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Lucia Helena Machado Rino and
Donia R. Scott

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ITRI, Univ. of Brighton, Lewes Road, Brighton BN2 4GJ, UK
TEL: +44 1273 642900 EMAIL: firstname.lastname@itri.brighton.ac.uk
FAX: +44 1273 642908 NET: http://www.itri.brighton.ac.uk

A Discourse Model for Gist Preservation

Lucia Helena Machado Rino * Donia R Scott †

Abstract

This paper describes an approach to gist preservation during automatic summarization whereby the source is a complex information structure which must be "pruned" and organized in such a way as to make it appropriate for textual expression. Based on a discourse model, we propose a process whereby gist is guaranteed at the deep level according to communicative and rhetorical settings. In our approach the production of a coherent discourse structure of a summary incorporates both communicative goals and the inter-relationships between information units, allowing for discourse organization by progressively constraining planning decisions. The main function of such a goal-driven summarization model is thus to map intentions onto coherence relations whilst still observing the semantic dependency indicated by the message source. We describe a method for associating discourse relations at these three levels of representation - intentionality, coherence and semantics - in order to obtain summary message sources that highlight the central proposition of the discourse.

Keywords: Automatic summarization, discourse modeling, text generation.

1 Introduction

This paper addresses the processes underlying automatic summarization within the context of natural language generation. In particular, the main problem under focus is how to derive the text plan of a summary of a complex information structure, i.e., a reduced but suitably enhanced structure that eliminates redundant or less relevant information while preserving the gist of its source. This problem can be viewed within the context of a traditional natural language generation system to which we add a summarization component (see Fig. 1). Since the focus of this work is in the underlying processes, a summarizer can be simply seen as a text structurer. Fig. 2 shows this special context, where the input to summarization is a complex information structure, henceforth referred to as *primary message source*, and its output is a new, concise, text plan derived from a subset of such a structure and overlaid with a discourse structure. The result of the summarization process, which we refer to here as the *summary message source*, can then be passed to a realization component for textual expression, not addressed here.

We will discuss two main issues concerning the production of summaries in the specified context:

- the required characteristics of the primary message source for it to be amenable to the derivation of coherent and accurate summaries that are gist-preserving;
- the nature of the process required to derive summary message sources.

*Departamento de Computação, Universidade Federal de São Carlos, Caixa Postal 676, 133565-755 São Carlos, Brazil. email: lucia@dc.ufscar.br

