A Mechanism for ellipsis resolution in dialogued systems.

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ABSTRACT

An ellipsis resolution mechanism is presented. The mechanism is a part of a Natural Language Understanding System developed in the last years in order to be included as a main component of several projects based on man/machine interactions. CAPRA, an intelligent system for teaching programming, and GUAI, a natural language interfaces generator, are two of such applications. In our approach, syntactic and knowledge-based techniques are combined in order to get a great coverage of elliptical cases.

1. Introduction.

Anaphoric reference always appear in any Natural Language application. Its occurrence is common in Dialogued Based systems. Present work describes an approach for the most emphasized form of anaphoric reference: the ellipsis. It has been implemented in a Natural Language Understanding System. This system is the core of some projects based on Human/Computer interaction. Tutor/student Interface of the CAPRA system [Garijo et al,87], and the interfaces generator GUAI [Rodríguez,87], are two of such applications.

Ellipsis resolution has to deal with two major subproblems:

1.- The analysis of the elliptical sentence.
2.- The reconstruction of the elided fragments.

Related to the first point, usually, flexible analysis techniques are applied [Hayes,Reddy,83]. For the second point, there is not a general solution. Several partial approaches have been made by means of syntactic [Weischedel,Sondheimer,82] or conceptual techniques based on focus exploration [Sidner,83].

Our approach uses both techniques in order to get a great coverage of resolved cases. The organisation of the paper is as follows: a short presentation of the dialogue structure in our system is given in section 2. Section 3 is devoted to the ellipsis resolution process. Finally, section 4 summarizes our contributions.

2. Dialogue management

2.1. Dialogue Representation

NL-Dialogue systems are usually based on three data structures [Grosz,Sidner,86]: Dialogue Structure, to represent the organization of the interactions between the speakers, the Intentional Structure to organize the intentions of the speakers, core of the communicative process during the dialogue, and the Attentional Structure where topics of the Dialogue are represented. Our system handles these structures, here we will present only some components. A detailed description is given in [Rodríguez,89] and [Díaz de Ilarraza, 89].

The Dialogue Structure

The Dialogue Structure is a modelization of the communication process. This structure is dynamically built and is represented by a tree. **Conversation** is the root of the tree. A conversation takes place between several participants and it is composed by one or more **Dialogues.** Dialogues are units of communication characterized by a specific topic. A Dialogue is composed by one or more **Interchanges**. There is a descriptor tying each dialogue with the Attentional Structure.

An Interchange has an **Objective** which must be filled. Objectives are simple or complex illocutionary acts performed by the speakers. An Interchange has information about its goal, level of satisfaction and its evolution. Interchanges are tied to fragments of the Attentional Structure.

In order to satisfy the goal of an Interchange some new Interchanges or speakers Interventions can be created.

The Intervention is the elemental component of the Dialogue Structure. An Intervention is produced in a specific time, and implies that a message has been sent by a speaker to a hearer. The content of the message is represented in different levels: Superficial, Morphological, Syntactical, Logical, Conceptual and Illocutive.

The Attentional Structure

The Attentional Structure is used as a search-space in the resolution of some types of References. In our system, definite reference, direct and anaphoric, and, specially, pronominal and elliptical reference use the Attentional Structure (other uses such as movement of constituents or generation of conceptual expectatives will not be treated here).

In our system, the Attentional Structure is mainly conceptual. The syntactic structures saved (in a simplified fashion) are those related to the last user intervention and the corresponding to interventions of the current Interchange. For the rest we keep only some syntactic features, like gender and number, which are incorporated to the conceptual objects associated to the semantic interpretation. Initially, every explicitly mentioned or inferred concept appearing during the conversation will belong to the Attentional Structure (there are some exceptions that we will not consider).

There are two ways for accesing the Attentional Structure: the **Theme**, tied to a Dialogue unit, and the **Focus**, related to an Interchange. Conceptual **Classes** as well as inferred (not explicitly mentioned) **Instances** are introduced in the Theme. Explicitly mentioned instances are placed in the Focus. Our focus mechanism is not limited to a single object, as usual, but to a collection of them. In some cases, as in pronominal reference, a distinguished object is needed. This is handled by the **Center**. The Center indicates, at any moment, the object of the focus which constitutes the main subject of the Intervention.

