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Theoretical Consideration of Goal Recognition Aspects for Understanding Information in Business Letters

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Jay C. WEBER[†], Andreas DENGEL and Rainer BLEISINGER

Authors´ Abstract

Businesses are drowning in information - paper forms, e-mail, phone-calls and other media do struggle the speed of managers in handling and processing information. Traditional computer systems do not support business flow because of their inflexibility and their lack in understnding information. A sophisticated understanding of the meaning of a business letter requires an understanding of why the sender wrote it. This paper describes some ideas to use goal recognition techniques as one possibility, or method to initiate information understanding. It brings together two areas of cognition: goal recognition and document understanding. To do so, it gives an overview of the application of goal recognition techniques to the discovery of the overall purpose of a letter and a coherent explanation of how the individual sentences are meant to achieve that purpose.

Keywords: Goal recognition, document understanding, plan recognition, NLP

CONTENTS:

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1 Introduction

All activities in an organisation require or produce information. Therefore, a document is not only the main information carrier but also the central aid for the integration of office functions [Donner, 1985]. The human stands at the centre of the office, with his own creativity for the drafting and design of documents and the capability to evaluate and make decisions regarding incoming information as to how it should be dealt with further. In a typical office, information arrives in multimedia (paper, electronic, audio and visual) and in mixed-mode (text, graphic, image, speech and handwriting) form. The carrier for this indirect communication is, in an abstract sense, the document. Person A creates a document. At later time person B attempts to interprete this document, in order to extract the transmitted information and to react with respect to the intented goal of person A.

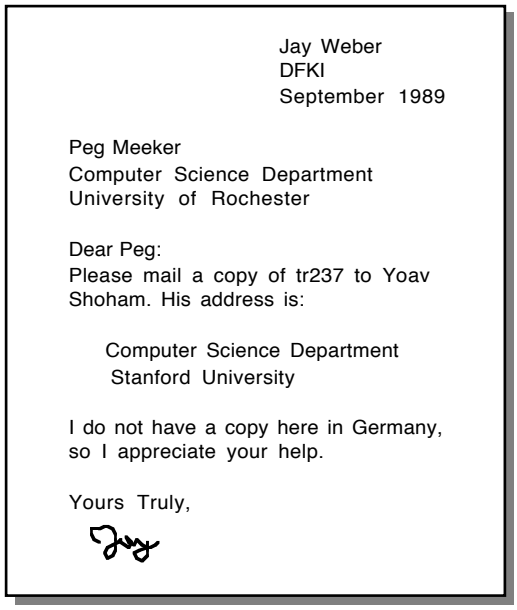
In [Dengel, 1989], we have introduced an approach to classify the structure of complex paper documents for the example of business letters. As a result thereof, we get information about where the different constituents of the letter, like the receiver, the company-specific printings or the subject are placed and therefore are able to direct further partial analyses. In this sense, we apply OCR techniques to obtain an electronical representation of the containing textual information. The resulting ASCII-Code is employed to initiate a full text search with keywords in connection with morphological analysis. Thereupon, the possibility exists to examine the recognized text as to its meaning. Depending on the results obtained by structural analysis and the text recognition as well as by the inclusion of a heuristical approach, a sequence of sections still to be examined is determined for textual analysis. In this way, as a concrete example, the domain of discourse of the reference part (invoice, offer, ...) can be restricted further from the identification of a certain sender as computer manufacturer.

With a such possibility of restricting the contained information to a concrete area of discourse (e.g., subject, address) the search space can be reduced to the point from which an efficient, sophisticated understanding of the meaning of a business letter is realizable first at all.

One task of this process is an understanding of why the sender wrote it. For example, the reason that the sender wrote the letter in Figure 1 is that he wants Yoav Shoham to have a copy of tr237, but this reason is not stated explicitly in the letter. This knowledge must be inferred from the meaning of the sentences and background knowledge about the sender's plans and goals; we call this process *goal recognition*.

Goal recognition often suggests a more appropriate response than a simple literal interpretation. In the above example, if the receiver knows that Shoham already has a copy of tr237, then she knows that the sender's goal is already true, and she does not actually need to follow the sender's explicit

request in order to be cooperative. This reasoning is especially important when a sender writes an *indirect speech act*, such as "Could you send a copy of tr237 to Yoav Shoham?", since merely sending a letter back that says "Yes" is inappropriate.



Jay Weber
DFKI
September 1989

Peg Meeker
Computer Science Department
University of Rochester

Dear Peg:
Please mail a copy of tr237 to Yoav Shoham. His address is:

Computer Science Department
Stanford University

I do not have a copy here in Germany, so I appreciate your help.