†email: donia.scott@itri.brighton.ac.uk

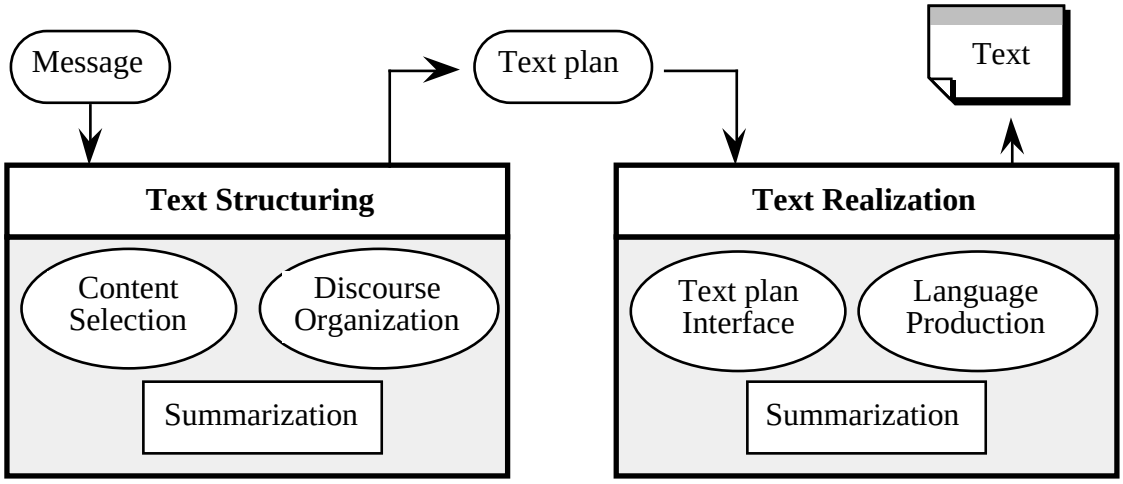

Figure 1: A summarization component in a classic text generator

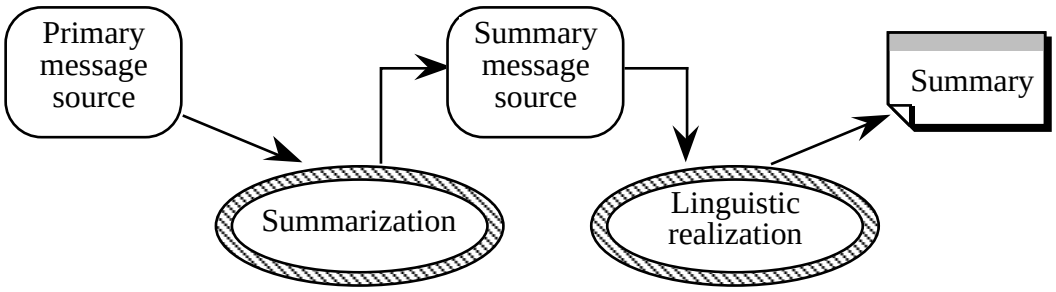

Figure 2: An automatic summarizer

2 Main concepts

A discourse is typically viewed within the computational linguistics community as a hierarchical composition of discourse segments represented linguistically by a structured collection of clauses (Grosz and Sidner, 1986; Hobbs, 1985; Hovy, 1993). Discourse segments are units of meaning (e.g., sentences or propositions), each having a specific function in the discourse, established by the inter-relationship among its elements. In general, each discourse segment reflects a subtopic of the global discourse topic and its relation to the overall communicative goal by means of its own communicative function in the discourse.

At the deep level of processing, the main elements manipulated or produced by our summarizer are the following:

The communicative goal. This is the primary intention of the writer in producing the text, expressed verbally to modify the behavior of the reader in some way (Levelt, 1989).

The central proposition. This is the "kernel" or "basic backbone" of the discourse (Hughes and McCoy, 1993; Levelt, 1989), i.e., the information around which the discourse is organized to satisfy the communicative goal. This information can be highly complex. For the purpose of this paper, however, we restrict it to a single component of the primarymessage source, i.e., a leaf of its information structure, as it is shown

below.

The primary message source. This is the abstract entity that justifies the existence of the discourse, represented by a complex information structure composed of three distinct kinds of information: a communicative goal, a central proposition, and a knowledge base. This base is a hierarchical structure of semantically inter-related content units, as illustrated in Fig. 3[1], and is the only component of the primary message source that is available for condensation. Such a structure can be "pruned" by extracting those propositions that are superfluous in the specific context determined by the communicative goal and the central proposition. In this work, any knowledge base is plausible of derivation from a text source. The one illustrated in Fig. 3 is particularly derived from the example text shown below.

Example text:[2]

1. This paper presents the results of measurements on the keyhole structure produced during the laser processing of materials.
2. A cw CO_2 laser was used to produce keyhole structures in water and measurements were made of the depth of the keyhole as a function of laser power and the force due to gravity.
3. The data show that as the laser power is increased, the keyhole depth also increases.
4. However, changes in the force due to gravity seem to have little effect on the depth.
5a. The data for the different power conditions are compared with calculations using the Andrews and Atthey expression for the hole shape
5b. and good agreement is achieved.
6. There is however no term in the theoretical description which accounts for the downward flow of liquid around the keyhole.
7a. This flow is estimated at 20 cm/s
7b. and is thought to be an important factor
7c. which it is planned to include in more detailed calculations.
8. Further measurements are also planned.

The summary message source. This is a discourse structure which reflects the logical chaining of ideas and propositions built around the central proposition by means of subthemes, or subtheses. It is derived from the primary source by selecting only the relevant material contained within it and organizing that material by means of coherence relations. Selection and organization are pipelined, so that firstly the knowledge base is pruned and secondly the discourse of the summary is organized by means of the resulting knowledge base, the communicative goal and the central proposition, giving rise to the summary message source. Fig. 4 and Fig. 5 show, respectively, the resulting knowledge base after selecting content from the original one and the summary message source produced for describing a result (bold branches indicate nuclear subtrees, according to the RST). In the model presented here, the condensed knowledge base is the only source of domain information for planning: its propositions will be

[1] Semantic relations are specified in the intermediate nodes, whilst content units are propositions specified as leaves of such a structure. The underlined words stand for the super-components of the knowledge base.

[2] Numbered clauses are considered to be propositions. However, the ones which are not directly related to the main segment in this example have not been dismembered. Occurrences of, e.g., X, Y or Z stand for implicit concepts that could not be retrieved from the text source.

