending classes) is intended to increase the reader's positive regard for the situation presented in the claim (buying a diploma on the Internet). In asserting the relevance of the ground to the claim, there need be no implied generalization that anyone who avoids attending classes is likely to buy a diploma on the Internet. For this argument to be instantiated, both the ground and the claim need to be satisfied. The force of the argument is not that one part is used to establish the other, but rather that the parts occur in a significant relationship to one another.

Further, to understand a situation is not simply to comprehend a collection of discrete facts and inferences, but rather to realize how they combine to produce an integrated view within a universe of discourse. Therefore the approach calls not for asserting claims on the basis of grounds, but for instantiating arguments as constituting specific applications of the argumentative form. Moreover, there must be two types of instantiation. The instantiation type is specified as the modality of the argument. One type applies to arguments wherein the claim may be inferred from the ground, and is this called *inferential instantiation*.

The second is applicable to arguments where both ground and claim must be satisfied for the argument to be instantiated. This is called *synthetic instantiation*. EVIDENCE is inferential; ELABORATION is synthetic. In the case of EVIDENCE, the nucleus is inferred from the satellite; in the case of ELABORATION, the satellite simply provides additional information about the nucleus.

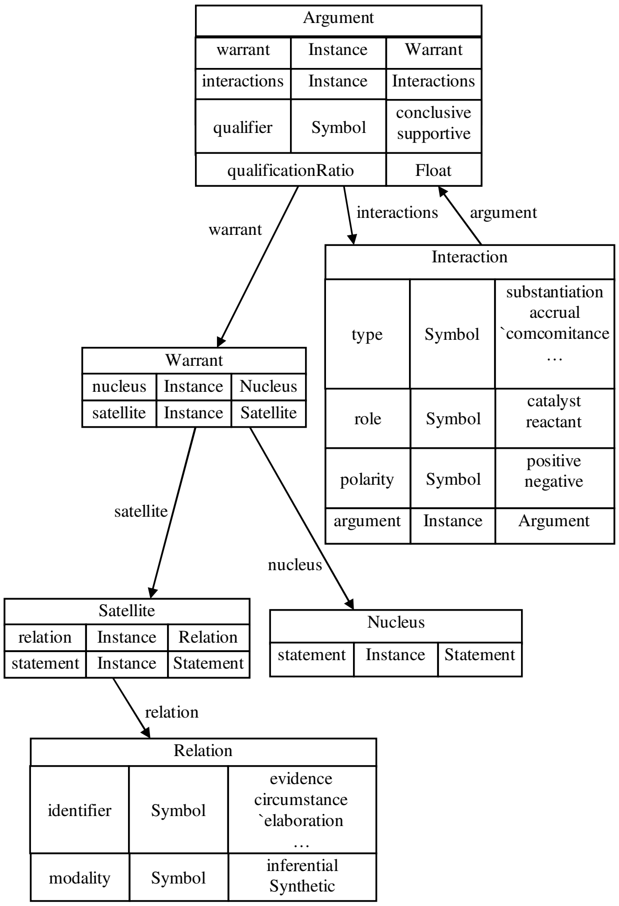

Figure 3: An Argument Ontology

When an argument is satisfied, either inferentially or synthetically, it is instantiated into a rhetorical network. The rhetorical network is a coherent expression of a situation as known to the system. These networks are similar to the inference networks used by Pollock (1995) and the explanation paths proposed by Wærn and Ramberg (2004). When an argument is instantiated, any variables specified in the ground and claim are bound, and the argument is added to the network. The network links are specified in terms of argumentative interactions

Argument Interaction

A rhetorical network is a map of the interactions among arguments. In a process involving multiple argumentative agents, patterns of interaction are likely to be complex. Arguments may conflict with one another by disputing each other's claims, their grounds, or their warrants. They may converge upon a single claim, or, from a single ground, multiple claims may issue forth. Thus, an important consideration is that interactions must be thought of as having a *type*. There are eight types of interaction: *substantiation*, *rebuttal*, *backing*, *undercut*, *dissociation*, *accrual*, *concomitance*, and *confusion*. These are described in detail below.

Other key concepts involved in argument interaction include *locus*, *polarity*, *catalyst*, and *reactant*. The *locus* of interaction identifies the elements of the arguments denoted in the interaction. Some interactions denote claims, some grounds, some combinations grounds and claims, and some combinations of claims and warrants. To provide a clear understanding of the nature of an interaction *type* it is necessary to identify these local elements precisely. Hence every type has a *locus*.

