An Empirical Methodology for Determining a Set of Coherence Relations

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Abstract

Coherence relations have proved a useful tool in recent computational models of discourse. However, there is much disagreement between theorists about which set of relations to use, and also between analysts working within a particular theory as to how to analyse individual texts. These difficulties arise from the fact that present conceptions of relations lack a solid empirical basis.

This paper describes a new methodology for determining a set of relations, whose starting point is a conception of relations as modelling **psychological constructs**. It is argued that evidence for these constructs can be sought in a study of the **cue phrases** that can be used to signal them in surface text.

Introduction: Coherence Relations

Many recent computational treatments of discourse make use of the notion of **coherence relations** to model the structure of text. Coherence relations have names like EVIDENCE, ELABORATION and SEQUENCE; they are taken to apply between two (typically adjacent) text segments, and they represent what must be understood by a reader over and above what is contained in each individual segment. For instance, consider the text in Figure 1: in addition to understanding

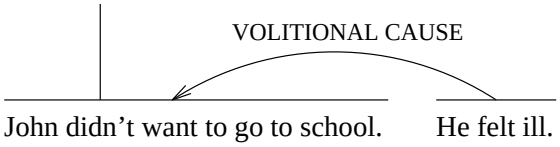

Figure 1: Two Text Spans Linked by a Coherence Relation

the two sentences in this text, the reader must appreciate that the state described by the second sentence causes that described by the first. This extra information is represented by the VOLITIONAL CAUSE relation. In the present case, the relation must be inferred by the reader from general knowledge about feeling ill, going to school, and so on. However, the writer could also have chosen to signal it more explicitly, using a **cue phrase** such as *because* or *since*.

Although coherence relations have featured for some time in theories of discourse, the first expressly 'computational' theories were put forward by (Hobbs 1985), (Grosz & Sidner 1986) and (Mann & Thompson 1988). The hierarchical, recursive model of relations put forward in these theories has recently found application in a growing number of text planning systems; for instance those proposed by (Hovy 1988) and (Moore & Paris 1989). It has also featured in several computational accounts of discourse interpretation, such as (Lascarides & Asher 1991), (Hobbs *et al.* 1993). In short, the concept of coherence relations forms the basis for an active research programme in computational linguistics.

Despite the widespread appeal of coherence relations, a number of problems with them remain outstanding. One concerns how to determine which relations are present in a given text; the other concerns how to decide on the *set* of relations in terms of which texts are to be analysed. Both problems stem from the lack of a well-defined empirical basis for relations. In this paper, an empirically founded conception of relations is presented which addresses both problems, identifying a clear theoretical role for relations, and grounding them in an account of surface textual phenomena.

Two Problems for Theories of Relations

A First-Order Problem: Analysing Individual Texts

Analysts often disagree about the relations which should be used to describe a text, even if they are both working within the same theory. For instance, the text shown in Figure 1 is analysed using VOLITIONAL CAUSE, one of Mann & Thompson's relations—however, their ELABORATION relation gives an alternative plausible analysis. Does it matter which of these relations is chosen? If so, how are we to justify our choice?

The problem is not with multiple analyses *per se*, but with the means used to support a given analysis. At present, theories of relations rely heavily on the theoretical intuitions of discourse analysts. For instance, Mann & Thompson's ELABORATION relation applies if, in the analyst's opinion, 'the reader recognises the situation presented in the second sentence as providing additional detail for that presented in the first'. Making such a decision about a text is quite different from simply reading it; it calls for introspection about the reading process, and this issue raises a number of problems.

For one thing, there is no obvious way to resolve a conflict between two analysts who come to different conclusions. Mann & Thompson suggest (p30) that analysts with more experience are more likely to come to a consensus than novices. But this could just mean that they are able to agree about *a way* of analysing texts; not necessarily the right way.

More importantly, 'analysing a text' is a process quite far removed from simply reading it. During ordinary reading, for instance, the question of whether one span 'elaborates' on another is seldom if ever asked in so many words. Some computation of this sort must clearly be made, but it is not something that a reader must typically be *conscious* of. Clearly, readers' intuitions of text structure count as some kind of data to be explained. However, it would be preferable to obtain data from tasks more closely associated with everyday reading and writing.

