A Theory of Argument Coherence

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Abstract

Previous research has suggested different approaches to analyze the coherence of discourses. But these approaches are not suitable to represent the structure of logical arguments. We develop a notion of reasoning relations and argue that it is more appropriate for characterizing argument coherence. Reasoning relations are naturally classified into two types, deductive and rhetorical, based on theories of classical logics and argumentation rhetorics. A set of commonly used relations is described. Ways of employing these relations to restructure and evaluate arguments are discussed. Possible connections between discourse coherence and Discourse Representation Theory are also explored.¹

1. Introduction

One of the most intelligent behaviors of people is their use of natural language. Every day we read newspapers, watch television, and talk with people. All these activities require our understanding of discourses, both long or short, written or spoken. Past researches in philosophy, linguistics, psychology, and artificial intelligence have taken different approaches and contributed different ideas to the study of discourse analysis. A full-scale theory of discourse interpretation must answer several questions. (1) How should knowledge be represented so that it can be used to understand a discourse and new knowledge can be assimilated? (2) What is the mechanism of translating a text in its natural form into the knowledge representation used in (1) as one reads the text, and vice versa, as one is generating a text? (3) How is knowledge used to understand a discourse? (4) How should we interpret a discourse? We will focus mainly on the last question.

When we are reading or listening to a discourse, we may encounter a number of problems. What entities or events are referred to by definite descriptions? How are anaphoric pronouns resolved? What is the connection of a sentence to its context? Examples of researches directed towards some or all of these problems include [Kamp 81], [Hirst 81], [Hobbs 85], [Lockman & Klappholz 80], [Lockman & Klappholz 83], [Alterman 82], [Wada & Asher 86], and [Reichman 85].

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Of particular interest is a *theory of discourse coherence* proposed in [Hobbs 85], and [Lockman & Klappholz 83]. This theory investigates what coherent continuation moves a discourse uses. *Rhetorical relations* are suggested to connect two segments of text together. For example, in the discourse "Al Haig’s never been in politics- he can’t even spell the word ‘vote’" ([Hobbs 85]), the second clause is an *elaboration* of the first one, where "elaboration" is one of the rhetorical relations proposed. Hence the structure of a discourse is represented as a graph with these relations as non-terminal nodes and textual segments as terminal nodes.

Altermann’s *theory of event concept coherence* is also interesting. Instead of capturing the rhetorical relation between segments of a text, this theory proposes seven *event coherence relations* that can be used to represent relevant event concepts as a network. ([Altermann 82]) For examples, "falling" is a *subclass* of "moving", which is an *antecedent* of "hitting". This network can be employed to organize the events mentioned in a text. Given the discourse "I dropped the ball. It hit the ground.", the discourse events of "dropping" and "hitting" will be represented with their connections to the action of "moving" accordingly.

Both the theory of discourse coherence and that of event concept coherence undoubtedly provide valuable insights to the understanding of discourses. Yet even with the relations of both theories, the following simple discourse cannot be represented satisfactorily.

1) Every man is mortal.
2) Socrates is a man.
3) Therefore, Socrates is mortal.

Notice that sentences (1) and (2) are two independent assertions. No rhetorical relations or event coherence relations can characterize this independence precisely. Also, (3) is a natural conclusion of both (1) and (2), but does not follow from any of them individually. Once again, this relation between the conclusion and its two premises, involving three sentences, is not covered by any rhetorical relations or event coherence relations, which are generally binary relations.
The above example exhibits a common discourse pattern. An outstanding characteristic of this pattern is that it sounds reasonable. Being rational is an important quality of our minds and reflected in our languages. A complete theory of discourse coherence cannot afford to leave out considerations of this type of reasoning patterns, which occur frequently in discourses containing arguments.