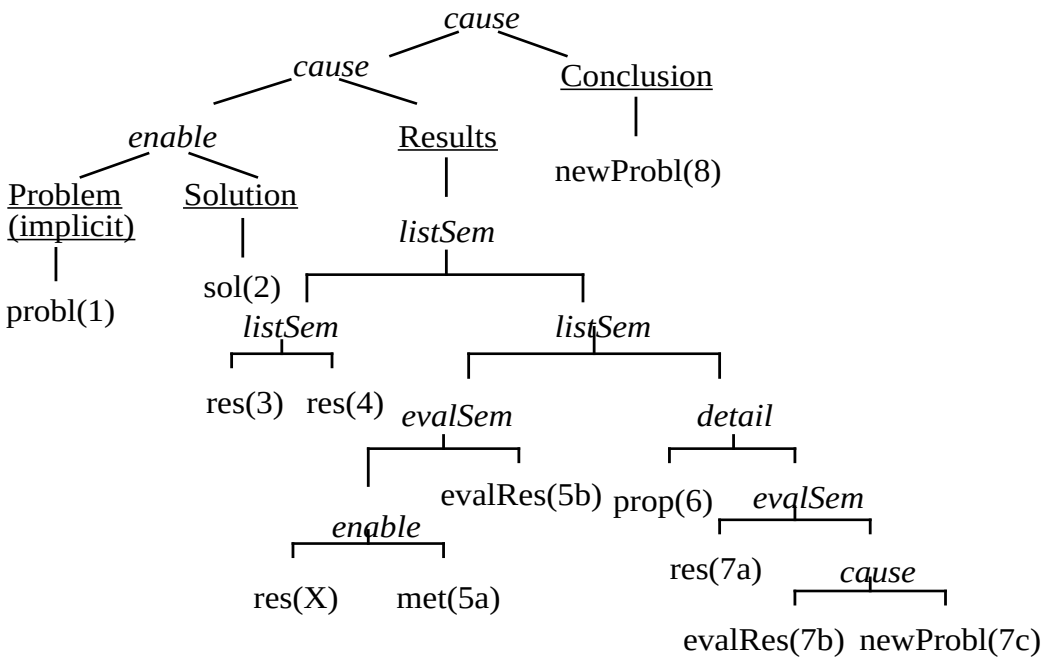

Figure 3: A knowledge base of a primary message source

used to complement or emphasize the central proposition, at the same time that they contribute to the communicative goal (Grosz and Sidner, 1986; Hughes and McCoy, 1993; Scott and Souza, 1990). The description so illustrated expresses the communicative goal (Describe) and the central proposition to be conveyed (e.g., *result "7a"* or *res(7a)*, as shown). A possible hand-generated summary based upon the summary message source is also given.

Example summary: A possible description of a result

The downward flow of liquid around a keyhole structure produced during the laser processing of materials has been estimated at 20 cm/s, an important factor which must be included in more detailed calculations. Although good agreement is achieved with a comparison between data for the different power conditions and calculations using the Andrews and Atthey expression for the hole shape, there is no term in the theoretical description which accounts for such a flow.

According to the above, the central proposition of a discourse will be one of the leaves of both, the primary and the summary message sources. If the summary is gist-preserving, the central proposition of both sources will be identical.

3 Strategic account

The results described in this paper are based on the analysis of a corpus of scientific journal articles from a single technical domain (physics). Given the highly stereotyped nature of this genre, our analysis revealed a well-known pattern of discourse organization, known as Problem-Solution (P-S) (Hoey, 1983). This pattern reveals the set of common semantic relations used in the primary message source (Rino and Scott, 1994). The analysis also identified the most frequent communicative goals (Describe, Relate, and Discuss). Many of the semantic relations found can be fairly straightforwardly mapped onto coherence relations