A Second-Order Problem: Deciding on a Set of Relations

A more fundamental confusion surrounding coherence relations concerns the many different *sets* of relations which appear in the literature. Many theories propose a set of coherence relations, but different theories propose quite different sets. The number of relations in alternative sets ranges from 2 (Grosz & Sidner 1986) to over 150 (Hovy *et al.* 1992). The primitives used to define relations also vary widely; for instance, Grosz & Sidner envisage relations as holding between the intentions underlying text segments, while Hobbs defines his relations in terms of the types of inferences a reader must make in interpreting a text. And the diversity amongst sets of relations increases still further when they are implemented in discourse processing systems, as new relations are created and existing ones redefined.

Needless to say, this situation makes for a great deal of confusion. From a practical point of view, the lack of consensus leads to problems of compatibility: it is hard to compare one system with another, and hard to combine systems which execute different stages of a discourse processing task. From a theoretical point of view, serious problems are also raised. If it does not matter which set of relations is used, we begin to wonder whether they do indeed represent *real phenomena* underlying a text, or whether they provide an entirely arbitrary way of describing it. The need for a standard set of relations, already noted by (Hovy 1990), is greater than ever.

A Methodology for Motivating Relations

The study of coherence relations is clearly an area which would benefit from greater attention to methodological issues. Relations are obviously useful constructs; but they are often appealed to without a clear idea about what they represent, and without a clear decision procedure for how to use them.

This section describes the results of a study which proposes a clear empirical role for relations, and a methodology for investigating them based on an analysis of the cue phrases in a language.

An Empirical Conception of Relations

In discussing how a linguistic theory should be assessed, (Chomsky 1964) distinguished between **descriptive** and **explanatory** adequacy. Essentially, a theory which not only describes the set of well-formed sentences but explains *why* people tend to produce such sentences is to be preferred over a theory which only accomplishes the former task. Similar criteria can be envisaged for theories of discourse. Ideally, a theory of relations should do more than just describe the space of coherent texts; it should contribute to an account of why coherent texts are the way they are. And since texts are created by human writers, for human readers, it makes sense to expect relations to tell us something about the psychological processes underlying their creation and interpretation.

In what follows, relations will be thought of as modelling a standard set of strategies used by readers and writers to reduce the complexity of the text processing task. Studies of skill acquisition frequently suggest that skilled performance is achieved through the operation of a set of specially developed mechanisms (see (Snyth, Morris, & Levy 1987) pp82–96); since reading and writing are highly skilled tasks, similar mechanisms are likely to govern their performance. For each task, relations can be thought of as constraining the search process—for writers, they would help in accessing relevant content from memory; for readers, they would help in generating hypotheses about what is coming next.

Given this model of relations, deciding which relations to include in the set becomes a matter of empirical investigation. How might we discover which relations are actually involved in human text processing? While it is conventional to investigate psychological constructs by means of behavioural experiments, this paper argues that in this case, they can be studied by looking at the linguistic expressions that are used to signal them. The argument, presented in (Knott & Dale 1994), can be summarised as follows.

In the proposed psychological model, relations are operative in both reading and writing—they provide an intermediate level of representation for both tasks. It thus makes sense to talk about relations actually being *communicated* at some level from a writer to a reader; it is through them that the communication of ideas and goals is effected. Hence the relations in a text *actually matter*: they are not just a useful tool for discourse analysts.

Given this fact, it is likely that writers have at their disposal the means to signal relations explicitly. (While a reader may often be able to infer a relation from context or background knowledge, no relation will *always* be thus inferrable; its 'inferrability' depends on the situation in which it is used, rather than on how it is defined.) Therefore, the devices used to signal relations can be used as evidence in a study of the mechanisms underlying reading and writing.

A Taxonomy of Cue Phrases

When studying the devices used for signalling relations, the set of cue phrases is an obvious starting point. In the present study, a corpus of some 150 cue phrases has been gathered, using a pre-theoretical test which identifies a heterogeneous set of sentence/clause connectives. These have been organised into a taxonomy using a second test for **substitutability**, in which a reader is presented with one cue phrase X in a certain context and asked whether (s)he, as a writer, would be prepared to replace it by another cue phrase Y. For example, in the context below, the phrase *so* can be substituted by *therefore*, but not by *because*:

(1) It was a hot day, $\left\{ \begin{array}{l} so \\ \surd\ therefore \\ *\ because \end{array} \right\}$ they ate outside on the patio.

