

# An Object-Oriented Linguistic Engineering Environment using LFG (Lexical Functional Grammar) and CG (Conceptual Graphs)

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## Abstract

In order to help computational linguists, we have conceived and developed a linguistic software engineering environment, whose goal is to set up reusable and evolutive toolkits for natural language processing. This environment is based on a set of natural language processing components, at the morphologic, syntactic and semantic levels. These components are generic and evolutive, and can be used separately or with specific problem solving units in global strategies built for man-machine communication (according to the general model developed in the Language and Cognition group: Caramel). All these tools are complemented with graphic interfaces, allowing users outside the field of Computer Science to use them very easily. In this paper, we will present first the syntactic analysis, based on a chart parser that uses a LFG grammar for French, and the semantic analysis, based on conceptual graphs. Then we will show how these two analyses collaborate to produce semantic representations and sentences. Before concluding, we will show how these modules are used through a distributed architecture based on CORBA (distributed Smalltalk) implementing the CAMEL multi-agent architecture.

## 1 Introduction

### 1.1 Generalities

Natural language processing is nowadays strongly related to Cognitive Science, since linguistics, psychology and computer science have to collaborate to produce systems that are useful for man-machine communication. This collaboration has allowed formalisms that are both theoretically well-founded and implementable to emerge. In this paradigm, we have conceived and developed a linguistic software engi-

neering environment, whose goal is to set up reusable and evolutive toolkits for natural language processing (including collecting linguistic data, analysing them and producing useful data for computer processes). Based on a large number of graphical, very intuitive, interfaces, this environment has two main goals:

- to provide tools usable by users outside the field of Computer Science (e.g., computational linguists) for them to be able to easily collect data and test their linguistic hypotheses
- to allow computer scientists to exploit these data in computer programs

*Remark:* in the text, some figures describe the structure of our tools; we have used Booch's conventions (Booch, 1994) about object oriented analysis and conception. They are summarized here:

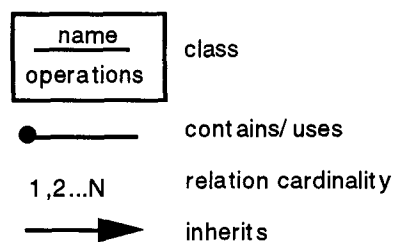


Figure 1: symbols used in the figures

### 1.2 Extensions to LFG formalism

Four types of equations are defined in classical LFG (Bresnan and Kaplan, 1981):

1. unifying structures (symbolised by "="),
2. constrained unification of structures, only true if a feature is present in both structures, but may not be added (symbol "=", "c"),
3. obligatory presence of a feature (symbol "&"),
4. obligatory absence of a feature (symbol tilde).

We have defined three non-standard types of equations used in our parser:

1. obligatory difference between two values (symbol “≠”),
2. disjunction of obligatory differences (a sequence of obligatory differences separated by the symbol “|”) (this can also be viewed as the negation of a conjunction of obligatory presences)
3. priority union, copy into a F-Structure the attributes of the other that are not present in the first one, nor inconsistent with it.

Among other existing systems (e.g., A. Andrew’s system, Charon, The “Konstanz LFG Workbench” and Xerox “LFG Workbench”; see <http://clwww.essex.ac.uk/LFG> for more details on these systems), only the last one is a complete environment for editing grammars and lexicons. Our system adds to this feature an open architecture and many interfaces that make it very easy to use.

## 2 The LFG Environment

### 2.1 Foundation: a LFG parser

According to the principles of lexical functional grammars, the process of parsing a sentence is decomposed into the construction of a constituent parts structure (c-structure) upon which a functional structure is inserted. C-structure construction is based on a chart parser, that allows the system to represent syntactic ambiguities (Kay, 1967), (Winograd, 1983). In order to be used within a LFG parser, a classical chart has to be complemented with a new concept: *completed arcs* (which represent a whole syntactic structure) have to be differentiated between completed arcs linked with a correct F-Structure, and those which are linked to an F-Structure that cannot be unified or that does not respect well-formedness principles.

### 2.2 Visualising the Chart

In the Chart interface, words are separated by nodes, numbered from 1 to numberofWords + 1. Each arc is represented by a three segment polygon (larger arcs are above the narrower, for readability reason).