Well-formed arguments should have clear structures. There are three components in a simple argument: a conclusion, premises, and a reasoning relation. Derivation of the conclusion is the major goal of an argument. To reach this goal, some foundational assertions must be assumed, and reasoning relations employed. Generally, the proposition of the conclusion is not obvious (otherwise the argument is trivial), while the premises are more concrete (otherwise the argument is weak), and the reasoning relation implicit. In the example discourse given above, the conclusion of the argument is "Socrates is mortal". The supporting premises are "Every man is mortal" and "Socrates is a man". The reasoning relations implicit in the argument are substitution and Modus Ponens, which will be explained later. As we have seen, rhetorical coherent relations and concept coherent relations are not suitable to represent argument structures. So we propose a theory of argument coherence as a solution to this problem.

The organization of this paper is as follows. First, reasoning relations will be introduced. Then a procedure to guide the reconstruction of arguments will be discussed, followed by the considerations of evaluation of reconstructed arguments. Next, focus will be turned to a formalism, known as Discourse Representation Theory (DRT), which is developed for the representation of discourses. (Kamp 81) Examples will be given to indicate results of the incorporation of coherence relations into DRT. Toward the end, conclusions will be presented.
2. Deductive reasoning relations

Our basic goal is to understand an argument discourse. As we mention before, a simple argument always consists of a conclusion, its supporting premises, and a reasoning relation that justifies the derivation of the conclusion from the premises. Since reasoning is the key idea behind an argument, it is important to characterize these reasoning relations as clearly as possible.

Reasoning relations can be classified into two types: deductive and rhetorical relations. Deductive relations between premises and conclusions, if used correctly, establish absolute truths of the conclusions given that the premises are true. Rhetorical relations, on the other hand, only suggest plausibility of the conclusions given that the premises are true.

Deductive reasoning relations are commonly used in arguments. Logicians and philosophers have been studying rules of reasoning since the time of Aristotle. Many studies are motivated by the interest in natural languages. In some cases, logicians try to represent natural languages by formal systems and to study arguments in terms of the formalism. These ideas can be applied to the representation of the structure of argument discourse.

A formal logical system generally consists of axioms and rules of inferences. Theorems can be proved by applying inference rules to axioms and other theorems repeatedly, and conjectures can be rejected by constructing a model that contradicts the conjecture. Deductive reasoning relations are like inference rules of a formal system, and an argument for a proposition is like the proof of a theorem. We are going to discuss some inference rules of predicate calculus that are commonly used in argument discourses. These rules can be found in almost any book about symbolic logics, e.g., [Kirwan 78].
2.1. Substitution

Consider the example:

"If an organism performs photosynthesis, then it is a plant.
Coral is an organism.
So, if coral performs photosynthesis, then it is a plant."

In this example, the first two statements are premises and the last is conclusion, and the argument relation is substitution. Since coral is an organism, we can substitute "organism" in the first premise by "coral", since we are given "coral is an organism", and obtain the conclusion. This relation is similar to that of exemplification in [Hobbs 85].

2.2. Modus Ponens

Consider the example:

"If John does not love her, then she will become a nun.
John does not love her.
Hence, she will become a nun."

The first two statements are premises and the third a conclusion, and the reasoning relation is Modus Ponens. Notice that this relation takes three parameters: an implication, its antecedent, and its consequent. This discourse cannot be represented satisfactorily by Hobbs's coherence relations nor Alterman's concept relations, since these relations do not deal with hypothetical assertions.

An argument can involve more than one reasoning step. In such case, it is called a compound argument. Consider the example discourse presented in the introductory section of this paper. Its full argument structure is:

Substitution(Premise: (1),(2) Conclusion: (3))
Modus Ponens(Premises: (3),(4), Conclusion: (5))

where
(1) If an entity is a man, then this entity is mortal.
(2) Socrates is an entity. (tacit proposition)
(3) If Socrates is a man, then Socrates is mortal. (tacit proposition)
(4) Socrates is a man.
(5) Socrates is mortal.