2.2. The organization of the analysis process.

In our approach the linguistic description follows a stratified model; however, parsing is a cooperative process between different **K**nowledge **S**ources. These KS generate partial interpretations, interrupt each other, ask for information to other components, etc . The main problem of this approach is control i.e. to decide when a Knowledge Source is activated, what goal must be satisfied after the activation of a KS, what kind of objects can be consulted, created and modified.

In order to describe and implement different parsing strategies, our system is based on the use of a multilevel **Blackboard Architecture.** Objects are placed in their corresponding level. When a blackboard is modified, its associated Knowledge Sources are activated. KS associated to a specific Blackboard can only manipulate objects tied to this blackboard. Other Knowledge Sources handles communication between levels; these KS are associated to a blackboard but will include information in other levels.

The procedural contents of a KS can be **Rules**, **Rule Sets** and **Procedures**. Rules are simply condition-action pairs. Rule sets are collection of rules grouped for methodological reasons. Procedures are the action components of rules.

Control Strategy

In a descriptive level, at any moment, there will be a collection of concepts, already built in the parsing process, called **Realizations,** and another collection of virtual concepts, objects we wait for, called **Expectations**. The core of the process consists of obtaining some new realizations satisfying current expectations (a similar approach is presented in [Jones, 83]). Realizations and Expectations are created at different levels. So, morphological Analysis creates **Morphological Interpretations**; syntactical analysis, **Syntactical Interpretations**; semantic interpretation, **Logical Forms** and conceptual elements: **Concepts** and **Conceptual Networks.** We implement all these objects in a frame-like formalism. Our system manages each level in three main ways: Refining expectations in simpler ones that, perhaps, will be satisfied. Composing realizations in order to obtain new ones. Matching realizations and expectations in order to determine if any of the former can be satisfied by any of the last ones. If all three ways fail new expectations are created in another level.

3. Ellipsis.

Since the appearence of C. Sidner´s works the relation between anaphora and focus is commonly accepted. The anaphoric treatment we propose is performed in a parallel way to the construction of the Attentional Structure. Relationships between anaphoric resolution and the Attentional Structure are as follows:

During the process of anaphora resolution, queries to the Attentional Structure are made in order to find the antecedent of the anaphoric expression. If the antecedent is found in the focus of the current Interchange, no alteration occurs in the Attentional Structure, if the antecedent of the reference is found in any of the previous Interchange or Dialogue, their attached focus is retrieved and a change in the Attentional Structure and, perhaps, in the Dialogue Structure is produced.

We will examine here one of the more important type of anaphora: Ellipsis. In systems based on dialogues, elliptical expressions appear very often. The following sequence is a good example:

What is today ´s index ?
…
And yesterday ´s one?
…
The volume

Two types of ellipsis can be considered: syntactical and conceptual. We say that a syntactical ellipsis happens when a syntactical component is missed. A conceptual ellipsis is detected when the value of a mandatory descriptor for that concept has not been given. When the first one happens the second one is also implied.

Conceptual ellipsis

When values of mandatory descriptors are not present, the system will generate expectations for instances that could fill the descriptors. The reference resolution process will try to solve these expectations, first, by means of the Attentional Structure and then by means of default values defined in the KB.

Let us consider the following example "The price of British Telecom stocks in today´s session": The semantic category of "price" is NAD (**N**ame that **A**ctivates a **D**escriptor). The semantic dictionary will associate the tuple <PRICE HOW-MUCH? QUANTITY>. The semantic interpretation will be an instance of QUANTITY filling the HOW-MUCH? slot of the PRICE schema.