Active arcs are grey and positioned under the words. Completed arcs with uncorrect F-Structures are red and also placed under the words. Completed arcs with correct F-Structures are blue and above the words. Lastly, completed arcs with F-Structures that don’t respect well formedness principles are grey and above the words. The user can select the kind of arc he is interested in. By clicking on an arc with the left button, the arc and all its daughters become green, thus showing the syntactic hierarchy. By clicking with the middle button, a

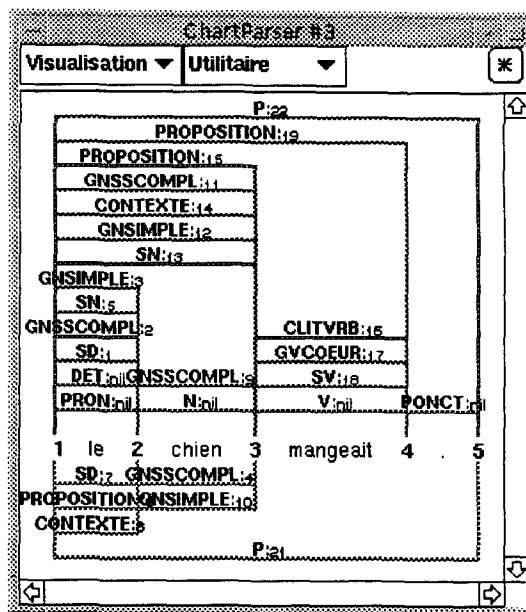


Figure 2: The Chart Interface

menu appears within which one can choose to examine the applied rule or the F-Structures (see below for the corresponding interface).

### 2.3 Visualising F-Structures

As shown in Figures 3 and 4, F-Structures are represented by attribute-value pairs (a value may itself be a F-Structure). In addition to such a graphical representation, a linear representation (more suitable for storing data on files or printing them) has been developed and it is possible to switch from one to the other. This allows us to keep track of previous results and to use them for testing the evolution of the system.

### 2.4 Lexicon and lexicon management

Since LFG is a “lexical” grammar, it is important to have powerful and easy to use lexicon management tools. To be as flexible as possible, we have chosen to use several lexica at the same time in the same analyser. The lexicon manager contains a list of lexica ordered by access priority. For each word analysed, the list is searched, and the first analysis encountered is returned.

Two kinds of lexica are currently used; this kind of structuration is quite flexible:

- if the user uses a big lexicon, but wants to redefine a few items for his own needs, he just has to define a new small lexicon containing the modified items, and to give it a high priority.
- if the user has a big lexicon with a slow access, the access can be optimised by putting the

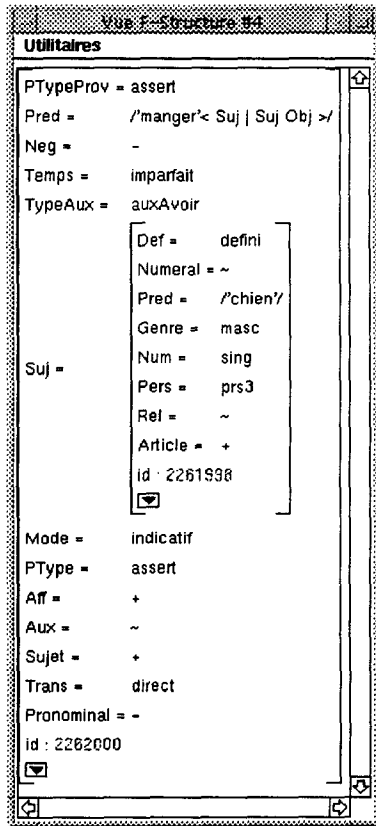


Figure 3: graphical representation of a F-Structure

words frequently used in a direct access lexicon stored in memory.

Our lexicon currently contains 7000 verbs, all the closed classes words (e.g., prepositions, articles, conjunctions), 12000 nouns and about 2500 adjectives. To mitigate the consequences of some lacks of this lexicon, a set of subcategorisation frames is independently associated with the lexicon (3000 frames).

The user may also define a direct access lexicon, whose equations are written in a formalism close to the standard LFG formalism. Dedicated interfaces have been developed for editing these lexica, with syntactic and coherence checking.