2.3. Modus Tollens

"If the government spends more than a billion dollars on defense, then it must cut education expenses. The government does not cut education expenses. Therefore, the government cannot spend more than a billion dollars on defense."

This relation is called Modus Tollens and is used to conclude the negation of the antecedent of an implication with the negation of the consequence of the implication.

2.4. Rule of equivalence

"Romeo will live if only if Juliet does. Juliet is not alive. Hence, Romeo will not live."

When two propositions are asserted to be equivalent, and the truth value of one of them is claimed, the other must have the same truth value. This is known as the rule of equivalence.

2.5. Modus Ponendo Tollens

"This metal is either sodium or potassium. This metal is not potassium. So this metal must be sodium."

When a statement asserts the truth of exactly one of two alternatives, and the truth of one of them is claimed, the other must have the opposite truth value. This relation is similar to the rule of equivalence and known as Modus Ponendo Tollens.

2.6. Modus Tollendo Ponens

"The pains in the arm of the patient are caused by a heart disease or by rheumatism. The cardiogram shows that there is no heart disease. Thus the pains are caused by rheumatism."

When a statement asserts a disjunction of two claims, and one of them is stated to be
false, then the other must be true. This relation is Modus Tollendo Ponens.

2.7. Regular Dilemma

"We will elect a Republican or a Democrat as president.
If a Republican is elected, military spending will be increased.
If a Democrat is elected, welfare spending will be increased.
So either military or welfare spending will be increased."

When a disjunction of two claims is asserted, and each disjunct implies some event, one of the consequent events must be true. This relation is known as regular dilemma.

2.8. Analytic Dilemma

"You are damned if you do.
You are damned if you do not.
Therefore you are damned."

When there are two implications whose consequences are identical, and whose antecedents are negations of each other, the common consequence must be true. This relation is a special case of regular dilemma and known as analytic dilemma.

2.9. Redundancy of an alternative

"John or Mary knows the secret.
If Mary knows the secret, then John knows the secret.
Thus, John must know the secret."

When a disjunction of two assertions is claimed, and one of the assertions implies another, the latter assertion will be true. This relation is called redundancy of an alternative.

2.10. Logical and illogical reasoning relations

The above relations considered are often used in arguments and should be very helpful for representing argument structures. Their major strength is that they establish the truth of the conclusions if all premises are true. These relations are actually meta-theorems of predicate calculus. As there are other meta-theorems in addition to those given above, they form deductive reasoning relations as well. But the ones given above
are most commonly used and should provide a useful guide for detecting an argument structure.

Since there exist infinitely many meta-theorems in addition to those considered here, we have infinitely many reasoning relations. That means the reasoning relations presented are far from being complete. This presents a problem. If a reasoning relation in an argument does not match any of our reasoning relations, how would one determine the validity of the relation?

Consider the example

"If Satan exists, there is evil.
There is evil.
Thus, Satan exists."

This argument is a fallacy because the reasoning is not logical. This is obvious by contrasting with a similar but more obviously bogus reasoning:

"If three equals four then the sun will shine.
The sun is shining.
So three equals four."

This sham reasoning relation can easily be confused with Modus Ponens so extra care must be taken. There are other ways of using illogical reasoning. Common forms of fallacies are easier to be detected than novel ones. A general heuristic of detecting illogical reasoning is to find counter examples of the reasoning relation used. Consider another example (Schwartz p.149)

"All communists are atheists.
Madelyn is an atheist.
Therefore, Madelyn is a communist."

From the first premise of the example, we know it is possible that atheists form a proper subset of communists, i.e., some atheists are not communists while all communists are atheists. So Madelyn may be a non-communist atheist. From this we conclude that the given argument is not valid.
3. Rhetorical reasoning relations

Reasoning relations are used to characterize argument structures. In the last section we have considered deductive reasoning relations. Although they are commonly employed in arguments, there are also many arguments that are not as formal as we want them to be. These less formal, non-deductive arguments, form a class of rhetorical reasoning relations, which include notions of generalization, analogical reasoning, making general and specific conjectures about cause and effect, and labelling. From a different perspective, they are like the elaboration of the relations "cause", "enablement", "generalization", and "explanation" proposed in [Hobbs 85]. Below we will examine members of this class by summarizing the ideas of [Eisenberg & Ilardo 72].