Note that the asterisk does not necessarily signal *ungrammaticality*: only a lack of substitutability for the original phrase.

There are four possible substitutability relationships between two phrases X and Y:

- X and Y are **synonymous** if in any context where one can be used, the other can also be used.
- X and Y are **exclusive** if they can never be substituted for one another in any context.
- X is a **hypernym of** Y—and Y is a **hyponym of** X—if whenever Y can be used, so can X; but there are some contexts where X can be used and Y cannot.
- X and Y are **contingently substitutable** if there are some contexts where they can be substituted, other contexts where X can be used and not Y, and still other contexts where Y can be used and not X.

The taxonomy is presented in the form of a **substitutability diagram**; a modified kind of directed acyclic graph, with cue phrases at its nodes. A legend is given in Figure 2.

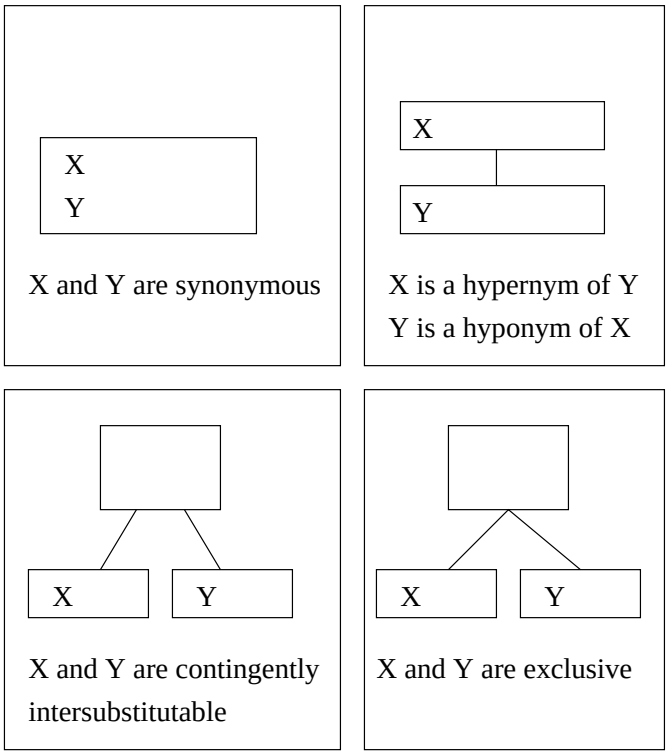

Figure 2: Diagrammatic Representation of Substitutability Relationships

The taxonomy depicts the substitutability relationship between every pair of phrases in the corpus—over 10,000 relationships in total. In representing all of these, extensive use is made of inheritance; any relationship which is true of one phrase is true of all its hyponyms. Thus in Figure 3 (i), D is a hyponym of B, so by inheritance, D is a hyponym of A and exclusive with C. Note that the an inherited contingent substitutability relationship can be overridden, as in 3 (ii) where R and S should be interpreted as exclusive.

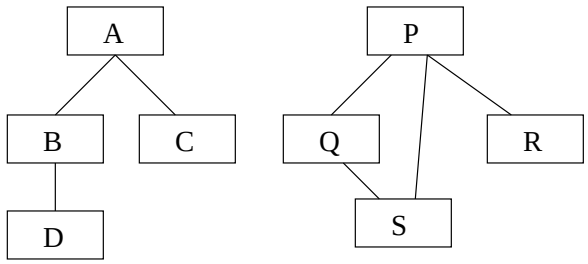

Figure 3: Inheritance in Substitutability Diagrams

The complete taxonomy, given in Knott (Knott 1995a), is too large to be presented here. However, some of its interesting characteristics can be noted:

- The taxonomy is moderately hierarchical. Chains of 2 or 3 hyponymic nodes are fairly common. The 'most general' cue phrase is *and*, which has 33 hyponyms.
- The taxonomy does not divide neatly into large exclusive subgroups of phrases. For any candidate grouping, many phrases can be found which fit into more than one group.
- Since the taxonomy has no strong macrostructure, most of the variation between cue phrases is represented at a relatively low level, close to the leaf nodes.