Example of an entry of a canonical form:

```
@chien={ 'chien canonique'
CAT = N;
↑ Pred = chien }
```

Example of an entry of an inflected form:

```
#chiennes={ 'chien fem plur' "chiennes f-flechie"
↑ Num = plur;
↑ Genre = fem;
@chien= 'chien canonique' }
```

All these lexica conform to the specification defined by an abstract lexicon class. It is possible, and

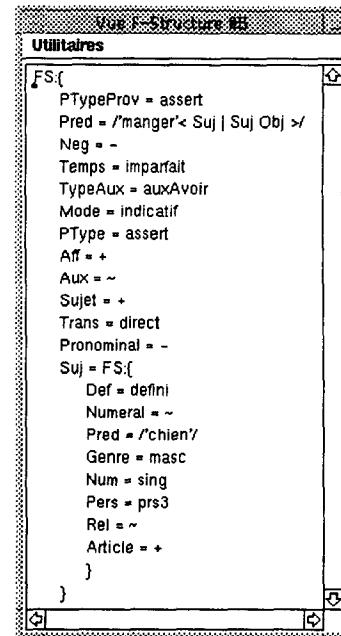


Figure 4: textual representation of a F-Structure

very easy, to add new kinds of lexica, provided they conform to this specification.

## 2.5 Tracking failure causes

A specific feature (“*Error*”) allows the system to keep a value that makes explicit the reason why the unifying process has failed. Possible situations are listed below:

1. Unifying failure. The values of a given feature are different between the two F-Structures to be unified. The generated F-Structure contains the feature *Error*, whose value is an association of the two incompatible values. Example:  $Num = sing \rightarrow plur$ .
2. A feature present in an equation has non value in either of the two F-Structures to be unified. Example: with the equation  $\uparrow Suj Num = \downarrow Num$  and two F-Structures without the Num feature, the generated F-Structure contains  $Num = nil \rightarrow nil$ .
3. While making a constrained unification (e.g.,  $\downarrow Num = c sing$ ) a feature does not exist. We obtain:  $Num = sing \rightarrow nil$ .
4. An obligatory feature is absent. Example:  $Num = obligatoire$ .
5. A forbidden feature is present. The forbidden state for a feature is represented by adding the value “tilde” to the feature (e.g.,  $Num = \textit{tilde}$ ). Therefore, this is the same situation as the simple unification. A failure results from

the case when a F-Structure contains this feature. Example:  $Num=sing \rightarrow \text{"tilde"}$ .

6. A feature has a forbidden value. Example:  $Num= \text{"tilde"} sing$ .
7. When a disjunction of constraints is the reason of the failure, the block itself is set as the value of the "Error" feature in the resulting F-Structure.

These errors can be recovered through the interface (errors are highlighted in the representation), which allows the user to track them easily. Moreover, these well defined categories make it easy to find the real cause of the error and to correct the grammar and the lexicon.

## 2.6 Structure of the rules

Smalltalk80 specific features (mainly the notions of "image" and incremental compilation) have been heavily exploited in the definition of the internal structure of the grammar rules. Basically a rule is defined as the rewriting of a given constituent (left part of the rule), equations being linked to the right constituents. Each non terminal constituent of the grammar is then defined as a Smalltalk class, whose instance methods are the rules whose left part is this constituent (e.g., NP is a class,  $NP \rightarrow ProperNoun$  and  $NP \rightarrow Det Adj^* Noun$  are instance methods of this class).

The Smalltalk compiler has been redefined on these classes so that it handles LFG syntax. Therefore, all the standard tools for editing, searching, replacing (Browsers) may be used in a very natural way. A specific interface may also be used to consult the rules and to define sets rules to be used in the parser.

A great interest of such a configuration is to allow the user to define his own (sub-)set or rules by defining sub-classes of a category when he wants to define different rules for this category (since a method with a given name cannot have two different definitions).

**On the use of the Envy/Manager source code manager to maintain the syntactic rules base.** Envy/Manager is a source code manager for team programming in Smalltalk, proposed by OTI. It is based on a client-server architecture in which the source code is stored in a common database accessible by all the developers. Envy stores all the successive versions of classes and methods, and provides tools for managing the history. Applications are defined as sets of classes, methods, and extensions of classes, that can be independently edited and versioned. Very fine grained ownership and access rights can be defined on the software components. The structuration of our syntactic rules base enables us to benefit directly of these functionalities, and hence to be able to manage versions, access rights, comparisons of versions (Figure 5)... on all our linguistic data.