3.1. Generalization

"I have known four Frenchmen. Each of them likes French bread. So, every Frenchman likes French bread."

By Generalization, a general proposition is concluded from specific instances. ([Eisenberg & Ilardo 72], p.45) This, the converse of the deductive relation of "substitution", is like turning some constant into a variable in a mathematical expression. The argument is convincing if: (1) the examples are typical, and (2) the body of examples considered is large.

3.2. Comparison

"A subway system has improved the traffic situation in San Francisco. Therefore, it will also work for Austin."

([Eisenberg & Ilardo 72], p.46) Reasoning by comparison involves three steps. First, facts are observed. Second, two similar entities or events are compared. Third, knowledge from a more familiar entity (or event) is transferred to the other which is less familiar. This reasoning method is convincing if: (1) the facts are established, and (2) significant similarities outweigh significant dissimilarities in the things compared.
3.3. Figurative analogy

"Vietnam is a puppet of Russia. Hence, it will obey orders from Russia to stay in Cambodia."

([Eisenberg & Ilardo 72], p.47) *Figurative analogy* is like comparison, except that the two situations compared are not literally, but metaphorically similar. This is a weak form of argument in general. The criteria of soundness of argument are the same as those of reasoning by comparison.

3.4. From effect to cause

"Our cat always makes strange noises a day before an earthquake occurs. So earthquake is the cause of our cat's unusual behavior."

Argument *from effect to cause* proceeds from observed data to conclusion about a causal relationship between them. ([Eisenberg & Ilardo 72], p.48) Not all such arguments are acceptable because causal relationships can be quite intricate. There are several criteria for judging the soundness of this type of reasoning. (1) If an effect emerges when a certain factor is present but fails to emerge when the same factor is absent, then that factor is either the cause or a contributing cause of the effect. (2) No factor can be a cause in whose presence the effect fails to occur. (3) No factor can be a cause in whose absence the effect occurs. (4) If an effect changes at the same time with the variations in a certain factor, then that factor is probably the cause (or a contributing cause) of the variation in the effect.

3.5. From cause to effect

"Federal control of the contraceptive industry will result in lowered manufacturing efficiency, because whenever a government controls an industry, lower efficiency results."

([Eisenberg & Ilardo 72], p.49) Reasoning *from cause to effect* involves the prediction of some event based on generalization from past instances. This form of argument is sound if: (1) the causal generalization is reasonable. (2) the facts of the case fit into the broad class of events and occurrences dealt with by the causal generalization. (3) there
are no factors present that would hinder the operation of the causal generalization.

3.6. From criteria to labelling

"Jones is a dictator in his family, because he always vetoes the demands of his wife and children."

([Eisenberg & Ilardo 72], p.51) Reasoning from criteria to labelling results in the application of a label to the situation in question, based on some observed data. This is the converse of reasoning by figurative analogy. This type of argument is convincing if: (1) the elements in the definition of the label are valid, clear, complete, and acceptable, (2) the data actually fit the definition of the label, and (3) the facts are established.

3.7. From circumstantial evidence to an hypothesis

"The airplane has disappeared from the radar scope, and radio contact with it has been broken. Therefore, it probably has crashed."

([Eisenberg & Ilardo 72], p.52) Reasoning from circumstantial evidence to an hypothesis results in a specific conjecture that explains the evidence. Notice that the hypothesis is not generalized, so this is a special case of reasoning from effect to cause. This form of argument is sound if: (1) the hypothesis accounts for all the data, (2) there is no available information contradicting the hypothesis, and (3) No other hypothesis is equally or more probable than the one advanced.