Motivating Relation Definitions from the Taxonomy

Before the taxonomy can be used to motivate relation definitions, one apparent problem must be addressed. The rationale for using cue phrases as evidence for relations was that they were likely to signal relations explicitly to a reader. But why, in that case, do we ever use 'general' phrases like *and*, which are patently ambiguous?

A plausible response is that a general cue phrase only signals *some features* of a relation; and that it is used in contexts where the other features of the relation are readily inferrable by the reader. The existence of general phrases can then be explained in Gricean terms: they are a means of avoiding redundancy when communicating relations, by not telling the reader what (s)he already knows. Indeed, the relationships in the taxonomy readily admit of a feature-theoretic interpretation:

- If X is **synonymous** with Y, then they signal identical features.
- If X is **exclusive** with Y, then they signal *different values* of at least one feature.
- If X is a **hyponym** of Y (and Y is a **hypernym** of X), then X signals all the features that Y signals, and *some other* feature(s) in addition, for which Y is undefined.
- If X and Y are **contingently substitutable**, then X and Y signal some of the same features, but in addition X is defined for a feature for which Y is undefined, and Y is defined for a feature for which X is undefined.

These new interpretations allow us to use the taxonomy to investigate the features into which relations decompose. For instance, consider the extract given in Figure 4: here, *whereas* and *then again* are represented as exclusive phrases, with *on the other hand* as a common hypernym. Evidence for these relationships is given below:

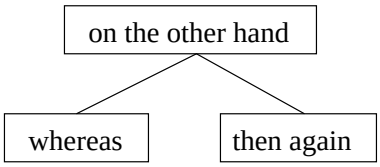

Figure 4: Some 'Contrastive' Cue Phrases

(2) Bill and Bob are very different.
Bill is tall; { *whereas* / ✓ *on the other hand* / * *then again,* } Bob is short.

(3) I don't know whether Spurs will win tonight.
They're on good form; { *then again,* / ✓ *on the other hand* / * *whereas* }
United are also playing well these days.

All of these phrases signal a contrast of some kind. However, while *whereas* contrasts the propositional content of two spans, *then again* is used in cases where conflicting arguments are to be presented. In Example 2 the contrast is between the predicates of tallness and shortness. In Example 3, it is between the conclusions one might draw from the two propositions.

The exclusivity between *whereas* and *then again* can be used to motivate a feature with alternative values of, say, 'PROPOSITIONAL' and 'ARGUMENTATIVE'. In fact, this distinction is very reminiscent of one found in several previous papers; for instance SEMANTIC and PRAGMATIC (Sanders, Spooren, & Noordman 1992), INFORMATIONAL and INTENTIONAL (Moore & Pollack 1992)). *On the other hand* can then be interpreted as undefined for this feature.

A second extract from the taxonomy is shown in Figure 5. This diagram is slightly more complex, cataloguing a total of six relationships (excluding those of synonymity). *Meanwhile* and *when* are exclusive, as are *meanwhile* and *after*, and *when* and *after*. *After* is a hyponym of *when*, and *meanwhile* is a hyponym of *while*. Finally, *when* and *while* are contingently substitutable. Motivating examples appear below:

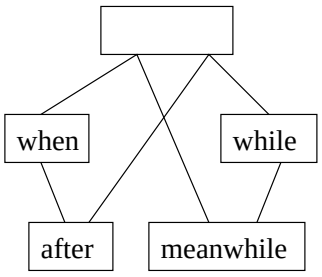

Figure 5: Some 'Temporal' Cue Phrases

(4) I studied physics $\left\{ \begin{array}{l} \textit{while} \\ \surd\ \textit{when} \\ *\ \textit{after} \\ *\ \textit{meanwhile} \end{array} \right\}$ I was at college.

(5) $\left\{ \begin{array}{l} \textit{After} \\ \surd\ \textit{When} \\ *\ \textit{While} \\ *\ \textit{Meanwhile} \end{array} \right\}$ the guests left, we went to bed.

(6) Sue cooked the stew; $\left\{ \begin{array}{l} \textit{meanwhile} \\ \surd\ \textit{while} \\ *\ \textit{when} \\ *\ \textit{after} \end{array} \right\}$ Bill peeled the potatoes.