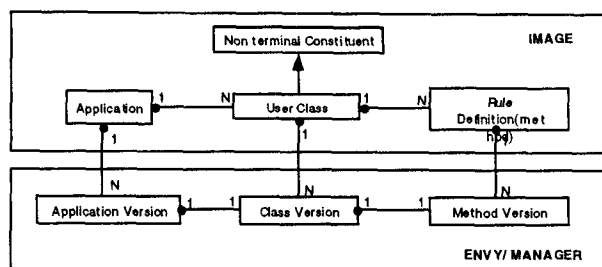


Figure 5: Structuring the set of rules

**Content of the rules.** The current grammar contains about 250 rules that covers most of the classical syntactic structures of French simple sentences. They have been tested on data coming from the TSNLP european project. In addition to these simple sentences, difficult problems are also handled: clitics, complex determiners, completives, various forms of questions, extraction and non limited dependancies, coordinations, comparatives. Some extensions are currently under development, including negation, support verbs, circonstant subordinate phrases and ellipses.

## 3 Conceptual graphs

Conceptual graphs (Sowa, 1984) form the basis of the semantic and encyclopedic representations used in our system. Conceptual graphs are bipartite graphs composed of concepts and relations. A conceptual graph database is generally composed of the following subparts:

- a lattice of concepts and relation types
- a set of canonical graphs, associated with concepts and relation types, used for example to express the selectionnal restrictions on the arguments of semantic relations.
- a set of definitions, associated with concepts and relation types, used to define the meaning of concepts.
- a set of schemas and prototypes.
- a set of operations, such as join, contraction, expansion, projection...
- a database containing the description of a situation in terms of conceptual graphs.

The framework we describe here aims at managing all this information in a coherent manner, and at facilitating the association with the linguistic processes described above.

Graphs can be visualized, modified, saved, searched through different interfaces, using graphical or textual representations. Operations can be performed programmatically or using the interface shown in Figure 7.

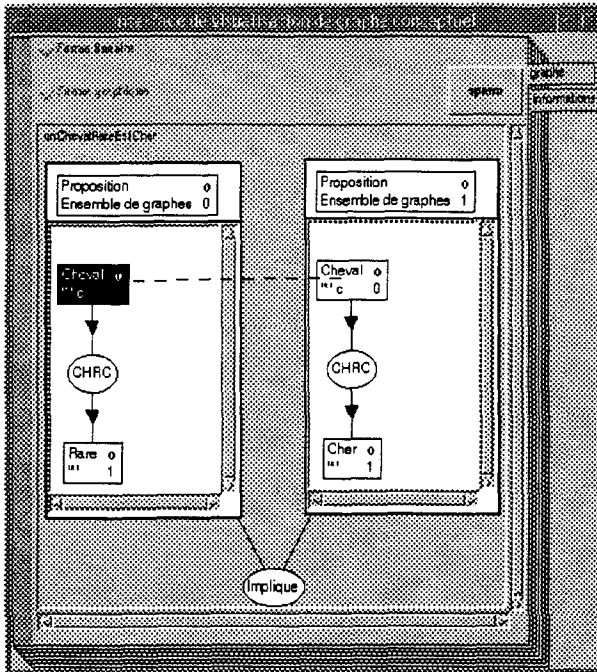


Figure 6: Graphical representation of “a cheap horse is scarce” (with second order concepts)

The lattice, and the different items of information associated with concepts and relations types, can be visualized, modified, searched and saved using graphical or textual representations (Figure 10).

An “individual referents inspector” allows to inspect the cross-references between references, concepts and graphs.

#### 4 Analysing a sentence

The process of analysis from sentence to semantic representation can be separated into three subprocesses. After the sentence has been segmented, we obtain the lexical items in LFG-compliant form via the lexical manager. After parsing, we obtain some edges with their respective F-Structures. (Delmonte, 1990) has developed a parser which uses basic entries with mixed morphological, functional and semantic informations. The rules use different level information. We propose to map the semantic structure on the syntactic one in a manner that avoids too many interdependencies. We use an intermediate structure (named “syntax-semantic table”) that expresses the mapping between the value of a LFG Pred and a concept, as well as connected concepts and relations. Semantic data in the lexical knowledge base are defined by using conceptual graphs, as shown in the paragraph 4.1 below about some verb examples. Selectional restrictions defined with canonical graphs are then used to filter the graphs, when more than one is obtained at this level.