3.8. Detection of reasoning relations

To interpret an argument discourse, we need to identify its reasoning relations. This is a problem since these relations are seldom explicitly stated. The relations covered in this and the previous sections provide a top-down guide to solve this identification problem.

Together with deductive reasoning relations, rhetorical reasoning relations are the inference rules people use for arguments. The former relations are relatively easy to detect since they have certain syntactic patterns. The most helpful clues are the presence of logical connectives such as "or", "and", "either or", "if and only if", "one
of two cases", "not", etc.

On the other hand, detection of rhetorical reasoning relations needs more world knowledge, e.g., the notions of typicality in a class; similarities and dissimilarities between two events (or entities); causal relationships; definitions of abstract labels; notions of circumstantial evidence and hypothesis. Assumptions of world knowledge in different representations such as event coherence relations, semantic relations, scripts, and conceptual dependencies can be used for this detection problem.

4. Reconstruction of argument

A full understanding of an argument discourse requires a systematic approach to reconstruct the argument in the discourse. We have shown in previous sections that an argument is the derivation of some conclusion from certain premises with reasoning relations. The process of reconstructing an argument is the task of identifying its conclusion, premises, and reasoning relation. If an argument has these components, then it is coherent.

Since the reasoning relation is usually hidden in an argument discourse, each proposition of the discourse can first be assumed to be either a premise or a conclusion. Later, a proposition can be considered extraneous to the argument if the proposition is not related to any part of the discourse by any reasoning relation.

There are clues to distinguish between a premise and a conclusion. The first one is the presence of key terms. A conclusion is frequently preceded by terms such as "therefore", "so", "as a result", "hence", "accordingly", "thus", etc. A premise is often preceded by terms such as "because", "due to the fact", "reason", "backed by", "provided", etc. The second clue is the order of the statements in a discourse. If there are no signal terms, then the conclusion is usually preceded by premises. The third one is the semantics of an argument and the world knowledge that is assumed. If the reasoning relation of an argument is clear with respect to the context and the world knowledge, the distinction between conclusion and premises is still clear even though no signal terms are expressed and the default order of argument statements is reversed.
To identify a premise which is not explicit in an argument is problematic. Like the fact that reasoning relations are almost always implicit, premises are sometimes assumed. There are various explanations for the author to leave the assumptions tacit. First, the author may assume that readers are aware of the truth of these assumptions. Second, he may be trying to turn away the readers' attention from these assumptions, which may be bogus. Third, it may just be his careless mistakes that these tacit premises are missed. Whatever the reasons of assumptions, we need to identify these missing parts of an argument during its reconstruction if we are to understand it clearly.

[Schwartz 80] (p.135) offers a general guideline for the reconstruction of an argument:

1. Standardize the argument, putting its explicit premises and then conclusion in order; express each premise as a fully declarative sentence with a clear logical form and delete all irrelevant parts.

2. Test the reasoning relation for validity.

3. If it is not valid, try to provide validating premises.

Let us consider several examples to see how this procedure can be applied.

(1) "This is what I think of the Electoral College:
Its members are either useless or dangerous--useless if they do their job, dangerous if they don't."

( [Schwartz 80p.137])

After turning the premises into complete declarative sentences, resolving the pronoun "they", and reordering the premise and conclusion, this argument can be reconstructed as:

"The members of the Electoral College are useless
if they do their job.
The members of the Electoral College are dangerous
if they don't do their job.
Therefore, by the reasoning relation of regular dilemma,
the members of the Electoral are either useless or dangerous."
(2) "We should go to war no more, whatever the provocation,
since the costs always outweigh the benefits." (Schwartz p.138)

By omitting the extraneous "whatever the provocation", expressing the referent of the
last clause as war, reordering the conclusion and premise, and supplying a tacit premise,
the reconstruction of the argument is:

"The cost of going to war always outweigh
the benefits of going to war.
We should not participate in activities whose costs outweigh
whose benefits. (tacit premise supplied)
So, by Modus Ponens, we should not go to war."