Interactions are typically, but not always, *catalytic*. That is, one argument attempts to influence another, but the favor is not returned. For example, one argument that substantiates another is not itself substantiated by the latter unless the reasoning is circular. Thus, in an argument interaction, one argument may be designated as the *catalyst* and the other as the *reactant*. If the influence exerted by the catalyst is supportive, the *polarity* is *positive*. If the influence is resistant, the *polarity* is *negative*. In some interactions, the influence may be benign, or *neutral*. When one argument substantiates another, the catalyst exerts a *positive* polarity on the reactant. When an argument rebuts another, the catalyst exerts a *negative* polarity on the reactant. With these concepts in mind, it now becomes possible to explore the details of the various interaction types.

Substantiation and Rebuttal. *Substantiation* occurs when the claim of one instantiated argument is used as the ground of another. The first argument substantiates the grounds of the second:

substantiation(**arg**(G_1,C_1,W_1) & **arg**(C_1, C_2, W_2))

The locus of interaction is C_1 and the polarity is positive. The catalyst is the first argument, and the reactant is the second. In *Rebuttal*, the locus of interaction is on the claims made by the interacting arguments. One claim disputes the other:

rebuttal(**arg**(G_1, C_1, W_1) & **arg** (G_2, C_2, W_2))
& **claim**(**incompatible**(C_1,C_2))

The incompatibility may be either logical contradiction or ontologically designated. The polarity of Rebuttal is negative, the catalyst is in the rebutting argument, and the reactant is the argument subjected to rebuttal.

Backing, Undercut, and Dissociation. In Toulmin theory, *Backing* is the policy, law, argument, or fact that supports the warrant. More generally, we may say that Backing is any argument that substantiates a warrant. Thus it is an argument with positive polarity whose locus of interaction resides in the claim of the catalyst and the warrant of the reactant:

backing(arg(G_1,**claim**(W_2),W_1) & **arg(** G_2,C_2,W_2))

Some researchers have used the term *Undercut* to refer to a claim that challenges a warrant (Pollock, 1995; Prakken, 2005). Such a claim challenges the standing of the argument itself; that is, if successful, there is no argument—the ground is no longer a ground and the claim is not longer a claim; rather they are henceforth dissociated units. The term *Undercut*, as used here refers to a less disruptive form of challenge, one in which the catalyst challenges the ground of the reactant and thus undercuts the claim:

undercut(
arg(G_1,**claim**(C_1), W_1) &
arg(**ground**(G2), C_2, W_2) &
claim(**incompatible**(C_1, G_2)

The more severe form of challenge, where a claim challenges a warrant, is referred to here as *Dissociation*, adopting the terminology of Perelman:

dissociation(
arg(G_1,**claim**(C_1),W_1) &
arg(G_2, C_2, W_2) &
claim(**incompatible**(C_1,W_2))

Accrual, Concomitance, and Confusion. In accrual, multiple arguments leading to the same claim, or multiple instantiations of the same argument leading to the same claim, might be expected to collectively strengthen the claim:

accrual(**arg**(G_1,C_1,W_1) & **arg**(G_2,C_1,W_2))

There seem to be two basic forms of accrual. These are *repeatability* and *convergence*. With *repeatability* the mere fact that there is a multiplicity of instances contributes to the persuasiveness of the claim. Repeatability occurs when the warrants of the accruing arguments are the same. These involve multiple instantiations of the same argument. With convergence, the warrants and grounds differ but the claims are the same. Prakken (2005) notes that such patterns do not necessarily strengthen the claim. The effect of accrual seems to be ontological in nature.

Concomitance occurs when two arguments use the same ground to establish distinct claims:

concomitance(
arg(G_1,C_1,W_1) & **arg**(G_1,C_2,W_2))

Concomitance is non-catalytic, and the polarity is neutral. However there may be compatibility issues between the claims.

Confusion occurs when incompatible grounds are instantiated. If either of the grounds is also the claim of some other argument, the condition may more appropriately be handled as an undercut, where one argument disputes the ground of another. However, if neither of the grounds are thus substantiated, then confusion results.