{{**PRICE**
IS-A: SCENE
SESSION:
[TYPE: MANDATORY]
HOW-MUCH?:
VALUE:
[TYPE: MANDATORY]
POSITION: }}

{{**STOCK-EXCHANGE**
IS-A+INV:
PROMISSORY-NOTE
MARKET-BOND
MARKET-SHARES
IS-A:COMMERCIAL-DOCUMENT
NAME:[TYPE: MANDATORY]
NOMINAL: }}

{{**MARKET-SESSION**
IS-A: SCENE
MARKET-SESSION-D:
[TYPE: MANDATORY]
FINISHED?:
GENERAL-INDEX-SESSION:
DATE: [TYPE: MANDATORY]}}

The class QUANTITY doesn´t add anything to the final interpretation. PRICE definition includes SESSION and VALUE slots as mandatories. MARKET-SESSION and STOCK-EXCHANGE are the corresponding ranges.

Values for all this mandatory slots have to be derived. In this case, STOCK-EXCHANGE doesn´t add anything to the semantic interpretation. MARKET-SESSION-D and DATE slots of MARKET-SESSION, are defined as mandatory and their correspondant ranges: MARKET and DATE are incorporated to the semantic interpretation. So, an expectation for instances of MARKET, defined bellow, and DATE are created.

{{**MARKET**
<SYNTACTIC-FEATURES: (:LIST GEN FEM)>
IS-A: INSTITUTION
INSTANCE+INV: BAR-M BIL-M MAD-M VAL-M
DEFAULT: BAR-M }}

During the reference search step, if there is not any instance of MARKET in the focus, the default value, BAR-M, will be the referent of the inferred instance of MARKET. Figure 1 shows the objects generated during the interpretation process.

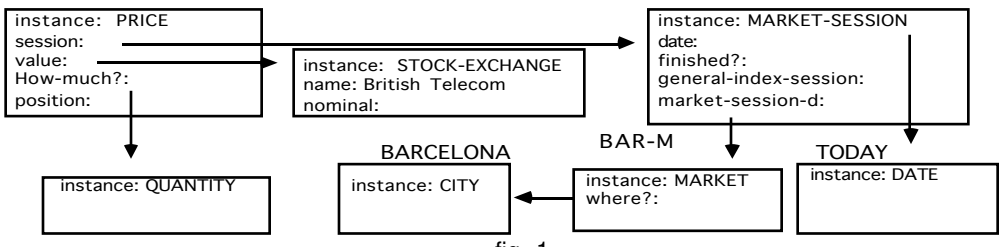

fig. 1.

Syntactical ellipsis

Syntactical ellipsis are usually short term anaphoric references. The resolution mechanism we have adopted considers that syntactical elements that are antecedent of the elided ones, must be found in the previous message of the user himself/herself. The method emphasizes the parallelism between the whole expression and the elided one. Our proposal is inspired on [Weischedel,Sondheimer,82]. Their approach was based on an ATN´s formalism and basically is a procedural one. Ours is made in a more declarative way and performs explicitly on the parse tree itself.

R_SIN_ELIP is the rule that activates the resolution process in the syntactical level. It´s important that its execution occurs before the semantic interpretation of the component that involves the elliptical element is built and, before the syntactic functions are assigned. Otherwise, these operations have to be done again. The rule is activated only once and treats with the whole syntactical structure. The reason is to get a more simplified matching process between the structure in course and the previous one.

The syntactic formalism we used is based on a Restricted Phrase Structure Grammar ([Sager,81], [Hirschman,Puder,82], [Hirschman,Puder,86]).

The syntactic structures managed by the system are parse trees and basically the process consists of an unification of two parse trees. Formally, they are n-ary labeled trees. The label keeps only the syntactical category and, eventually a list of associated syntactic features.

The classical formulation of unification for two trees is based on a preorder traversal of both trees, in parallel, trying to unify the different nodes. A strict application of the unification algorithm will not be very useful. In order to get a great coverage it is necessary to make more flexible the unification conditions. This will be done in three aspects:

Taking into account the type of components to be unified. In the kind of syntactical formalism we use, rules, and so the structure of the parse tree, belong to one of the following two types:

1.- Substitution of a syntactic category by another.