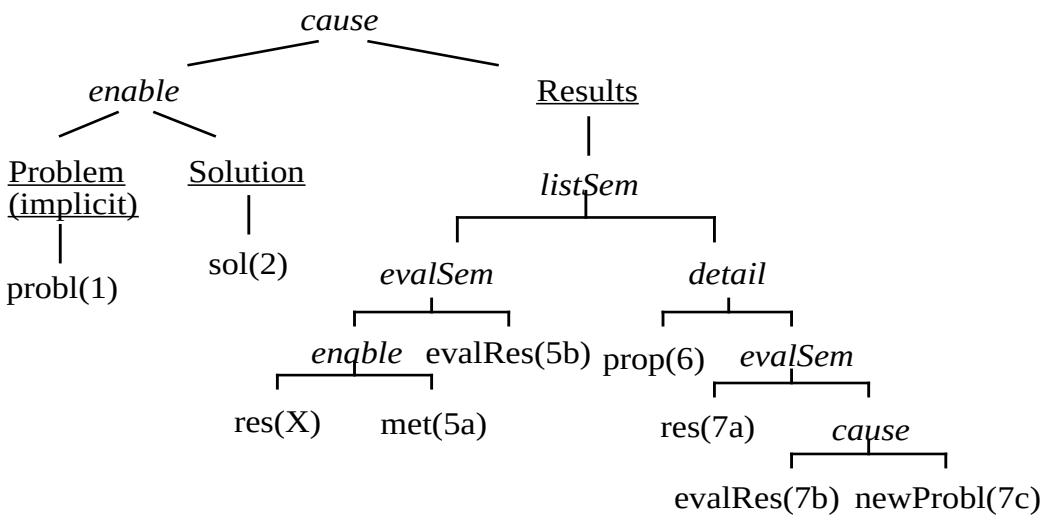

Figure 4: A condensed knowledge base

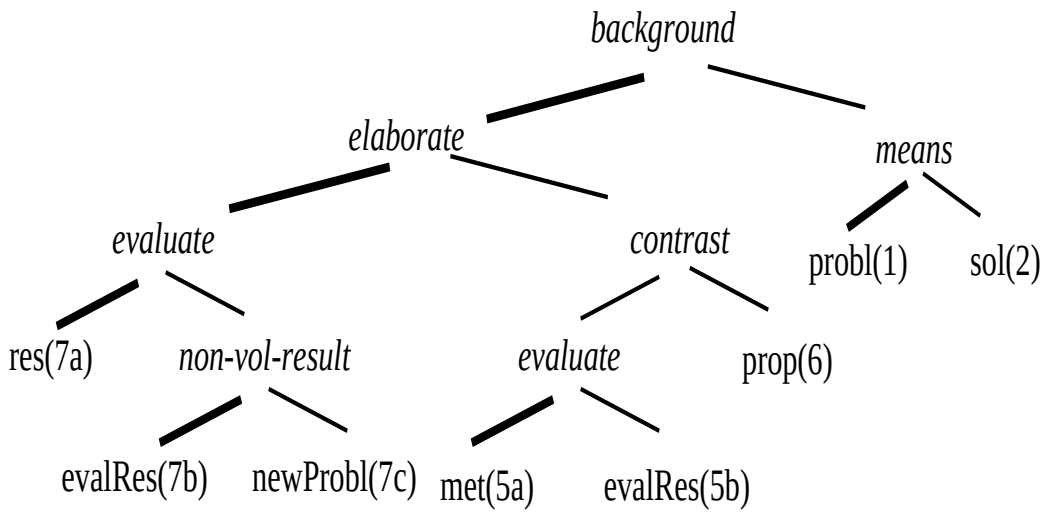

Figure 5: A summary message source of a description

drawn from existing theories of discourse organization: *Rhetorical Structure Theory* (RST) (Mann and Thompson, 1987) and Hobbs' (1985) coherence relations.

For an intentional account, we add to our model the *Grosz and Sidner Discourse Theory* (GSDT) (Grosz and Sidner, 1986), whose dominance and precedence relations are independent of a linguistic behavior and characterize the search for a communicative setting at a high level of abstraction. GSDT and RST are complementary and both allow for a functional approach. RST specifies the intended effects of a coherence relation on the behavior of the reader and expresses (albeit coarsely) the underlying discourse intentions, conveying the propositional content in a relational form that is essential for coherence. GSDT, on the other hand, focuses fundamentally on the intentional contribution of individual discourse segments to the overall discourse by allowing for structural relations between intentions. We show here that this theory can lead to the choice of specific coherence relations, complementing the lack of a clear specification of communicative purposes of the RST[3].

The following premises hold in the strategic process: first, relevance and prominence of information are dependent on the context, which is initially delimited by the specification of the communicative goal and the central proposition; second, the primary message source provides all the information needed to structure a summary, i.e., it is complete. Planning a summary is a process of specifying and making use of the particular intentions that contribute to the overall communicative goal and determining the possible coherence relations to express those intentions linguistically. So, the inter-relationship between intentions and coherence relations is critical to summarization: it is this that provides the basis for determining the partial contribution of content information to gist preservation and the satisfaction of the overall communicative goal. The planner must also ensure that chosen relations do not violate the conceptual dependence specified in the primary message source.

4 Modelling discourse

Formal and functional perspectives both hold in our discourse modeling: a discourse is composed of information derived from the primary message source, semantically structured by means of a formalism which gives rise to the summary message source. The functional perspective is responsible for the discourse internal structure and is related to both, the intentional and coherence levels: a discourse hierarchical setting, and even the coherence relations, must convey the constraints that allow for the success of the discourse. Therefore, discourse organization is determined by mapping intentionality onto coherence, accounting for the discourse functionality. At the same time, it observes the conceptual dependence between content units, which is given by the primary message source. Thus, the semantics of the knowledge base in the primary message source provides the informative means of the discourse.