To describe this pattern of substitutability, we need at least two independent features, F and G, as illustrated in Figure 6. A plausible candidate for G in this case

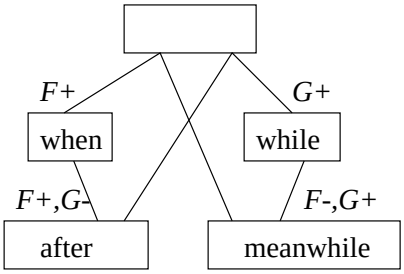

Figure 6: Describing the Temporal Phrases with Features

would relate to the temporal ordering of the two related propositions—whether they occur simultaneously ($G+$), or in sequence ($G-$). A plausible candidate for F relates to whether or not one of the propositions is presupposed: $F+$ denotes that this is the case, and $F-$ denotes it is not.

By considering isolated extracts from the taxonomy as shown above, a set of features for defining relations can be systematically motivated. The justification for each feature is the same—that it permits some portion of the taxonomy to be described. However, it is also important to consider the set of features as a whole: the number of features should be kept to a minimum, so that no generalisations are missed and each feature does as much descriptive work as possible.

The Complete Set of Relation Definitions

The three features suggested in the previous section are intended only to illustrate the method by which features are motivated from the taxonomy. A more comprehensive set of features has been worked out, however, which accounts quite efficiently for a large set of substitutability relationships. These features are described in detail in (Knott 1995b). The general form of the definitions is outlined below.

Relations are thought of as planning operators, following (Hovy 1988) and (Moore & Paris 1989). Each relation is defined in terms of the **preconditions** necessary for its use, and the **postconditions** achieved by using it. For instance, the relation signalled by *Y, because X* demands as a precondition that the reader has a set of causal rules that allows Y to be proved from X and the rest of the reader's knowledge base; and that Y cannot be proved *without* the addition of X. As a postcondition it specifies (among other things) that the reader believes that Y. Features typically relate either to the preconditions of a relation or to its postconditions, allowing a conveniently modular approach to the generation and interpretation of text.

The planning paradigm brings with it a compositional, recursive conception of discourse structure. Each relation is a binary structure, comprising two **text spans** which together form a single composite text span. A given relation represents the intention behind a large span of text in terms of the intentions behind its two component spans. The system bottoms out at the level of single clauses, which are treated as atomic text spans.

Relation definitions are represented in a nonmonotonic logical formalism, Commonsense Entailment (Asher & Morreau 1991). This formalism makes use of **defeasible rules** to express regularities about the world, such as 'birds can normally fly'. Commonsense Entailment has already been adapted for use in processing coherence relations (Lascarides, Asher, & Oberlander 1992). But Lascarides *et al* use defeasible rules to *decide* about which relations are present in a text, rather than to model the relations themselves. In the present system, relations are actually defined in terms of the defeasible rules which the reader and writer use to represent the world.

The relation definitions also draw on the temporal ontology of **culminations**, **processes** and **states** proposed by (Moens & Steedman 1988). A strong interaction has often been noted between cue phrases and the aspectual classes of the clauses they link. For instance, the substitutability of *when* and *after* in a given context is partly determined by the aspectual class of the two related clauses:

(7) $\left\{ \begin{array}{l} \textit{When} \\ ?\ \textit{After} \end{array} \right\}$ we were ready, we left.

(8) $\left\{ \begin{array}{l} \textit{When} \\ \surd\ \textit{After} \end{array} \right\}$ we had made our preparations, we left.

Moens & Steedman's temporal ontology provides a good framework for capturing constraints such as these.

Analysing Texts Using the New Relations

A methodology for motivating a set of relations has now been presented, and a brief description has been given of the relation definitions produced by following it. In specifying a systematic way of motivating

relations, the methodology addresses the second-order problem of deciding on a set of relations with which to analyse texts. We now turn to the first-order problem of actually analysing texts. To re-iterate the problem: we need to find a way of legitimising the analysis of a text, preferably without relying on the authority of a specialised discourse analyst. What is called for is an approach to text analysis which is founded on a task more central to the ordinary processes of reading and writing. The present methodology, which posits a determinate link between relations and cue phrases, sanctions just such an approach.

The following two sections describe the cue phrase based approach to text analysis in more detail.