Yours Truly,

Figure 1: A sample letter

This paper is an overview of the application of goal recognition techniques to the problem of understanding the meaning of business letters. Since the formal representation of speech acts and the process of goal recognition involves many subtle issues in temporal, causal, natural language, belief and plan reasoning, the notation will be used in an informal way, allowing us to present the main ideas in a concise fashion.

2 Speech Acts

The *speech act* model of natural language communication [Searle 1975] views an utterance as an action performed by the speaker in order to make changes in the beliefs and intentions of the hearer. This model has been shown to capture many important aspects of language understanding, and has recently become the standard model with which to analyze discourse [Allen 1987].

Traditional semantic analysis produces a logical form or an equivalent frame-like structure that represents the propositional content of an utterance. For example, a *semantic grammar* analysis [Allen 1987, chapter 9] of the sentence "John loves Mary." spoken during time t could produce the fact "loves(John,Mary,t)". A speech act representation would take this knowledge a step further, and state that the speaker performed an action to inform the hearer of a fact, i.e.:

informs(speaker,hearer,"loves(John,Mary,t)",t) ,

where the condition-producing function informs takes four arguments: the speaker of the utterance, the hearer of the utterance, the condition being communicated, and the time of the speech act. Note that the temporal argument of the communicated fact is the same as the temporal argument of the inform, namely t; this is because the original sentence was in the present tense.

This representation allows us to use techniques from belief reasoning and causal reasoning [Moore 1977] to relate the performance of the speech action to changes in the hearer's beliefs [Cohen and Perrault 1979, Perrault and Allen 1980]. If the speaker successfully performs an inform of a fact, then the hearer will believe that fact after the inform has occurred. A speaker will perform an inform for this very reason: to make the hearer believe the fact. Therefore, the inform tells us something about the desires of the speaker, namely that the speaker wants the hearer to believe the fact. This inference can be represented as the following rule:

informs (s,h,f,t) → wants(s,"believes(h,f,after(t))",t) ,

where after(t) is the time immediately after the inform. Note that this inference does not require that the speaker actually believes the fact, nor whether the hearer will actually decide to believe it.

In addition to inform, another important type of speech act is the request. An example of a request is the utterance "(Please) empty the trash tonight" at time t, which could be represented by the following structure:

requests(s,h,"empty(trash,tonight)",t) .

A request is an attempt to modify the wants of the hearer, like an inform attempts to modify the beliefs of the hearer. If a speaker asks a sympathetic hearer perform some action, then the hearer will want to perform that action. Thus a request tells us that the speaker wants the hearer to want to perform the action, as in the following rule:

requests(s,h,a,t) → wants(s,"wants(h,"perform(h,a)",after(t))",t) .

If an agent h wants to perform an action, and able to perform that action, then that agent will perform that action. This corresponds to the rule:

(wants(h,"perform(h,a)",timeof(a)) ∧ able(h,a)) → perform(h,a) .

This is both a fact about agents and a belief of the speaker, since usually the reason a speaker wants a hearer to want to perform an action, is that the speaker wants the hearer to perform the action.

There is an interesting relationship between requests and informs, due to the relationship between utterances of the form "I want you to empty the trash tonight." and "Please empty the trash tonight". The former case would be

written as:

informs(s,h,"wants(s,"perform(h,empty(trash,tonight))",t)",t) ,

whereas the latter request is represented above. These representations differ in that by the inference rules above, the inform implies that the speaker s wants the hearer h to believe that s wants h to perform the action, but the request implies that s actually wants h to want to perform the action. What is missing is a mechanism that converts belief about the wants of others into wants for yourself, as happens between a speaker and a sympathetic hearer. A simplified version of such a mechanism is captured by the following inference rule:

(sympathetic(h,s) ∧ believes(h,"wants(s,f,t_u)",t_u)) → wants(h,f,t_u) .

Therefore, if the hearer is sympathetic, then a request is equivalent to an inform-of-a-want-to-perform.

3 Speech Acts in Business Letters

The techniques described in the last section were developed for general natural language communication. These techniques appear to be especially appropriate for modelling the utterances in business letters. Belief reasoning is simplified because when considering a single letter, the conversation is one-sided: the meaning of the letter is an expression of the beliefs and wants of the writer. Also, these beliefs and wants have essentially the same temporal extent, namely the period over which the letter is written, so it is not necessary to model changing beliefs as with a discourse understanding system.