Modeled in such a way, discourse is organized considering three distinct levels of structural relations: the functional one, which combines intentions and coherence relations, the informative one, given by the knowledge base, and the formal one, which addresses linguistic resources based upon the interaction between informativity and functionality. This formal means to produce discourse is illustrated in Table 1. For example, if Case 5 holds, there is a formal correspondence that reads: *If a "symmetry" intentional relation holds between discourse segments X and Y, and if both corresponding segments in the semantic repre-*

[3]This limitation of RST has been addressed by Cawsey (1993), Maybury (1992), Moore and Paris (1989, 1993), Moore and Pollack (1992), and Moser and Moore (1993).

sentation of the primary message source are in a "listSem" relation, then the preferrable coherence relations between X and Y are either LIST *or* CONTRAST.

Table 1 addresses all the possible mappings of our current discourse model. So, all three sets of relations (coherence, semantic, intentional) are necessary and sufficient for summary planning. Semantic relations are naturally depicted in the English language. Coherence ones are determined through the propositional delimitation of spans of sample texts. Structural relations between intentions follow GSDT (Grosz and Sidner, 1986): there are basically two relations, namely dominance and satisfaction-precedence, which determine the contribution of discourse segments to the overall discourse. In addition to these, the GSDT supplies two others: supports, between propositions, and generates, between actions, which respectively outline the *belief* and *action* cases. We find it necessary to add a further intentional relation to those provided by GSDT, namely symmetry. A symmetric relation holds between two intentions when one contributes to the other and vice-versa. Of the coherence relations relevant to our task, only two present a symmetric account at the intentional level: LIST (Scott and Souza, 1990) and CONTRAST (Mann and Thompson, 1987), as shown by Case 5.

Along with the main communicative goals, there are other subgoals whose interplay display a complex interaction among different text types. For example, narratives exchange features with expositions when they narrate facts of an explanation of plans. Such a complex interplay can provide a systemic network, which allows for the mapping between communicative goals and coherence relations in a special way, as partly shown in Fig. 6.

Conceptual classes found in the corpus analysis determine another kind of network, i.e., a *communicative inheritance network* (partly shown in Fig. 7), which details further the communicative goals. For example, an entity description (Desc-Entity) comprises a description of a solution (Desc-Solution) or a problem (Desc-Problem), which are two conceptual classes of the scientific discourse model. Such classes are used to annotate the content units of a knowledge base, e.g., "Result" produces "res" in Fig. 3.

5 Computational account

Both inheritance and systemic networks allow for the definition of discourse schemata (McKeown, 1985) and plan operators (Cawsey, 1993; Hovy, 1988; Maybury, 1992; McKeown, 1985; Moore and Paris, 1993; Moore, 1995; Paris, 1988). A schema guarantees that the proper communicative setting is initially established, in order to preserve gist. For example, given that a super-structure of a summary can be represented by the logical sequence *Situation-Problem-Solution-Results-Discussion and evaluation of results* (Hoey, 1983), to describe a specific result[4] a schema is chosen which emphasizes either the subpath *Desc-Feature,Desc-Attribute,Desc-ValueOfResult* or the subpath *Desc-Object,Desc-Result* in Fig. 7. Plan operators allow for distinct rhetorical settings to organize discourse, based upon different choices of rhetorical strategies (see Fig. 6).

Gist preservation is addressed at all levels of discourse processing. The most important resources to address this issue are the plan operators, which are responsible for discourse organization, in that they map intentional and semantic relations onto coherence relations, according to the correspondence shown in Table 1. Planning is gradual, so that the summary message source conveys the relevant content units as leaves, with the central proposition as

[4]This is a shorthand for the following: Communicative goal: *Describe*; central proposition: *result(R)*, where R is a concept classified as a result in the domain.

Semantic relations	**Coherence relations**	**Structural relations between intentions**	**Cases**
enable(Y,X)	purpose1(X,Y) means(Y,X)	X sat-precedes Y Y dom X	1
rationale(X,Y)	purpose2(X,Y) justify1(X,Y)	Y supports X X dom Y not X sat-precedes Y	2
proof(X,Y)	evidence(X,Y) justify2(X,Y)	Y sat-precedes X X dom Y Y supports X	3
cause(X,Y)	non-vol-result(Y,X) non-vol-cause(X,Y)	Y sat-precedes X X dom Y Y generates X	4
listSem(X,Y)	list(X,Y) contrast(X,Y)	X symmetr Y	5
attribute(X,Y) *detail*(X,Y) *exemplify*(X,Y)	elaborate(X,Y)	Y supports X	6
evaluateSem(X,Y)	evaluate(X,Y)	X dom Y	7
reason(X,Y)	explain(X,Y)	Y generates X	8
sequence(X,Y)	sequence(X,Y)	X sat-precedes Y	9
background(X,Y)	background(X,Y)	not X sat-precedes Y Y supports X	10