Explanations

Argumentation and explanation are closely allied discourse modalities; the principal distinction is that in argumentation, there is a presumption that the claims presented may not comprise the sole possible interpretation of a situation (Moulin, et al., 2002; Walton 1996); multiple points of view are possible. Thus, a rhetorical network is an argumentative explanation for the claims made by instantiated argumentation. Relational information may be captured in the argument warrant:

warrant(
satellite(G, **relation**(R), **qualifier**(Q)), **nucleus**(C))))

The satellite consists of ground, relation, and qualifier, and the nucleus contains the claim. The relation may be any RST relation. The explanatory power results not only from the use of the rhetorical model, but through use of both inferential and synthetic interaction structures. By this means, explanatory information is contained in the inferred interaction structure. For example, a substantiation structure may be inferred when its catalyst and reactant claims are satisfied. The substantiation then functions as a structured explanation for the reactant argument.

Further, any given claim may be augmented with synthetic support. Through the use of synthetic and inferential argumentation it is possible to assemble a structured explanatory discourse. The basic idea here is that the network is the explanation.

These thoughts may be made more concrete through specific examples. The examples include five arguments using the RST EVIDENCE, VOLITION-CAUSE, JUSTIFY, and CONCESSION relations. They include both inferential and synthetic modalities, and they interact to generate a rhetorical network using the substantiation, rebuttal, concomitance, backing, and dissociation. Thus, while remaining simple, the arguments are representative of the concepts presented in this paper. Figure 4 shows an overview of the rhetorical network. For these examples, we use the ontology presented earlier, represented here as a Prolog clause:

argument(
warrant(
satellite(**claim**(G), **relation**(R,M)),
nucleus(**claim**(C))),
qualifier(Q),

qr(QR),
interactions(I))

Thus, as defined in the ontology, an argument consists of a warrant, a qualifier, a qualification ratio, and a possible set of interactions. The warrant contains the satellite and the nucleus of the argument. The satellite defines the argument ground and its relation and modality with respect to the claim. The claim is defined in the nucleus. The qualifier and qualification ratio will not be discussed in these examples.

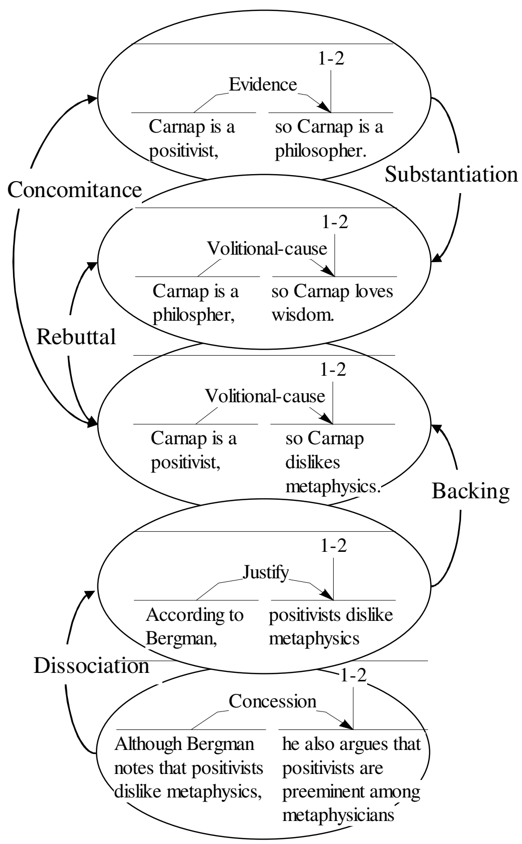

Figure 4: A Rhetorical Network

The first example argues that anyone who is a positivist is probably also a philosopher:

argument(
warrant(
satellite(**claim**(**positivist**(P)),
relation(evidence, inferential)),
nucleus(**claim**(**philosopher**(P)))),
qualifier(probable),
qr(QR),
interactions(I)).

As stated, the argument contends that any instantiated claim that P is a positivist provides probable evidence for the inference that P is a philosopher. Thus, the statement

claim(**positivist**(carnap))

would suffice to trigger instantiation of the argument:

argument(
warrant(
satellite(**claim**(**positivist**(carnap)),
relation(evidence, inferential)),
nucleus(**claim**(**philosopher**(carnap)))),
qualifier(probable),
qr(QR),
interactions(I)).

Note that what is instantiated is the complete argument, not merely the claim. As such, the reasoning process preserves its own structure. Similarly, the second example argues that anyone who is a philosopher certainly also loves wisdom:

argument(
warrant(
satellite(**claim**(**philosopher**(P)),
relation(cause, inferential)),
nucleus(**claim**(**loves**(P, wisdom)))),
qualifier(certain),
qr(QR),
interactions(I)).