Often a discourse contains a compound argument, which involves more than one
reasoning step. In this case, a sub-argument first establishes a conclusion which then is
used as a premise for another sub-argument. Consider the discourse

"Because standard IQ tests are culturally biased,
they are discriminatory.
That makes it unconstitutional to use them in public schools."
(Schwartz p.140)

A reconstruction of the argument results as:

(1) Standard IQ tests are culturally biased.
(2) Tests that are culturally biased are discriminatory.
    (tacit premise)
Therefore, by Modus Ponens with (1) and (2),
(3) Standard IQ tests are discriminatory.
(4) Tests that are discriminatory are unconstitutional.
    (tacit premise)
Therefore, by Modus Ponens with (3) and (4),
(5) It is unconstitutional to use standard IQ tests in
    public schools.

From the above examples, we can see how argument reconstruction clarifies the
structure, confirming or disapproving the reasoning relation involved. But as far as
determining the validity of the whole argument, we are not done yet, because the
premises of the argument may be false or not. To validate the whole argument, the
premises must be true, in addition to the soundness of the reasoning relation used. Nevertheless, the reconstruction process has improved the clarity of the premises by turning them into standard logical declarative form and bringing tacit premises out of the closet. This should facilitate the process of evaluating the premises.

5. Evaluation of argument

We are bombarded with arguments every day. Some of them may be persuasive enough to change our opinions. But many of the arguments are not as convincing as they sound, if we are willing to think about them twice.

In previous sections, we have addressed the problem of argument interpretation and shown how argument structure can be obtained and represented. Now we can take a further step to tackle the problem of argument evaluation. Below, we will discuss the problems encountered during this process.

5.1. Questioning of premises

Consider the political problem in Hong Kong. People in this city are concerned about the return of the British colony to the People's Republic of China in 1997. And someone comes along and says (1) this political situation must be the fault of either Britain or PRC. After arguing that (2) Britain cannot do anything but to listen to the demand of PRC and so is innocent, the person concludes that (3) the fault must lie in PRC. Notice that the reasoning relation used is Modus Tollendo Ponens (refer to Section 2), since it fulfills the requirement that (1) one premise uses an "exclusive or" relation between two assertions A and B, (2) assertion (not A) is claimed, and (3) B is concluded. A close look at this argument reveals sources of weaknesses or fallacies. A major weakness lies in the first premise. The political situation in Hong Kong may be due to the fault of both Britain and PRC, or Hong Kong, or the Chinese government or British government in the late 19th century, etc. Also, the assertion that Britain is innocent may be invalid. So one needs to justify the evidence before being convinced about the conclusion.
5.2. Nature of propositions

Difficulty of evaluating the evidence used in an argument lies in the nature of propositions. A proposition can fall under one of three classes, depending whether it is about a fact, value, or policy. (Eisenberg & Ilardo 72, p.26) These classes represent different levels of abstractions. The more abstract a proposition is, the more elaborate and complicated its argument will be.

Facts are relatively easy to argue about. For examples, "the sun is the center of our planetary system"; "the car is parked illegally"; "this is a telephone." A fact statement asserts a natural phenomenon, a historical event, or attribute a commonly recognized name or materialistic property to an object. Many researches done on natural language processing deal mainly with fact statements. This supports the observation that treatments of facts are less problematic than those of value and policy.

A proposition of value is built on subjective feelings and emotions. For examples, "Ronald Reagan is a conservative president"; "love is beautiful"; "this symphony is very pleasant". A value statement in general contains some abstract terms such as "conservative", "love", "beautiful", "very pleasant". These terms are subject to personal affects and tastes and are very difficult to define. Hence argument for or against propositions of value are more problematic for evaluation than those of facts.