Table 1: Mapping of intentions and semantic relations onto coherence relations

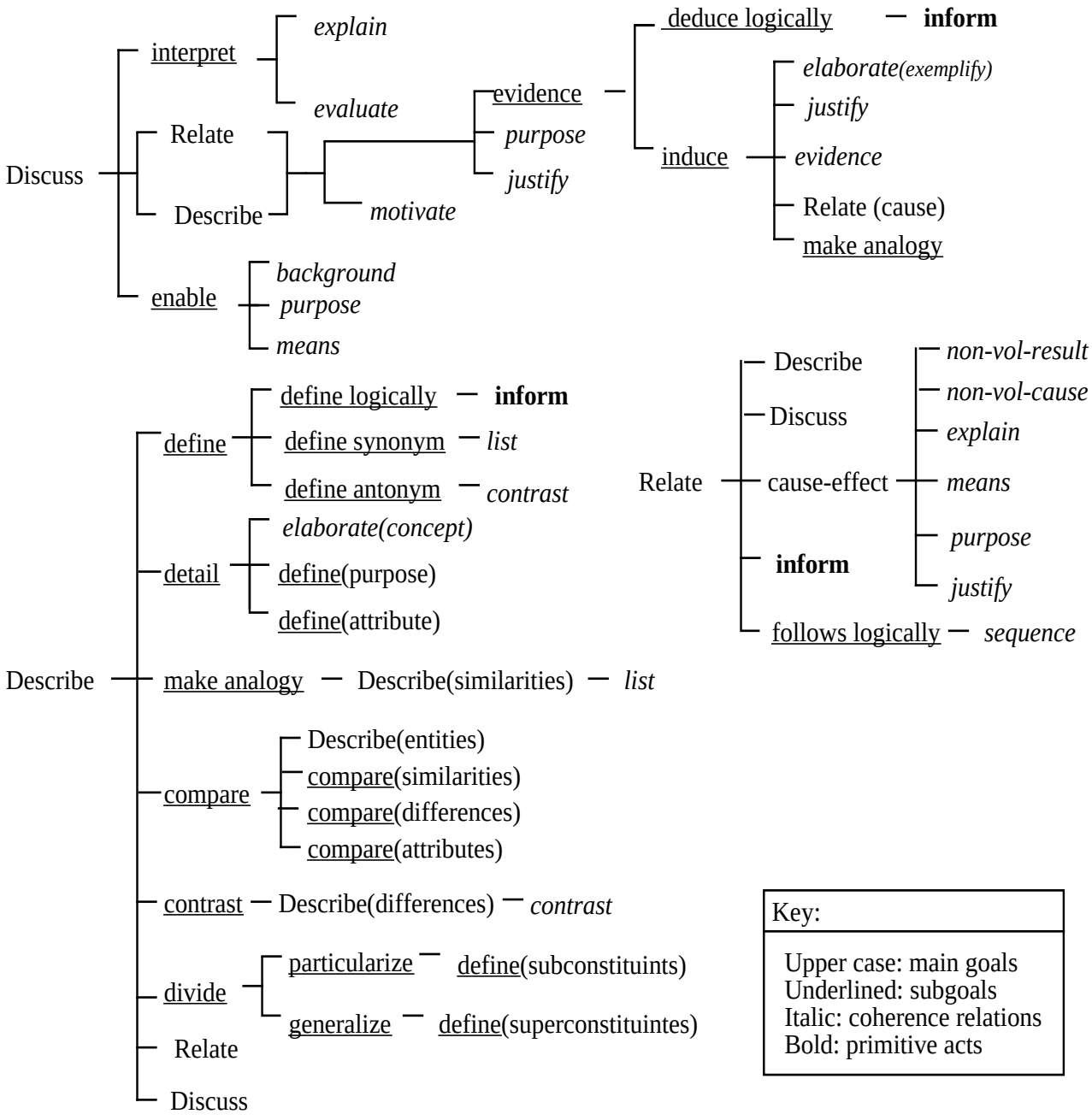

Figure 6: Communicative goals and their interaction with coherence relations

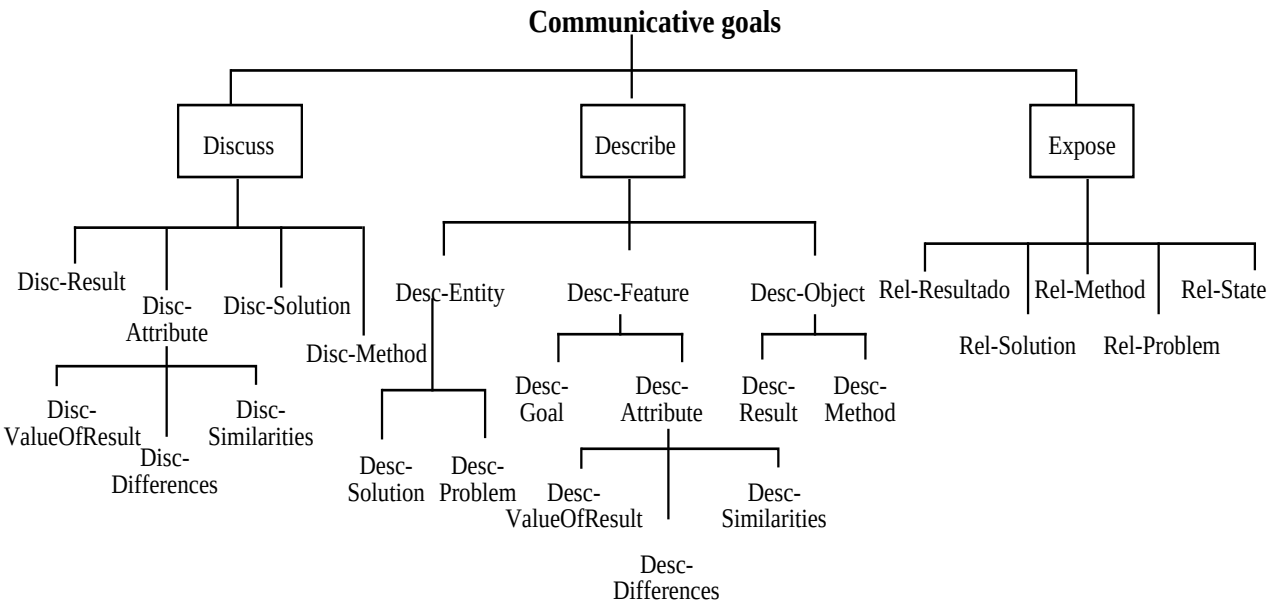

Figure 7: A taxonomy of communicative goals

the "most nuclear" unit[5].

We follow Moore and Paris (1993) to specify our plan language. Communicative goals can be represented, for example, by *Describe, Interpret, or Discuss*, as depicted by the networks above, and can be associated to the writer's intention to make the reader believe, or act according to, a proposition. A discourse is successfully produced when it achieves the intended change of the mental state of the reader. Linguistic goals to support these intentions can be primitive acts (only inform in our current model) or rhetorical goals (e.g., evidence, or justify), which are directly expressed as coherence relations.

Plan operators handle both types of goals. However, only those that explicitly post linguistic goals can modify the discourse structure under construction. This is done by associating intentions with coherence relations. Planning is complete when all the active plan operators are successfully applied, generating all the leaves of the discourse structure, i.e., the primitive acts given by *inform* nodes. At this point, we have a collection of plan operators that actually determines the proof space that gives origin to the discourse through a recursive and progressive account of constrained discourse organization. Such a space registers not only the thread of discourse, but also the space of contribution of each discourse segment to the overall discourse, in terms of the purpose of each particular segment.

Each plan operator is an RST plan[6] composed of the following fields:

Name: to identify the plan operator.

Header: to specify the goal that the plan operator is intended to achieve when applied successfully.

Effect: to specify the mental state of the reader when the plan operator is successfully applied.

[5]See (Mann and Thompson, 1987) for further details on nuclearity.

[6]Modifications of RST relations as RST plans have been proposed by Hovy (1991), Maybury (1992), and Moore and Paris (1989) to embed functional aspects of discourse organization, resulting in more flexible operators.

Constraints: a list of conditions that must hold for the plan operator to be applicable. This list includes the intentional and semantic constraints depicted by the possible mappings between discourse relations at the levels of intentionality, coherence, and semantics specified in Table 1.

Nucleus (N): a communicative or a linguistic goal whose satisfaction is essential for discourse progression.

Satellite (S): one or more subgoals classified as essential or optional. It specifies additional information to complement the nucleus and contribute to the satisfaction of the goal defined in the header by searching for other focus spaces (Cawsey, 1990).