For example, we can rewrite the category <SENTENCE> as a declarative, interrogative or imperative one

<SENTENCE>::= <DECLARATIVE> | <IMPERAT> | <INTERROG>

2.- Adjunction of modifiers chains to a central one. For example, Nominal Phrase can be defined by adjunction of modifier chains to the right or to the left of a noun:

<LNR>::=<LNN> <*N> <RNN>

Grammatical categories are then subcategorized into central and adjunct.

In our unification algorithm, the adjunct components of the first tree (ea: **e**llipsis **a**ntecedent) dont´t have to participate in the unification process. The adjunct components of the second tree (ec: **e**lliptical **c**omponent) are considered in the unification process but they can be unified with empty trees.

On the other hand, the order of the adjunct components in any of the trees doesn´t matter to the unification process (even in the case that this order would had been important during the syntactic process)

Another point to be considered is the relaxation of the unification conditions between components. Usually, two nodes are unifiable if they have the same syntactical category and their syntactic features are compatible. We establish a flexible criterium introducing the concept of compatibility between categories. We will not require that two categories must be identical but compatible. The idea of compatibility between categories is based on the equality of distributional features, though it has been weakened.

So, for example, <*N > and <*PRON> (Noun and Pronoun) are compatible and so are <*ADJ> <SP> (Adjective and Prepositional).

The last consideration doesn´t affect the algorithm itself but the rule that activates it. The algorithm must be activated when a syntactical ellipsis is detected. The question is, "when can the absence of a component be considered an ellipsis?" Here, the descriptors associated to the syntactical functions are useful. The precondition of the rule R_SIN_ELIP, previously mentioned, indicates that if the syntactic category is DECLARATIVE, the absence of the SUBJECT or the OBJECT will produce the execution of the action. In the case of an INTERROG only the absence of the OBJECT will produce it. All these considerations complicate the formulation of the algorithm but provides a powerful mechanism.

3.1 Unification Algorithm

The algorithm has two phases: During the first one *ea* (ellipsis antecedent) and *ec* (elliptical component) trees are unified. If the unification has been successful, the result of this phase is a target tree in which some adjunct components can be incorrectly placed. The second phase transforms the target tree in order to get a right placement of all the constituents.

Unification Phase

Components of *ea* that are categorized as central are incorporated to the target tree in the same structural position they had in *ea* . If the algorithm finds theirs equivalents in *ec* then the label of constituents in the target tree will hold the information contained in *ec*.

The adjunct components of *ec* are incorporated, together with their labels, to the target tree having or not been unified with a corresponding component in *ea* .

The adjunct components of *ea* whitout equivalent in *ec* are not incorporated to the target tree. They are saved in a list of pending components.

If there is a central component in *ec* whitout equivalent in *ea* , the unification process fails.

The implementation of the algorithm is based on two main mutually recursive functions: **dd-tree-unification** and **dd-forest-unification**.

The function dd-tree-unification takes as arguments the trees to be unified. It examines the compatibility of the roots by means of a call to the **dd-compatible** function. If the roots are not compatible, the function returns an empty list.

If the roots are compatible, the function makes a call to dd-forest-unification whose arguments are forests composed by the children of both trees. The function returns a tuple composed by the target tree, the two pending forests and the list of pending adjunct elements we talked above.

The function dd-forest-unification takes as arguments two forests and tries to unify their initial fragments. Both forest are traversed in parallel trying matching their corresponding trees until one of the forests becomes empty or the unification fails. Each matching considers the following cases:

1.- Both trees are unifiable (a call to dd-tree-unification has been successfully made). In this case the unification goes on and, eventually, the size list of pendings is increased, the unified trees are eliminated from the respective forests and the pending forests that the function dd-tree-unification returns are incorporated to the new ones for their treatment.

2.- The tree of the first forest is neither unifiable nor adjunct. The component is incorporated to the target tree and its children to the correspondent forest.

3.- The tree of the second forest is not unifiable but adjunct. The component is incorporated to the target tree and its children to the correspondent forest.

4.- None of the previous cases happen. In this case, the unification process is stopped.