A proposition of policy is a proposition of value that calls for actions to be done. For examples, "Texas should collect state taxes to make up loss of revenue due to dropping oil prices"; "fewer restrictions and tariffs on international trade benefit the participating countries"; "the province of Quebec should be separated from the Dominion of Canada and become an independent country". These types of propositions are very common in political debates in Congress, campaigns for elections, and newspaper editorials. They are even more challenging to argue about than propositions of value since actions are demanded in the propositions.
6. Discourse Representation Theory

Reasoning relations are high-level abstractions of argument structures. If we want to implement this theory of reasoning relations, we need a formal language to represent discourses. In ([Kamp 81]), Kamp proposed a representational language for discourses known as the Discourse Representation Theoretical Theory (DRT). This theory has been shown to be able to solve certain cases of contextual relations which have puzzled linguists and logicians for a long time. ([Guenthner, Lehmann, & Schonfeld 86]).

A major task of DRT is to translate natural language texts into discourse representation structures (DRSs), which are like sentences of predicate calculus. The description of DRS construction algorithm is given in both [Wada & Asher 86] and [Guenthner, Lehmann, & Schonfeld 86]. A DRS generally has reference markers to refer to individual entities, event markers to refer to individual actions, instantiated predicates, and other discourse structures embedded in it. Each reference marker has its own scope and is accessible only within its scope. This helps to resolve pronominal reference problems within a sentence and between sentences of a coherent discourse. ([Wada & Asher 86]) Another type of markers, event markers, are used to indicate the temporal relations between different actions. ([Guenthner, Lehmann, & Schonfeld 86])

Since deductive reasoning relations often occur in argument discourses, a representation language that can readily denote logical relations is desirable. [Guenthner, Lehmann, & Schonfeld 86] has shown the notation used in DRT is closely related to standard predicate logic. Hence DRT should be a nice representation language for argument discourse.

We have said before that every coherent discourse has structure. In the current form of DRT, a notion of coherence is anaphora resolution. A discourse is coherent if its pronominal references can be resolved. But we have already discussed other notions of coherence such as Hobbs's and Lockman and Klapplholtz's theory of rhetorical coherence, Alterman's theory of event concept coherence, and the theory of argument coherence developed in this paper. These theories try to account for the relations
between segment (or event) units of a text and explicitly represent these relations as part of the structure of the text.

Assume we want to write programs to analyze texts and answer questions about the texts, using the theories of argument coherence, rhetorical coherence, and event coherence. Should DRT be used as a representational language for this purpose? At this stage, we are not ready to address this question in detail. But we will look at several examples of incorporating coherent relations to DRT to gain insights to the question.

Consider an example adapted from [Guenthner, Lehmann, & Schonfeld 86]:

"The car ran off the road. It hit a lamp post."

After resolving the pronoun "it", the following DRS results:

\[
\begin{align*}
&[ u_1, u_2, e_1, e_2: \\
&\quad \text{car}(u_1) \\
&e_1: [\text{run off the road}(u_1)] \\
&\quad \text{lamp post}(u_2) \\
&e_2: [\text{hit}(u_1, u_2)] \\
&\quad e_1 < e_2 
\end{align*}
\]

With Alterman's concept coherence relations ( [Alterman 82])

\[
\begin{align*}
&[\text{subclass MOVE RUN ...}] \\
&[\text{antecedent HIT MOVE ...}]
\end{align*}
\]

embedded in DRT, the following DRS results:

\[
\begin{align*}
&[ u_1, u_2, e_1, e_2, e_3: \\
&\quad \text{car}(u_1) \\
&e_1: [\text{run off the road}(u_1)] \\
&\quad \text{lamp post}(u_2) \\
&e_2: [\text{hit}(u_1, u_2)] \\
&\quad e_1 < e_2 \\
&e_3: [\text{move off the road}(u_1)]
\end{align*}
\]
ANTECEDENT(e2,e3)
SUBCLASS(e3,e1)]

Notice that in the DRS, the event "e3" is not explicitly mentioned in the given text. Instead, it is inferred from the events mentioned in the text using the event coherence relations between "running" and "moving", and between "hitting" and "moving".