Essential satellites affect the purpose of the nucleus and, consequently, the contribution of the corresponding discourse segment to the overall communicative purpose (Grosz and Sidner, 1986). For this reason, they must be further developed in the plan. Optional ones, on the other hand, may elucidate the nucleus, but are not crucial. The decision to include optional satellites in a plan under construction depends on the constraints (for example, the degree of detail required). Such satellites are responsible for varying degrees of conciseness at the deep level of summarization.

Since subgoals can be either communicative or linguistic, coherence relations are determined only when a plan operator applies to a context that provides appropriate conditions for the mapping between intentions and semantic relations. This approach proves appropriate for summarization in that it provides the flexibility to choose plan operators that can convey and organize information in varied ways, provided that the central proposition is preserved and is guaranteed to be available to the realization phase. Moreover, built on a constraint satisfaction model, the final discourse structure is guaranteed to achieve the communicative goal because it operates on partial information, gradually constraining the range of possible choices of new information to compose such a structure.

6 Discussion

Other work has explored a similar communicative account to the one presented here, e.g., in text generation by Cawsey (1990) and Maybury (1992), and in automatic summarization by Sparck Jones (1993). However, none have addressed the crucial problem of preserving gist in the context of condensing the message to be conveyed. Pursuing this view, we add to Moore and Paris' (1993) discourse model the specific constraints for gist preservation and prominence, assigning the position of the central proposition of a summary message source to the "most nuclear" leaf of an RST-like discourse structure. In addition, we trigger the planning process by narrowing the possible paths to achieve the communicative goal based on the typical semantic organization of the primary message source, which constitutes the only knowledge accessible to our summarizer at the current stage of the research[7]. The consistency provided by the highly stereotyped discourse under investigation allows us to identify the possible super-components that involve the central proposition of the discourse to be constructed. In this respect, the Problem-Solution pattern is particularly

[7]Other research on summarization has also investigated the role of purpose in discourse processing (Cawsey, 1993; Grosz and Sidner, 1986; Maybury, 1992; Moore and Paris, 1993; Moore, 1995). Frames and scripts have also been amply used to represent knowledge (e.g., (Liddy, 1991)), often allied to theories of discourse structure (e.g., (Paice, 1990)).

interesting, allowing for schemata definitions that indicate the possible ways of achieving the communicative goal, and emphasizing the central proposition specified in the primary message source.

The correspondence between semantics and coherence described here is based on an empirical study. From Table 1, we can see that the mapping of semantic relations to coherence relations can be one to many or many to one, and that coherence relations do not necessarily map to the same structural relations at the intentional level (e.g., PURPOSE and JUSTIFY). This is fortuitously advantageous for summarization, in that it provides the necessary flexibility to produce different discourse structures for the same message and also varying degrees of conciseness or informativeness.

Compared to other approaches based on schemata (e.g., (McKeown, 1985)), the approach described here provides more flexibility through the addition of plan operators to the discourse model of summarization, this addition is particularly interesting for discourse production, because it combines in a single formalism the interdependence between three distinct levels of discourse representation, namely intentionality, coherence and semantics. None of these structural levels taken alone is able to address any of the others, e.g., a communicative setting does not completely account for a rhetorical one; semantic relations, on the other hand, do not express intentions by themselves (Sparck Jones, 1993). Besides such advantages, the "reasoning" of the plan operators is not predetermined: special cases where the choice of a specific discourse relation runs the risk of obscuring the central proposition in the corresponding discourse structure can be handled at the level of constraints in the plan operators.

6.1 Conclusion

We have presented an approach to automatic summarization based on conventional text generation processes for modeling discourse, to which we add a severe constraint: the preservation of the gist of a message source. We show that a communicative account is essential to determine the space of contribution of communicative goals to gist preservation, adding to the coherence approach by searching for discourse segments that contribute to both the overall communicative goal and to gist prominence. In this, our work supports the insights provided by Sparck Jones (1993).

Our approach relies on the active identification of information that can complement the central proposition to be conveyed. However, it takes an inverse view to that proposed by Robin (1994). Whereas we identify less relevant propositions, *omitting* them from the primary message source and reorganizing them, Robin identifies relevant propositions, *adding* them to a given proposition in order to build up a text.

In carrying out this work, we have provided a specification of the correspondence between intentions and coherence relations on the basis of the highly stereotyped discourse of science. We have applied our discourse model to a small number of scientific domains and to another genre (technical texts) (Rino, 1996). Our results so far show that gist can be preserved in summary generation provided that the corresponding primary message sources are structured according to the Problem-Solution pattern. This pattern is not specific to scientific texts, but can be found in a number of other genres (Fries, 1992; Jordan, 1988; Hoey, 1983). This suggests that our discourse model for gist preservation may be more

generally applicable to a wider context of natural language generation.

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