An interesting complication of interpreting written sentences as speech acts is when a speech act is said to have occurred. For example, consider again the letter in Figure 1 (for what it's worth, it is an actual letter). The first sentence in the body of the letter is certainly a request, but is the time of the request when the writer wrote the letter (t_w), when the reader read it (t_r), or the entire period from writing to reading? All three of these alternatives are problematic: if the request occurs during writing, then we do not know when to say that the reader's beliefs changed; if the request occurs during reading, then we do not know when to describe the writers beliefs; in the third case we don't know when to specify either's beliefs. Instead, we will specify two temporal arguments to a written speech act, when it was written and when it was read. Thus the first sentence would be represented as:

requests(Jay,Peg,"mail-copy(tr237,Shoham,t_u)",t_w, t_r) ,

where t_u, the time of the mailing, is constrained (by social convention) to be some time shortly after t_r, the time that the letter is read. The fact that the

writer made this request tells us something about his beliefs, namely that he wants Peg to want to perform the mail action, i.e.:

wants(Jay,"wants(Peg,"perform(Peg,mail-copy(tr237,Shoham,t_u))",after(t_r))",t_w)
,

and ultimately that he wants Peg to perform the mail action.

The second sentence in Figure 1 is an example of an inform. We represent this inform as:

informs(Jay,Peg,"address(Shoham)=Comp…sity",t_w,t_r) ,

and this leads to the following inference about Jay's wants:

wants(Jay,"believes(Peg,"address(Shoham)=Comp…sity",after(t_r))",t_w) .

Similarly, the last two sentences are also informs. Interpreting the sentences in this way provides information about the goals of the writer, which is vital to understanding the meaning of the letter. The next section shows how to use this information to build a coherent explanation of why the writer might have these particular wants, based on recognizing his/her top-level goals (Jay wants Yoav Shoham to have a copy of tr237) and how lower-level goals (Jay wants Peg to know Shoham's address) arise in plans to accomplish the top-level goals.

4 Plan and Goal Recognition

After deriving information about the speaker's wants and beliefs from the sentences individually, the next step is to combine them into a coherent plan. For example, in the letter of Figure 1 we have derived that Jay wants Peg to know Shoham's address, but this want is unmotivated. The underlying reason for this comes from information about the actions involved, namely in the previous sentence Jay requested that Peg perform a mail-copy(tr237,Shoham) action, but in order for Peg to be able to perform that action, she must know Shoham's address. This kind of reasoning about plans is generally called *plan recognition* or *plan inference*, and has been shown to play an important role in communication [Litman and Allen 1987].

The standard form of plan recognition takes actions performed by an agent and postulates a simple, general plan that contains those actions as steps [Kautz and Allen 1986]. For example, if an agent is observed boiling water and also opening a can of tomato sauce, a plan recognition system might postulate that the agent is in the process of making a pasta dish. This is nearly a suitable inference mechanism for our purposes, but not exactly, since it does not postulate a reason for making the pasta dish (hunger, perhaps). When understanding a letter we wish to understand the goals of the writer. Therefore, we suggest a variant of plan recognition, which we call *goal recognition*, where the goals of the writer enter into the recognition

process explicitly. A similar and more detailed approach appears in Allen [1987, pg. 382].

The basic connection between the two speech acts corresponding to the first two sentences of the letter in Figure 1 is that they both achieve preconditions of a single plan. For Peg to actually perform the mailing action, she must both want to perform the mail action (an effect of the request) and also know the correct address (an effect of the inform). A simple goal recognition system would look for a single tree which describes how the speech acts are connected as part of a coherent plan, as shown in Figure 2.

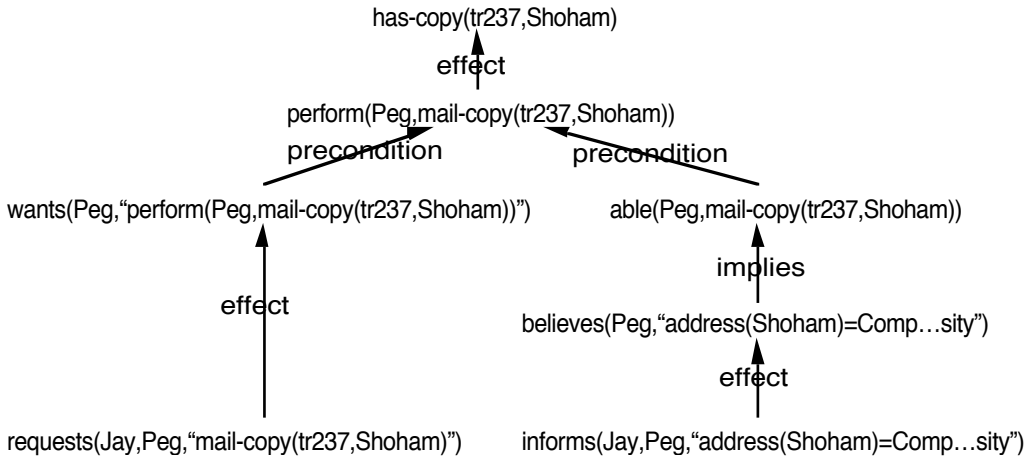


Figure 2: Speech acts as part of a coherent plan. The actions and properties in this plan do not have temporal arguments, since the temporal relations are too complex for that simple plan structure. The relations, however, are strongly suggested by the arrows.