With Hobbs' rhetorical coherence relation of elaboration (Hobbs 85) embedded in DRT, the following DRS results:

[ u1,u2,e1,e2:
car(u1)
e1: [run off the road(u1)]
  lamp post(u2)
e2: [hit(u1,u2)]
e1 < e2
ELABORATION(e1,e2)]

Now consider the argument discourse:

"John does not love Mary.
So she will become a nun."

With the deductive reasoning relation of Modus Ponens added into DRT, the following DRS, after resolving the pronoun "she", results:

[ j,m,u1,e1,e2,e3:
j=John
m=Mary
e1: not(love(j,m))
nun(u1)
e2: will become(m,u1)
e3: [e1 -> e2]
MODUS PONENS((e1,e3),e2)]

Notice that event "e3" is a tacit premise used in the given argument. It is supplied during the reconstruction of the argument.
The above examples indicate what discourse representation structures may look like after the incorporation of discourse coherent relations into DRT. Such incorporation can help to clarify the structure of discourses. But it would also increase the difficulty of the process of DRS construction, and the resulting DRSs, having more reference and event markers, would become more complex. These preliminary observations do not lead us to any definite conclusion about whether coherence relations should be embedded in DRT. Much research is needed to investigate the theories of discourse coherence and to explore possible expansions of DRT in this direction.

7. Conclusion

As Hobbs’s theory of discourse coherence is based on the rhetorical structure of a discourse, our theory of argument coherence is based on the reasoning structure of an argument. Coherent relations suggested by Hobbs and Alterman are not suitable for the representation of argument structures. So the notion of reasoning relations is developed, based on theories of classical logics and argumentation rhetorics.

Since reasoning used in natural language arguments can be deductive or persuasive, our reasoning relations are separated into two classes: deductive or rhetorical. The former are like meta-theorems of first order logic. They establish the truth of the conclusion provided the premises are true. The latter are common in arguments for abstract propositions. They establish the plausibility, rather than truth, of the conclusions.

A simple argument is coherent if it has a well-defined structure composed of premises, conclusion, and reasoning relation. A compound argument is coherent if it consists of simple coherent arguments, where the conclusion of a sub-argument is used as a premise for other sub-arguments. To interpret an argument discourse, we need to reconstruct the argument properly. All statements should be in formal declarative form. Premises and conclusions should be distinguished and related by reasoning relations. Tacit premises and conclusions, and reasoning relations should be represented explicitly. Extraneous segments should be deleted. This clarifies the argument and facilitates
further evaluation.

Arguments can be judged to be sound or not. Difficulties of the evaluation of arguments occur in several dimensions. First, the reasoning relation may be invalid. Second, the premises may be wrong. Third, propositions, no matter whether a premise or conclusion, can be abstract and subject to personal feelings and emotions, and so hard to justify.

Logical terms are used heavily in argument discourses. Discourse Representation Theory has a formal basis and is suitable for representing logical propositions. So DRT is suitable to represent argument discourses. But it is not clear if reasoning relations, as well as rhetorical, and event coherence relations, should be represented in DR Structures. It is an open research question that is worthwhile to be pursued.

We have seen that a text can be measured with three standards of coherence: rhetorical coherence, event coherence, and argument coherence. There are no conflicts among these three theories, rather they focus on different aspects of the discourse structure. Rhetorical coherence relations refer to the rhetorical moves a discourse can take. Event coherence relations represent the taxonomic, partonomic, and temporal relations among event concepts. Reasoning relations are the implicit inference steps in deriving conclusions from premises in an argument. All of these relations contribute to the understanding of discourses and should form complementary parts of a full-blown theory of discourse interpretation. Such a unified theory can be expected, if we keep on working towards this goal.

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