In any of the previous cases, the function returns a similar tuple to the dd-tree-unification. dd-forest-unification never fails. If the algorithm fails in this first phase, then the unification is not possible.

Transformation Phase

Inputs for the second phase of the algorithm are the target tree and the list of pending adjunct components. The adjunct components of the target tree not unified in the former phase are examined and their corresponding elements are searched in the list of pending elements. If an element is found, it is deleted from the list and the position of the component of the target tree is modified, indicating that its correspondent element has been found (unified).

When the process is finished, the pending adjunct components are not considered anymore and constituents of the target tree are confirmed in their positions. Sometimes, information is lost when an element is eliminated in this way. If this happens, the semantic interpretation of the component will infer it by the process described at the beginning of this section.

Example

Let us follow the application of the algorithm with an example. Figure 2 shows the syntactic structure of the first intervention "Cuál es el índice de hoy?". The second intervention "Y el de ayer?" is shown in figure 3. Figure 4 shows the target tree "Cuál es el índice de ayer?", result of the unification process.

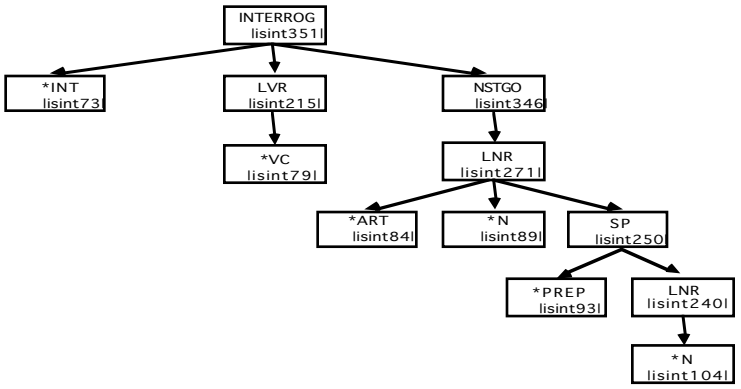

fig. 2.

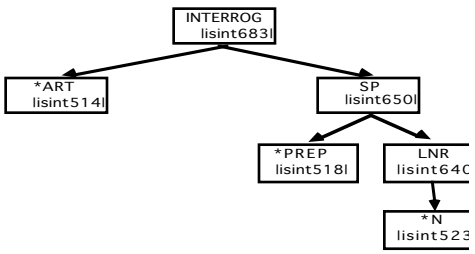

fig. 3.

The algorithm starts by trying to unify trees with roots |isint351| and |isint683|, there are not pending adjuncts. Syntactic categories of these components are identical, INTERROG, and there is not syntactical features, so the unification is possible. Now, the problem is reduced and we must unify two forests, the first one composed by the trees with roots |isint73|, |isint215| and |isint346| and the second one by |isint514| and |isint650|.

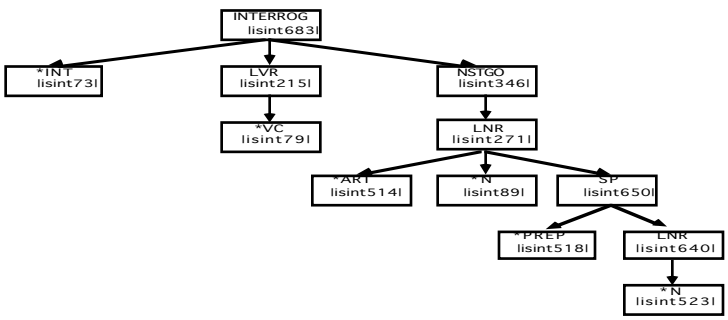

fig. 4.

|isint73| and |isint215|, are central and without any possible unificator in the second forest, then they are incorporated to the target tree. The first forest now is composed by the trees |isint79| and |isint346|, and there are no changes in the second one.

The same considerations will lead to incorporate components |isint79| and |isint346|. The first forest is now composed by the element whith the |isint271| root. Second one remains without changes.