#### 4.1 Semantic verb classification in the lexical knowledge base

The lexical knowledge base is based on a hierarchical representation of French verbs. We have developed a systematic and comprehensive representation of verbs in a hierarchical structure, data coming from the French dictionary “Robert”. Our method relies on classification method proposed by (Talmy, 1985) and (Miller, Fellbaum and Gross, 1989), (Miller and Fellbaum, 1991). We chose a description with a structure composed of a basic action (the first of the most general superclasses. e.g. *stroll* and *run* can be associated with *walk* as a basic action, and *walk*, *ride*, *pass* point at *moving*, which is a step further in generality) associated with thematic roles that specify it (i.e., object, mean, manner, goal, and method). The basic actions are in turn defined with the same structure, based on a more general basic action.

The hierarchy of verbs depends on the thematic relations associated with them. A verb V1 is the hyperonym (respectively a hyponym) of a verb V2 (which is noted  $V1 > V2$ , respectively  $V1 < V2$ ) if they share a common basic action and if, in the thematic relations structure associated with it, we have:

- absence (for the hyperonym) or presence (for the hyponym) of a particular thematic relation: e.g. for the pair *divide* / *cut*; to cut is to divide using a sharp instrument, thus *divide*  $>$  *cut*
- presence of a generic value thematic relation vs. a specific value (example *cut* (object is generic: *solid object*  $>$  *behead* (object is *ahead*))

For every verb:

- the semantic description pointed out is coded in the lexical knowledge base as a definitional graph.

type *cut* (\*x) is [*divide*: \*x]-

(obj)  $\rightarrow$  [*Object*: \*y]  $\rightarrow$  (*car*)  $\rightarrow$  [*solid*]  
 (method)  $\rightarrow$  [*traverse*]  $\rightarrow$  (*Object*: \*y)  
 (mean)  $\rightarrow$  [*Instrument*]  $\rightarrow$  (*car*)  $\rightarrow$  [*sharp*].

- a canonical graph makes explicit the selectional restrictions

Canonical graph for *cut* is

(Agent)  $\rightarrow$  [*Animate*]  
 (Obj)  $\rightarrow$  [*Object*: \*y]  $\rightarrow$  (*car*)  $\rightarrow$  [*solid*].

#### 4.2 An example

Below, we give an example for the sentence “Un avocat vole une pomme” (a lawyer steals an apple), where “avocat” is ambiguous and refers to a lawyer or to an avocado. A semantic representation of this sentence is derived from its non-ambiguous F-Structure.

The entries in the translation table (from LFG pred [in French] to conceptual graphs types [in English]) are as follow:

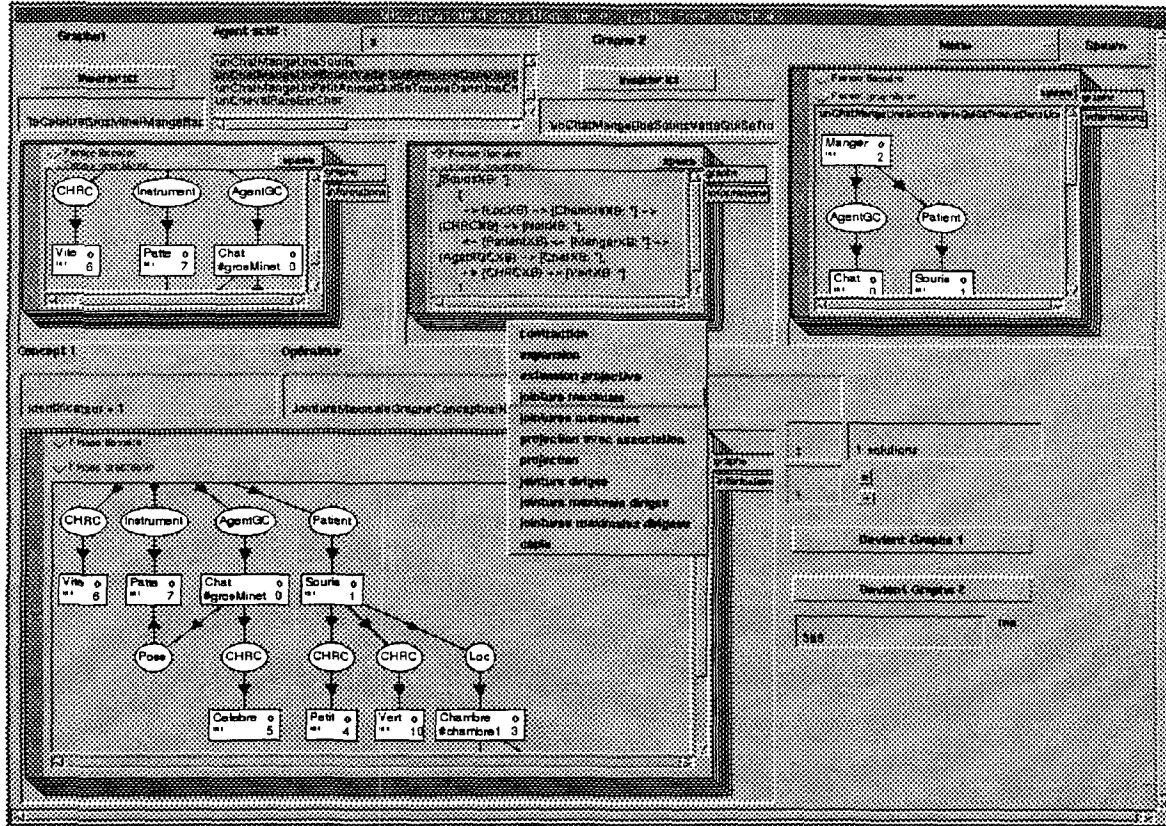


Figure 7: Conceptual graph operation manager, showing the result of a join between two graphs, and the list of available operations.

'avocat' → (Lawyer Avocado)

'pomme' → (Apple).

'voler(derober)' → (Steal(Agent → ↓ Suj; Object → ↑ Obj)),

Explanations: the first item between quotes is the Pred value, followed by a list of types of concepts (or types of relations) and their mapping definition structure in the F-Structure. ↓ represents the local F-Structure. ↑ represents the F-Structure that contains the local F-Structure. For example, Agent → ↓ Suj means that a concept of Type "Steal" is connected to a concept that can be found in the F-Structure of the feature "Suj" in the local F-Structure. From these data, the following graphs (Figure 8) are obtained.

The "Def" feature of the F-structure gives us information about the referents of concepts. For example, the F-Structure for 'apple' contains "Def = indefini", which implies the use of a generic referent for the concept (corresponds to *an* apple, indicated by a star in Figure 8). Then, since canonical graphs express selectional restrictions, they are used to filter the results through the join operation. For ex-

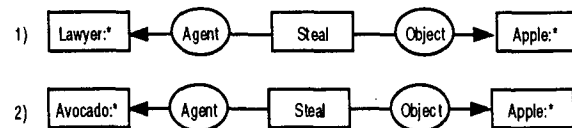


Figure 8: Graphs from the sentence "Un avocat vole une pomme"

ample, "Steal" needs an animated agent (Figure 9), therefore graphs with the "Avocado" concept can be removed from the selection.

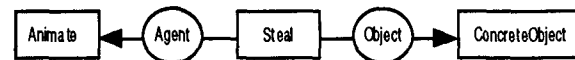


Figure 9: Canonical Graph for "Steal"

These principles are the bases of the system currently available, but we are working on improvements and extensions. We want to address the issue of adjunct processing, prepositional comple-