Taken together, these two examples offer an opportunity for substantiation, as shown in Figure 4; that is, the nuclear claim of the first argument may be unified with the satellite of the second. Thus, given the original premise that Carnap is a positivist, we are now able establish a line of reasoning that identifies him as a philosopher and a lover of wisdom as well.

The next example reveals further information about positivists; this example argues that anyone who is a positivist undoubtedly also dislikes metaphysics:

argument(
warrant(
satellite(**claim**(**positivist**(P)),
relation(cause, inferential)),
nucleus(**claim**(**dislikes**(P, metaphysics)))),
qualifier(certain),
qr(QR),
interactions(I)).

Given the previous claim that Carnap is a positivist, we may now infer that he both loves wisdom and dislikes metaphysics. Arguably, these claims are ontologically incompatible with one another:

```
incompatible(
   claim( loves( X, wisdom )),
   claim( dislikes( X, metaphysics )))
```

If so, the argument that Carnap dislikes metaphysics rebuts the earlier argument that he loves wisdom, as shown in Figure 4.

The next example illustrates how Backing can be used to affirm warrants. The argument contends that Bergman's claim that positivists do not like metaphysics provides backing to the warrant that positivists do not like metaphysics:

```
argument(
 warrant(
  satellite(
    claim(
      accordingTo(bergman,
        dislikes(positivist, metaphysics))),
    relation( justify,inferential )),
  nucleus(
    claim(
     warrant(
      satellite(
        claim(
          positivist( X )),
          relation( cause,inferential )),
      nucleus( claim( dislikes( X, metaphysics ))))))),
   qualifier( probably ),
   qr( QR ),
   interactions( I ))
```

Using arguments such as this, embedded warrants may be treated as claims, just as any other statement. That is, the argument is no longer about positivists; it is about reasoning about positivists. While meta-talk of this nature is sometimes viewed as a form of topic drift (Potter 2007; Hobbs, 1990), this example illustrates its utility in argument development.

The final example shows synthetic instantiation using the RST CONCESSION relation. This argument links into the rhetorical network using Dissociation, contending that although Bergman concedes that positivists dislike metaphysics, it is also the case that positivists are preeminent among metaphysicians:

```
argument(
 warrant(
  satellite(
    claim(
      accordingTo( bergman,
        dislikes( positivist, metaphysics ))),
      relation( concession, synthetic )),
    nucleus( claim(
      accordingTo( bergman,
        preeminent(
          positivists, metaphysicians ))))),
 qualifier( possible ),
  qr( QR ),
  interactions( I ))
```

Because the argument modality is synthetic, its instantiation requires that both the satellite and nucleus claims must be satisfied in order for the argument to be instantiated. Thus synthetic modalities can be used to amplify explanations with additional information in a non-inferential manner. A synthetic argument, once instantiated, may be mapped into the rhetorical network using rhetorical relations and argument interactions.

Conclusion

The argumentative reasoning theory described here outlines a discourse approach to knowledge representation, explanation, and argument interaction. It is intended to support intelligent human-computer collaboration and inter-agent deliberation. The approach uses the Toulmin model and Rhetorical Structure Theory to define a set of constraints for governing argument interactions and formulation of explanations within an ontologically normalized context. Arguments, when satisfied, are instantiated into a dynamic rhetorical network that represents the system's model of a situation. Two modalities of instantiation are used. Inferential instantiation is used when the claim is inferred from the ground; synthetic instantiation is used for descriptive argumentation where both ground and claim must be satisfied for the argument to be instantiated. The instantiation process maps arguments into the network using interaction links. Defined interactions include accrual, concomitance, backing, substantiation, dissociation, rebuttal, undercut, and confusion.

It is envisioned that communities of agents endowed reasoning capabilities would engage in collaborative explanatory argumentation using argumentative interactions as mechanisms for detecting and managing conflict and agreement. Future research will include completion of the rhetorical network model, definition of evaluation criteria, and development of tools and a multi-agent test bed for modeling and testing. Specific enhancements to the current theory include the use of qualifiers and qualification ratios for managing argument defeasibility. Another possible research direction would be the extension of the ontological model using concepts such as those defined by Newman and Marshall (1991) in their application of the Toulmin model to legal reasoning. This might serve to strengthen the expressiveness of the ontology. In addition, the creation of argumentative knowledge bases for use in manipulating and examining the theory would be of value. Finally, tools for rendering and visualizing rhetorical networks would enhance the usefulness of the theory.

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