The incorporation of |isint271| to the target tree produces the unification of the forest composed by |isint84| , |isint89| and |isint250|, and the second one, still remains without changes.

Nodes |isint84| and |isint514|, both with *ART category, "masculine" and "singular", are unifiable without problems. |isint89| being a central node is also incorporated. Now the problem is reduced to the unification of the prepositional phrases |isint250| and |isint650| which it is done easily and the resulting target tree is shown in figure 4.

For this example, second phase is not needed. Further cases can be found in [Rodriguez, 89] and [Diaz de Ilarraza, 89]

4. Conclusions

We have presented here a mechanism for ellipsis resolution in dialogued systems. Our proposal combines syntactic and contextual information. First one is used to unify the parse tree of the elliptical sentence with trees of previous sentences. The unification algorithm is more flexible than those presented in the literature, and in consequence, solves more cases. Its flexibility is based on the differentiated treatment for central and adjunct components of the parsing trees as well as a greater freedom in the syntactic realization of the constituents. Syntactic resolution is complemented with resolution rules for conceptual ellipsis working on the dialogue structures. As a result a broad range of cases are covered by the system.

5 . References.

[Clark,Marshall,81] Clark, H. H., Marshall, C. R.: "Definite Reference and Mutual Knowledge". En "Elements of discourse understanding". Joshi, Webber, Sag, eds. Cambridge University Press, 1981.

[Diaz de Ilarraza, 89] Diaz de Ilarraza, A.: "Sistema de gestión de diálogos para un sistema de enseñanza inteligente". Tesis Doctoral. 1989

[Garijo et al,87] Garijo, F., Verdejo, F., Díaz de Ilarraza, A., Fernández, I. ,Sarasola, K.: "CAPRA: An intelligent system to teach novice programmers". International Conference on Artificial Intelligence, San Sebastian, 1987.

[Goodman,86] Goodman, B.A.: "Reference Identification and Reference Identification Failures". Computational Linguistics Vol. 12, Num. 4, 1986.

[Grosz,Sidner,86] Grosz, B., Sidner, C.: "Attention, Intentions and the Structure of Discourse". Computational Linguistics Vol. 12, Num. 3, 1986.

[Hayes,Reddy,83] Hayes, P.J., Reddy, D.R.: "Steps toward a graceful interaction in spoken and written man/machine interaction". I.J.M.M.S. Vol. 19, 1983.

[Hirschman,Puder,82] Hirschman, L., Puder, P.: "Restriction Grammar in Prolog". Procs. 1st. International Logic Programming Conference. 1982.

[Hirschman,Puder,86] Hirschman, L., Puder, P.: "Restriction Grammar: A Prolog implementation". En "Logic Programming and its applications". Ablex Series in Artificial Intelligence, 1986.

[Hirst,79] Hirst, G.: "Anaphora in Natural Language Understanding: A survey". Tech. Report 79.2, D.C.S.U. British Columbia, Vancouver, Canadá, 1979.

[Jones,83] Jones, M.: "Activation based parsing". I.J.C.A.I. 1983.

[Rodríguez,87] Rodríguez, H.: "GUAI: A natural language interfaces generator". International Conference on Artificial Intelligence, San Sebastian, 1987.

[Rodríguez,89] Rodríguez, H.: "GUAI: Un generador automático de interfaces en lengua natural". Tesis Doctoral. Facultat d' Informàtica U.P.C. Barcelona, 1989.

[Sager,81] Sager, N.: "Natural Language Information Processing". Addison-Wesley, 1981.

[Sidner,83] Sidner, C.: "Focusing in the comprehension of definite anaphora". En "Computational Models of discourse".Brody, M. y Berwick, R. eds. MIT Press, Cambridge, MA, 1983.

[Thomson,81] Thomson, H.: "Chart Parsing and rule schemata in Phrase Structure Grammars". 19th. A.M. of A.C.L., 1981.

[Weischedel,Sondheimer,82] Weischedel, R.M., Sondheimer, N.K.: "An improved heuristic for ellipsis processing". 20th. A.M. of A.C.L., 1982.