Interpreting the Cue Phrases in a Text

If a given relation in a text has been signalled by a cue phrase, most of the analyst's work has already been done by the writer. The cue phrase will be associated with a particular set of features (it will be defined for some and undefined for others); the simple fact of its presence in the text legitimises a complex feature-theoretic description of the text at that point.

Note, however, that if the writer can assume that the values of one or more features will be easily inferrable by the reader from context or world knowledge, she does not have to use the most specific possible phrase. This means that if the cue phrase is a general one, the analyst must decide whether or not any of the more specific hyponymic cue phrases *could* have been used in its place. Consider Example 9:

(9) We could hire Jim to do the work. He's good at his job. $\left\{ \begin{array}{l} \textit{On the other hand} \\ \surd\ \textit{Then again} \\ *\ \textit{Whereas} \end{array} \right\}$ he's quite expensive.

In this case, the writer can use the general phrase *on the other hand* because it will be clear to the reader that the contrast signalled is between the conclusions suggested by the two spans, rather than their propositional content. It is in exactly this case that the analyst is able to judge *then again* as substitutable for, and *whereas* as not substitutable for, the original phrase. The task of the analyst in such a case is achievable, almost by definition.

Texts Where No Cue Phrase is Present

Of course, texts don't contain cue phrases at every point. In fact, unmarked relations are probably more common than marked ones in most text types. How does the analyst proceed in cases where no cue phrase is present?

Such cases can be classified into three distinct types. Firstly is the case where an appropriate cue phrase can simply be inserted into the text without changing it at all. We can imagine such relations as being marked by 'the null cue phrase', and then treat them just like the cases in the previous section where an ambiguous cue phrase is used. For instance:

(10) My two brothers are very different. Bill always got straight 'A's in school; $\left\{ \begin{array}{l} \phi \\ \surd\ \textit{whereas} \end{array} \right\}$ Bob flunked out of nearly every course.

By using the null cue phrase, the writer is judging that the reader will be able to infer the value of *all* the features of the relation from context or background knowledge.

A second case where no cue phrase is present is where the text can be rephrased using an anaphoric expression to make a cue phrase appropriate. Consider the following example:

(11) We could hire Jim to do the work. $\left\{ \begin{array}{l} \phi \\ ?\ \textit{Because} \\ \surd\ \textit{I say this because} \end{array} \right\}$ He's good at his job.

It is hard to find a simple cue phrase that can appear naturally in this context. However, adding a cue phrase in conjunction with a clause which refers anaphorically back to the first span is quite acceptable. And there are many contexts where a similar procedure can be used.

Finally, there are some contexts where none of the above methods are suitable. Such a case is illustrated below:

(12) Dow Associates is Britain's largest company. $\{\ \phi\ \}$ Its head office is in London.

No cue phrase seems quite right here. (The very general phrase *and* is perhaps the best candidate. But imagine that the text comes from the opening of a brochure about Dow Associates: *and* definitely seems wrong in this context.) In such a case, the present method has nothing to say about the structure of the text. (It is interesting, however, that contexts such as this one seem to form a fairly homogeneous group. For instance, it is often possible to re-express them using a non-restrictive relative clause:

(13) Dow Associates, *whose head office is in London*, is Britain's largest company.

At least, this text seems a preferable alternative to the one where *and* is inserted.)

With the exception of this latter class of contexts, the method of inserting cue phrases seems a promising approach to text analysis. The analyst's task is quite tightly constrained, and centres around observable manipulations of surface text. Note that I am not trying to propose a system whereby the relations in a text can be determined *automatically*. Maybe this is the eventual goal for a computational theory of discourse—but an essential preliminary to achieving this goal is to have a reliable way of deciding what the 'right answer' should be. There is no reason why people should not be involved in making this decision, as long as their task is clearly defined, and closely related to the ordinary processes of creating and interpreting text.

Conclusions

This paper argues that an attention to the surface structures in text is not out of place in an investigation of the cognitive mechanisms underlying discourse creation and interpretation. Indeed, it provides attractive solutions to the problems of justifying a set of coherence relations and of using these relations to analyse texts.

Nevertheless, much remains to be done to consolidate the methodology being proposed. The set of features for modelling the set of cue phrases is still under development. And the question of how to analyse texts where no cue phrase is suitable is still unanswered. These two issues should prove useful foci for future research.

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