The most important part of the goal recognition tree is the goal at the root. In the case of Figure 2, this is the writer's goal "has-copy(tr237,Shoham)". In general, the reader knows that as long as this goal is achieved, the writer will be satisfied, and that the underlying plan involving the mailing is only a suggested manner of achieving this goal. If the reader has special information that makes this suggested plan non-optimal, then he/she may modify the plan. An extreme case of this is if Peg knows that Shoham already has a copy of tr237, i.e. the goal is already true, then it is appropriate for Peg to modify the plan to do nothing except perhaps communicate that fact to Jay. This supports the kind of response reasoning mentioned in the introduction.

It is important that background knowledge be available for goal recognition, or unreasonable goal hypotheses may be derived. For example, it is possible that if Shoham is a stamp collector, the overall goal of the example letter is "has-stamp(Shoham)" instead of "has-copy(tr237,Shoham)": both are effects of "mail-copy(tr237,Shoham)", and therefore both are possible goals of the

writer. We require background knowledge about what kinds of general goals are typical of the writer. If we know that Jay is a computer science researcher, then we may reason that a typical goal of his is to have other researchers read his work, and we know that a precondition of "read(tr237,Shoham)" is "has-copy(tr237,Shoham)". Also, we know that Jay specifically requested that Peg mail tr237, but the possible goal "has-stamp(Shoham)" does not involve tr237, and therefore is probably not the general goal. This reasoning involves the principle that a speaker will not supply more information than is needed to specify the situation [Grice 1975].

5 Basic Ideas for a Practical Approach

Section 3 and Section 4 have presented techniques of goal recognition and the principles for their use for understanding business letters. Our research activities in text analysis are mainly concentrated on a content-based classification of business letters, and an extraction of important informations.

Considering business letters we have established different letter classes (e. g. offer, order, invoice), which imply goals of the containing information. For example, an inquiry implies the writer's goal to receive a specific offer:

get-offer(writer, offer(....), ...).

Such final goals are considered as roots for respective goal recognition trees. In doing so, we store knowledge in form of different sets of predicates (*description predicates*) to express the essential as well as the optional information for each of the classes, e.g.,

informs(... , mail-address(.....),...),

requests(writer, reader, mail-offer(product, number, price), t_W, ..)).

The description predicates will be used as leaves of a goal recognition tree when an analyses of an actual business letter are initiated.

The system we have developed [Dengel and Barth, 1989] is capble of automatic identification of the position of constituents of business letters (e. g. sender, subject, date) as coherent regions within a document page. This information is used to support goal recognition. Taking a certain order of examination of these logical units, we attempt to classify the letter and thus generate the goal of the containing information. For example, this can be done by analyzing the reference part, searching for specific key words expressing the topic of the letter.

By examining the contents of *sender*, *receiver*, *date* etc., we furthermore perform basic unifications. In the above requests the variable t_W could be unified with date, the variable writer and the reader with the appropriate names of the sender and the receiver. Subsequently the entire letter-body can

be analyzed sentence by sentence, like mentioned in Section 2 by using *semantic grammar analysis* [Allen, 1987, chapter 9]. As a result we obtain for each sentence one or more predicates expressing communicated facts of it's contents:

(mail-offer (ECAI-proceedings-1990, 1, 100, 28$)).

We take these facts and relate them to the description predicates of the actual letter class. By unifying the variable parts of the description predicates with instantiated arguments of the facts ,we attempt to successively assign semantic relationships to an actual letter. As a consequence, the unified description predicates are used as leaves for an automatic generation of the corresponding goal recognition tree with the final goal of the letter class as its root. Thereby, stepwise unification of the containing variables is performed and finally the variable parts of the final goal are bound.

The resulting instanciated final goals of single letters are related to the global goal of an entire office procedure, for example, an employment procedure, which consists, e.g., of inquiry, offer, order, invoice.

6 Conclusions

This paper has informally presented the subjects of speech acts and goal recognition, as a step towards the development of programs that understand the textual information within business letters. These techniques represent sentences as actions by the writer in order to accomplish underlying goals. These actions are then viewed as parts of a plan, and hypo-theses are generates about the missing parts of the plan, which correspond to general goals and causal knowledge of the writer.

We are interested in these programs as part of the ALV (**A**utomatiches **L**esen und **V**erstehen/Automatic Reading and Comprehension) project which is planned at DFKI. This project involves knowledge from a number of different sources: structure of the document, word recognition, beliefs about the writer, and the semantics of the text. We believe that speech act and goal recognition analysis play an important role in the combined task of understanding documents.

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