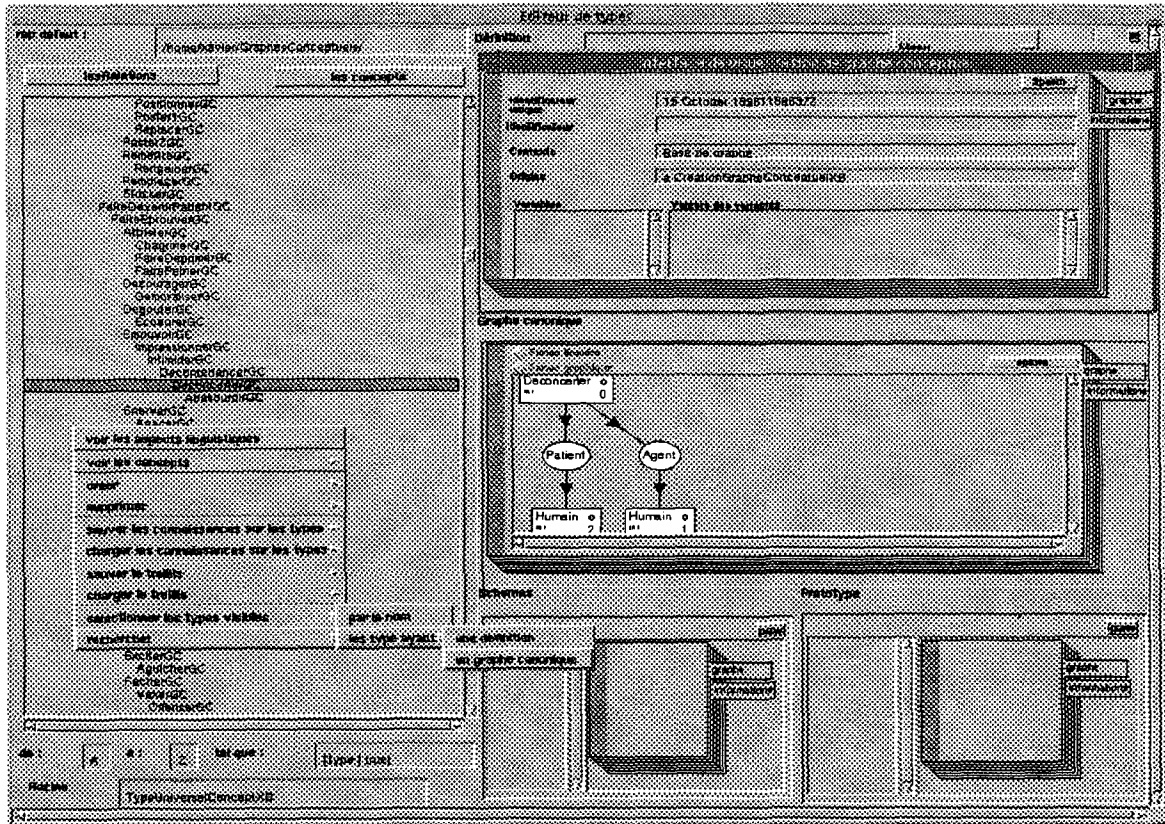


Figure 10: Lattice visualizer, showing (bottom right) the canonical graphs of “déconcerter” (to disconcert), the “graph origin” inspector (top right), and the menu of operations (bottom left)

ments (with problem of second order concepts), etc.

## 5 Concluding remarks: Sharing the tools on a network with CORBA

The different tools described in this paper are currently being extended to be CORBA-compatible. CORBA (Common Object Request Broker Architecture) (Ben-Natan, 1995), has been defined by the OMG as an interoperability norm for heterogeneous languages (Smalltalk, C++, JAVA) and platforms (UNIX, Macintosh, PC). CORBA defines a common interface definition language (IDL), as well as a set of services (naming service, security, concurrency management...). CORBA objects can be distributed worldwide (for example using Internet) using an ORB (Object Request Broker). Various tools implement this CORBA norm. We have used Distributed Smalltalk (Parc Place Digitalk) to realize the distributed implementation of an analyser. With this system, users can currently make an analysis, see the results of this analysis, the F-structures, see the syntactic rules base... With this kind of architecture, systems necessitating a large amount of

ressources can be distributed amongst workstations on a network and/or be used by clients having few ressources. Moreover these ressources can be physically located in any place of a network, allowing thus to distribute the responsibility of their management and maintenance to different persons. With the communication possibilities offered by Internet, it makes it possible to coordinate the cooperative efforts of several teams in the world around a single, coherent, though distributed system. We are continuing our work toward the implementation of a complete distributed multi-agent system, following the CAMEL architecture (Sabah and Briffault, 1993), (Sabah, 1995), (Sabah, 1997).

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